THE FORECASTING APPROACH TO

EFFICIENCY IN THE WOOL MARKET

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ABSTRACT

This paper develops and presents estimates of a simultaneous equations model of the Australian wool market, the world's largest producer and exporter of fine wool. The model contains functional relationships for unhedged inventories, consumption of raw wool, and the activities of both hedgers and speculators in wool futures. Expectations are represented by the adaptive hypothesis. This model extends the work of Leuthold and Hartmann (1979) and Leuthold and Garcia (1988) by including expectations in the spot-futures model, and that of Goss and Giles (1986) by including composite equations for hedger-speculators, extending the expectations hypothesis to the consumption equation, and by using the model to test the efficient markets hypothesis. Wald tests and likelihood ratio tests for unit roots in wool cash prices are conducted and in no case can the hypothesis of a single unit root be rejected. Estimation is by three stage least squares, with correction for first order serial correlation. The model provides good intra- and post-sample forecasts of most variables, especially of unhedged inventories and consumption of wool, both important spot market relationships. The model-derived forecast of the spot price is inferior to the forecast implicit in the futures price, although a composite predictor clearly outperforms the futures price as an anticipation of subsequent cash prices. Nevertheless, it is suggested that the efficient markets hypothesis should not be rejected, because there is evidence that futures market agents are learning to use the information contained in the model.

1. INTRODUCTION

The issue of informational efficiency is important in the study of commodity and financial markets. If market prices reflect all relevant information as fully as possible then agents whose decision making is based on current prices are responding to the most useful signals the market can provide. Moreover, in markets which provide forward trading facilities, so that their prices are projected into the future, and if the markets are efficient in the above sense, then current spot and forward prices, under certain conditions, can be expected to be unbiased anticipations of subsequent spot prices. This not only assists markets in performing their price discovery function, but facilitates the intertemporal allocation of economic resources, for example, by minimizing the adjustment costs of agents who use forward prices for hedging or forward contracting purposes.

The methodology and results of research on informational efficiency in the area of equities markets have been summarized by Fama (1970). In the area of futures markets, the issue of weak form efficiency has been studied by many writers including Larson (1960), Stevenson and Bear (1970), Leuthold (1972), Cargill and Rausser (1975) and Praetz (1975), using research methodologies essentially the same as those employed in the equities area. While some departures from the strict random walk model have been found, it is not clear that these could have been used to generate returns in excess of transaction costs.

The question of semi-strong form efficiency in futures markets, that is efficiency with respect to publicly available information, has been studied using three different approaches. Hansen and Hodrick (1980) investigated whether a relationship existed between the current forecast error for a particular currency and immediately prior forecast errors for related currencies. This approach, which exploits the "predictive" quality of futures prices, is based upon the idea that the information contained in forecast errors will be immediately exploited in an efficient market, so that there will be no systematic relationship between the current forecast error for a futures contract and the elements assumed to comprise the information set. This method has been applied to a group of non-ferrous metals by Goss (1986, pp. 168-71), and to the Australian wool market by Goss (1987).

Another method used to address this question, which also exploits the predictive qualities of futures prices, requires the employment of a quantitative model of the market to forecast the cash price at future dates. If the futures price does not predict at least as well as the model, this suggests that the model contains information not reflected in the futures price. This method has been used by Leuthold and Hartmann (1979) and Leuthold and Garcia (1988) for U.S. livestock Rausser and Carter (1983) for the U.S. soybeans complex and Brasse (1986) for the London tin market, all of whom discovered some inefficiencies in the markets studied.

Failure to reject the hypothesis of semi-strong form efficiency, under either of these approaches, is not proof that the market is efficient. There remains the possibility that an alternative model may lead to rejection. More recently Chance (1985a, 1985b) has studied the response of the U.S. Treasury Bond and GNMA futures markets to "news" (in this case the unanticipated component of inflation rate announcements). The results are generally consistent with the hypothesis of semi-strong form efficiency. In this paper the second method is employed to examine whether Australian wool futures prices reflect publicly available information as fully as possible. A simultaneous model of the Australian wool market is developed in Section 2 and estimated and used to predict the cash price of wool in Section 3. Some conclusions are presented in Section 4.

Australia is the world's leading producer and exporter of wool, producing in 1979-1980 more than the next four major exporting countries in aggregate. Almost all of this wool is sold in competitive auction markets in Australia, and typically more than 70 per cent is exported as greasy wool, the major destinations being Japan, the U.S.S.R. and E.E.C. countries.

The Australian Wool Corporation (AWC), a government instrumentality, administers a price support scheme, buying wool at auction at times of deficient demand and selling wool at times of buoyant demand. Since 1971 the AWC has been the major holder of supply stocks of wool in Australia with 39% of total Australian inventories in 1974, approximately 90% from 1975 to 1978, and in 1983, and 60% to 76% in the period 1979-82. AWC inventories of wool are not hedged on the Sydney Futures Exchange (SFE).

Futures trading in wool in Australia began in May 1960, and the SFE became the world's leading wool futures market with turnover exceeding 10,000 lots per month on average in 1964 and peaking at 15,500 lots per month in 1973. After 1981 turnover of wool contracts diminished (see Appendix 1) with the growth of financial futures trading on the SFE, especially the Bank Accepted Bills of Exchange (interest rates) and Share Price Index contracts.

The merino wool contract on the SFE provides for delivery of greasy wool 22 micron type 78 (64 type 78 prior to 1976) equivalent to 1500 kg clean weight, in the months of March, May, July, October and December at specific delivery points around Australia. Hedging interest in this contract has come from inventory holders, who are normally short hedgers, and from agents who have sold wool forward (especially Australian exporters) and processors of wool, who are normally long hedgers. The Sydney wool futures market has been studied by Snape (1968), who investigated the behaviour of price spreads, Goss (1972) who studied the formation of expectations by traders, Praetz (1975) and Taylor (1983) who tested for dependence in past prices, and Goss and Giles (1986a, 1986b) who estimated a simultaneous model of the wool market. Giles and Goss (1980) tested the unbiasedness hypothesis with wool price data, while Goss (1987) used the forecast error approach outlined above to examine wool market efficiency. Fisher (1983) developed a simultaneous model of the wool spot market with rational expectations.

2. A SIMULTANEOUS MODEL OF THE AUSTRALIAN WOOL MARKET:

2.1 SPECIFICATION

This model extends the work of Peston and Yamey (1960) and Goss and Giles (1986a, 1986b). In these last two papers the disaggregation of turnover data between hedgers and speculators was based on information obtained in interview with Floor Members of the Sydney Futures Exchange. This information is not available beyond 1978, and therefore is not available for the last five years of the sample period of this study. Accordingly, in this model the following groups of agents are distinguished: (i) sellers of futures, for both hedging and speculative purposes (i.e. short hedgers and short speculators); (ii) buyers of futures, for both hedging and speculative purposes (i.e. long hedgers and long speculators); (iii) holders of unhedged inventories; (iv) consumers of raw wool, whose demand is a derived demand.

This classification of agents' activities gives rise to four separate equations. In the specification of the combined hedging/speculative equations the question arises whether such an equation should be predominantly a hedging relationship, predominantly speculative, or whether the two groups of elements should be given approximately equal weight. This has been treated essentially as an empirical question, and estimation has been permitted to settle the relative importance of hedging and speculation in these two equations.

Specification of the equations in such a model should reflect the equilibrium conditions for the respective agents. Hence, the relationship for sales of futures contracts is based on equilibrium conditions for profit maximizing short hedgers, such as inventory holders (who gain when the forward premium declines), derived from Working (1953) and for profit maximizing short speculators in futures (who expect the price to fall) (see Goss (1972), p.23). The volume of hedged stocks, therefore, is assumed to be an increasing function of the forward premium while short speculators are assumed to extend their sales of futures until

$$P_t = P^*_{t+1} + r_t$$

where

P_t = current futures price of wool;

P^*_{t+1} = expected futures price of short speculators for period (t+1) formed in period t;

r_t = marginal risk premium; r_t is assumed to increase with agents' commitments.

t = time in months.

In initial estimation, inclusion of the price spread, and risk premium did not yield the anticipated signs and significance, and so these variables were omitted. Price expectations were represented by the adaptive expectations hypothesis (Nerlove (1958)), and in this relationship commitments of short hedgers are represented by non-Australian Wool Corporation inventories (NK_t), so that the specification of this equation is

$$HSS_t = a_1 + b_1 NK_t + b_2 P_t + b_3 P^*_{t+1} + u_{1t} \qquad (1A)$$

where

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

and

HSS_t = total sales of futures;

u_t = disturbance term;

a_1 = constant; b_1, $b_2 > 0$; $b_3 < 0$.

The adaptive expectations hypothesis, which postulates that expectations are revised by a fraction of the immediately prior expectational error, implies that the current expectation of next period's price is a weighted average of past actual prices, where the weights decline geometrically backward in time. The adaptive model, therefore, can be expected to under-predict on a rising market and to over-predict on a falling market. In comparison, the rational expectations hypothesis (Muth (1961)), which assumes that agents utilize all relevant publicly available information, and that agents correctly anticipate P_{t+1}, would require that λ=1 (see Giles, Goss and Chin (1985) and Dewbre (1981) for applications to commodity futures markets).

We can write $P^*_{t+1} = (1-\beta)P_t/(1-\beta L)$

where $\beta = (1-\lambda)$ and L is the lag operator.

Substituting for P^*_{t+1} in equation (1A) gives the final specification

$$HSS_t = \theta_1 + \theta_2 NK_t + \theta_3 P_t + \theta_4 HSS_{t-1} + \theta_5 NK_{t-1} + \theta_6 P_{t-1} + e_{1t} \quad (1)$$

where the expected signs are $\theta_2 > 0$; θ_5, $\theta_6 < 0$; $0 < \theta_4 < 1$; $\theta_3 > 0$ provided $b_2 > | b_3 (1-\beta) |$, otherwise $\theta_3 < 0$.

Purchases of futures by long hedgers (such as fabricators of the commodity) were taken to be inversely related to the price spread, and directly related to their expected price spread and commitments (see Giles, Goss and Chin (1985)). Purchases of futures by long speculators (who expect the price to rise), on the other hand were assumed to be inversely related to the current price and marginal risk premium and directly related to the expected futures price (see Kaldor (1939)). In initial estimation, the purely speculative components of this equation did not result in parameter estimates of the expected sign, and therefore this relationship reflects essentially the activities of long hedgers. Expectations of the price spread are again represented by the adaptive hypothesis, with commitments represented by planned exports which are, in effect, assumed to be realized two periods later. Hence, total purchases of futures (HSL) are given by

$$HSL_t = a_2 + b_4 (P_t - A_t) + b_5(P_{t+1} - A_{t+1})^{**} + b_6 X_{t+2} + u_{2t} \quad (2A)$$

where

A_t	=	current spot price of wool;
$(P_{t+1} - A_{t+1})^{**}$	=	long hedgers' expected price spread;
X_{t+2}	=	exports of wool two periods hence;

$b_4 < 0$; b_5, $b_6 > 0$; and

$$(P_{t+1} - A_{t+1})^{**} = (1-\gamma)(P_t - A_t)/(1-\gamma L), \qquad 0 < \gamma < 1.$$

Substituting in (2A) gives

$$\begin{aligned} HSL_t = \theta_7 + \theta_8(P_t - A_t) + \theta_9 X_{t+2} + \theta_{10} HSL_{t-1} \\ + \theta_{11}(P_{t-1} - A_{t-1}) + \theta_{12} X_{t+1} + e_{2t} \end{aligned} \tag{2}$$

where

$\theta_8 < 0$ if $|b_4| > b_5(1-\gamma)$, otherwise $\theta_8 > 0$; θ_9, $\theta_{11} > 0$;

$0 < \theta_{10} < 1$; $\theta_{12} < 0$.

The equation representing the holding of unhedged inventories exhibits the characteristics of a speculative demand function with current price and expected spot price variables, but without storage cost and marginal risk premium which again did not yield parameter estimates of the expected sign. Hence the demand for unhedged inventories (U_t) is based on the relationship:

$$U_t = a_3 + b_7 A_t + b_8 A_{t+1}^* + u_{3t} \tag{3A}$$

where $b_7 < 0$, $b_8 > 0$; A^*_{t+1} is the expected cash price of unhedged inventory holders (assuming adaptive expectations) and

$$A^*_{t+1} = (1-\eta)A_t/(1-\eta L), \qquad 0 < \eta < 1$$

This leads to

$$U_t = \theta_{13} + \theta_{14} A_t + \theta_{15} A_{t-1} + \theta_{16} U_{t-1} + e_{3t} \tag{3}$$

where $\theta_{14} < 0$ if $|b_7| > b_8(1-\eta)$, otherwise $\theta_{14} > 0$;

$\theta_{15} > 0$; $0 < \theta_{16} < 1$.

The consumption demand for raw wool is a function of the current spot price, parameters of the demand for the finished product, and parameters of the supply of other inputs used in conjunction with wool. This equation, which is log-linear, employs real household disposable income to represent the first group of parameters and the relative price of synthetic fibres to represent the second group (see also Douglas and McIntyre (1970)). Extending the adaptive hypothesis to disposable income, and relating consumption demand to the lagged wool-synthetic price ratio, the equation is

$$\ell n\ C_t = a_4 + b_9\ \ell n\ Y^*_{t+1} + b_{10}\ \ell n\ (A/S)_{t-1} + u_{4t} \qquad (4A)$$

where Y^*_{t+1} = expected real household disposable income;

S_t = spot price of synthetic fibres;

and $Y^*_{t+1} = (1 - \delta)Y_t/(1 - \delta L) \qquad 0 < \delta < 1\ ;\ b_9 > 0\ ,\ b_{10} < 0.$

This gives

$$\ell n\ C_t = \theta_{17} + \theta_{18}\ \ell n\ C_{t-1} + \theta_{19}\ \ell n\ Y_t$$

$$+ \theta_{20}\ \ell n\ (A/S)_{t-1} + \theta_{21}\ \ell n\ (A/S)_{t-2} + e_{4t} \qquad (4)$$

where $0 < \theta_{18} < 1; \quad \theta_{19}, \theta_{21} > 0; \quad \theta_{20} < 0.$

This model has six endogenous variables HSS, HSL, U, C, P, A and is completed with the identities

$$HSS_t \equiv HSL_t \qquad (5)$$

$$K_t \equiv U_t + HSL_t \qquad (6)$$

where K_t represents total stocks of raw wool. Each of the structural equations in the model is overidentified.

2.2 DATA

Data on HSS and HSL are turnover of wool contracts on the Sydney Futures Exchange for the period 1974(02) to 1984(03) from the SFE Statistical Yearbook 1980-84 (weekly summaries prior to 1980). Cash price data are daily prices (see Gilbert (1986)) for 22 micron type 78 (21 micron in 1976, good 64s prior to 1976) on the median trading day of each month from AWC Wool Market News. Similarly, futures price data are daily prices for the median trading day each month for the contract grade for a future approximately six months prior to delivery from the SFE Statistical Yearbook.[1] Both wool spot and futures prices are quoted in Australian cents per kilogram, clean basis. Data on NK, C, K, X, are in mill. kg. clean basis converted to contracts from the Australian Bureau of Statistics (ABS). Identity (6) was used to calculate U because data on U are unobservable. Estimation of U in this way resulted in three negative values of U during the sample period (these were January to March 1980), which were deleted, because the model employed here is not defined for negative unhedged storage. Real disposable income is Australian Household Disposable Income divided by the Consumer Price Index from the ABS Databank (CAT. 6401.0), while synthetic price data are for 70 denier Japanese acrylic tow from the Japan Textile News (various issues), converted to \$A at the Reserve Bank of Australia spot rate. Data on C and NK are on an annual basis interpolated to monthly, while data on Y are quarterly interpolated to monthly.

2.3 TESTS FOR UNIT ROOTS

Tests for unit roots have been of interest in recent research on the determination of prices and financial time series for several reasons. First, a time series which has an autoregressive representation with a single unit root, can be approximated by a random walk, which is of special interest to students of the behaviour of efficient markets. Second, rational expectations models of commodity and financial markets require stationarity in order that conditional expectations of prices in such models are time invariant. Moreover, the task of forecasting economic time series is obviously easier if they are generated by stationary processes, although it is not necessarily impossible if these processes are non-stationary.

Tests for unit roots have been studied by Fuller (1976), Dickey and Fuller (1979, 1981), Evans and Savin (1981, 1984) and have been applied by Doukas and Rahman (1987) to foreign currency futures data (see also comments by Hodrick (1987, p.29)). In this paper tests are executed for a single unit root in wool cash and futures price series, using the test statistics developed by Dickey and Fuller (1979, 1981). This hypothesis is of special interest here, given the focus of this paper on the informational efficiency of the wool market.

In the autoregressive representation of the cash price series:

$$A_t = \rho A_{t-1} + e_t \tag{7}$$

where it is assumed that ρ is a real number and e_t is NID $(0,\sigma^2)$, if

(a) $|\rho|<1$, A_t converges to a stationary series as $t \to \infty$.

(b) $|\rho|>1$, the series is non-stationary, and the variance of A_t grows exponentially as $t \to \infty$.

(c) $|\rho| = 1$, there is borderline non-stationarity. If $\rho = 1$, there is a single unit root.

The models used to test the hypothesis of a single unit root are (7) as well as the two following representations:

$$A_t = \mu + \rho A_{t-1} + e_t \tag{8}$$

$$A_t = \mu + \beta t + \rho A_{t-1} + e_t \tag{9}$$

In these models, A_1 is assumed fixed, (8) contains an intercept, while (9) contains an intercept and time trend. The tests employed are the Wald test and the likelihood ratio test developed by Dickey and Fuller (1979, 1981). The Wald test requires estimation of the unconstrained model, while the likelihood ratio test requires that the model be re-estimated according to the constraint of the null hypothesis.

The least squares estimator $\hat{\rho}$ (which, on the assumptions is the ML estimator) is consistent for all values of ρ (Dickey and Fuller (1979) p.427). The estimates of the parameters for the models in (7), (8), (9) are presented in Table 1 for wool cash prices, for 134 observations, together with the relevant Wald test statistics as developed by Dickey and Fuller (1979), which are used to test the hypothesis $H(\rho = 1)$. These calculated statistics are compared with the tabulated critical values, given in Fuller (1976) Tables 8.5.1 and 8.5.2 (pp.371, 373). In the derivations of the tabulated values in Fuller (1976), the value of A for $t = 1$, A_1, is fixed. While the distributions of $\hat{\rho}_\mu$ and $\hat{\tau}_\mu$, and the limiting distribution of $\hat{\rho}$ do not depend on A_1, the small sample distribution of $\hat{\rho}$ will be influenced by A_1 (Dickey and Fuller (1979) p.430). It will be seen that the hypothesis of one unit root $H(\rho = 1)$ cannot be rejected at the 10% level in any of the versions formulated in (7), (8) or (9). This statement applies whether the test statistic $n(\hat{\rho} - 1)$ or the statistic $\hat{\tau} = (\hat{\rho} - 1)/SD_{\hat{\rho}}$ is employed (where $SD\hat{\rho}$ is the sample standard deviation of $\hat{\rho}$).

What can be said about the comparative powers of these two tests? In Dickey and Fuller (1979, p.430) the powers of the various tests in a Monte Carlo study are given, using the model in (7), for different sample sizes and different values of ρ. For a sample of n = 100 with $\rho = 0.95$, the powers of the test statistics $n(\hat{\rho} - 1)$ and $\hat{\tau}$ are identical, and both are more powerful than the statistics $n(\hat{\rho}_\mu - 1)$ and $\hat{\tau}_\mu$. When the sample value of $\rho = 1.02$, the power of $\hat{\tau}$ slightly exceeds that of $n(\hat{\rho} - 1)$, and again both these test statistics are more powerful than $n(\hat{\rho}_\mu - 1)$ and $\hat{\tau}_\mu$.

Likelihood ratio tests are employed also to test for the presence of unit roots in wool cash prices, and these tests, as noted below, can under some circumstances be more powerful than the Wald tests reported in Table 1. Three likelihood ratio tests are reported here. The first hypothesis considered is $H(\alpha, \rho) = (0,1)$, in which the alternative model $A_t = \alpha + \rho A_{t-1} + e_t$, which is the model in (8), is tested against the null model $A_t = A_{t-1} + e_t$, and the test statistic is ϕ_1. The second hypothesis is that $H(\alpha, \beta, \rho) = (0,0,1)$; in this case, the model in (9) is tested against the same null as above, and the test statistic is ϕ_2. The third hypothesis tested is $H(\alpha, \beta, \rho) = (\alpha, 0, 1)$; here the alternative model in (9) is tested against the slightly wider null $A_t = \alpha + A_{t-1} + e_t$, and the test statistic is ϕ_3. Table 2 gives the calculated values of the relevant statistics for these various hypothesis tests, according to the formulae in Dickey and Fuller (1981, p.1059). Empirical distributions of the test statistics ϕ_1, ϕ_2, ϕ_3 are given for various sample sizes in Tables IV, V, VI of Dickey and Fuller (1981, p.1063). Comparing the tabulated critical values with the calculated values of the test statistics in Table 2, supports the view that in none of the three cases is it possible to reject the hypothesis of a single unit root. This result is consistent with the outcome of the Wald tests in Table 1, and is consistent with the finding of Praetz (1975) that the behaviour of wool cash prices over time is not inconsistent with the random walk model.

It is observed by Dickey and Fuller (1981, p.1069) that the statistics $n(\hat{\rho}_\mu - 1)$ and $\hat{\tau}_\mu$ display poor power when ρ is close to unity and $\alpha \neq 0$, as in some of the models estimated here. Moreover, these authors note (p.1068) that the test statistic ϕ_1 has more power than ϕ_2 , because the alternative model for ϕ_2 is wider.

These tests were executed also for wool futures price data for the same sample period, and again in no case could the hypothesis of a single unit root be rejected (these latter tests are not reported here for reasons of space).

3. ESTIMATION AND RESULTS

The estimation of the simultaneous system of equations was executed by three stage least squares (3SLS) with the program TSP 4.1A (Hall, 1986). The initial values of the parameters for this simultaneous estimation were obtained from single equation estimates of the coefficients in the respective equations. For equation (1), these initial values were obtained by Ordinary Least Squares (OLS); all coefficient estimates were of the anticipated sign, most were significant, and there was no evidence of serial correlation among the residuals. This implies that if the error term (e_{1t}) in (1) is independently and identically distributed (i.i.d.), then the error term (u_{1t}) in (1A) follows a first order autoregressive process (AR1), since $u_{1t} = \beta u_{1t-1} + e_{1t}$. In any case, since there is no evidence of serial correlation in e_{1t}, it was not necessary to make allowance for serial correlation of this term in the 3SLS estimation of the model. A similar statement can be made about (2) except that in this case the initial values were obtained by Instrumental

Variable (IV) estimation,[2] because Durbin's h statistic, following OLS estimation, was in the inconclusive region. Again, there was no evidence of serial correlation when the initial values for (2) were estimated by IV.

In equations (3) and (4), initial parameter values were obtained by IV estimation with an AR1 correction (using the Cochrane-Orcutt method), following which there was no evidence of remaining serial correlation, all coefficient estimates were of the anticipated sign although some were not significant.[3] This implies that if u_{3t} in (3A), for example, is i.i.d., then e_{3t} in (3) follows a first order moving average process (MA1), where $e_{3t} = u_{3t} - \eta u_{3t-1}$. Since there was no evidence of further serial correlation in e_{3t} following the AR1 correction, this would seem to imply that u_{3t} is not strictly i.i.d.

These single equation estimates of the coefficients provide the initial values for simultaneous estimation[4] by 3SLS. The 3SLS estimates are consistent and asymptotically efficient (Hall (1986) p. 270). The AR1 correction made in the estimation of initial values was extended to systems estimation, by means of an autoregressive transformation of the relevant equations. For example, if we take equation (3) for unhedged storage, lag it by one period, multiply by ρ_3 (the autocorrelation coefficient) and subtract the result from (3) we obtain

$$U_t - \rho_3 U_{t-1} = \theta_{13}(1-\rho_3) + \theta_{14}(A_t - \rho_3 A_{t-1}) + \theta_{15}(A_{t-1} - \rho_3 A_{t-2})$$
$$+ \theta_{16}(U_{t-1} - \rho_3 U_{t-2}) + e_{3t} - \rho_3 e_{3t-1} \qquad (3.1)$$

This transformation was applied also to equation (4), and the 3SLS procedure was employed to estimate the structural parameters of the model and the autocorrelation coefficients. An autoregressive transformation was not applied to (1) and (2) because there was no evidence of inter-equation serial correlation affecting (1) and (2) after the estimation by 3SLS.

The performance of the model within the sample period was assessed, and this model was used to predict the cash price during the forecast period. This model-derived prediction of the cash price was then compared with the prediction contained in the futures price.

The 3SLS estimates of the parameters of the model for the sample period February 1974 to December 1980 (80 observations) are reported in Table 3. The main features of these results are as follows. First, the signs of all parameter estimates are as expected. Second, all adaptive expectations adjustment coefficent estimates are between zero and unity, as economic theory requires, and are significant. (The relevant estimates are $\hat{\theta}_4$, $\hat{\theta}_{10}$, $\hat{\theta}_{16}$, $\hat{\theta}_{18}$, and the adaptive adjustment coefficients are $(1-\hat{\theta}_4)$, $(1-\hat{\theta}_{10})$ etc.) Hence, the adaptive hypothesis seems to be an appropriate representation of expectations in the wool market. Third, the estimates of income and relative price elasticities for equation (4) ($\hat{\theta}_{19}$ and $\hat{\theta}_{20}$ respectively) suggest that wool is indeed a superior good as one would expect, and that consumers respond inversely to changes in the price of wool relative to the price of synthetics. The estimates of θ_{19} and θ_{20} are plausible, although it would appear that the influence of income as a parameter of demand is not strong. Fourth, of seventeen structural parameters of the simultaneous model, only eight (or 47 per cent) are significant at the five per cent level (one tail test).

Although significance is lacking in several of the parameter estimates of the foregoing model, a critical test of the performance of a simultaneous model with an expectations function, is its ability to predict or simulate values of the endogenous variables, both within and outside the sample period. In Table 4 are reported the correlation coefficients between simulated and actual values, Theil's Inequality Coefficient (TIC) and per cent root mean squared error of forecast (%RMSE) for P, A, U, C and HSS (= HSL) for within sample simulation. These simulations are illustrated in figures 1 to 5. Note that there are no separate predictions for HSL, because observations on this variable are equilibrium values, so that HSS and HSL are always equal.

This model exhibits an ability to predict intra-sample values extremely well for futures and cash prices, holdings of unhedged inventories and consumption of raw wool, and moderately well for total sales and total purchases of futures contracts. Indeed, the per cent RMSE's for this model compare favourably with those reported by Goss and Giles (1986b, p. 109) for an alternative model of the wool market.

On this basis, it was decided to employ this model to predict the cash price for the forecast period June 1981 to March 1984 (34 observations). The semi-strong form of the efficient markets hypothesis is addressed by comparing this prediction of the cash price with the forecast implicit in the futures price six periods earlier. The correlation coefficient, TIC and per cent RMSE for these two sets of predictions of the cash price during the forecast period are reported in Table 5 Section 1, and the simulations are illustrated in Figure 6. These statistics suggest unambiguously that the simulated cash price from the model is inferior to the futures price as a prediction of the actual cash price,[5] although the difference between the two is not significant (see Appendix 3).

In order to evaluate further the comparative performance of these two predictors, it was assumed that each contributes to a composite prediction of the cash price (see Leuthold and Hartmann (1979)). If the two predictors contribute equally to the composite prediction, then in the following relationship $\alpha = 0.5$

$$A_t = \alpha E_{t-6,t} + (1-\alpha)P_{t-6,t} + e_t \qquad (10)$$

where $E_{t-6,t}$ is the value of the cash price at time t, as simulated by the model at time (t-6). If, however, one of these predictors uses available information more efficiently than the other, then the former will have the greater coefficient in (10), which was estimated by OLS in the following form:

$$A_t = \alpha E_{t-6,t} + \beta P_{t-6,t} + e_t \qquad (11)$$

In the estimation of (11) α and β were <u>not</u> constrained to add to unity. The results of these estimations are reported in Table 5 Section 2, where it will be seen that the coefficient attaching to the model predictor is slightly less than the coefficient of the futures price. Normally, possible collinearity between the two predictors, in a relationship such as (11), would caution against attaching undue importance to the precise values of the coefficient estimates. (Due to sample error, the estimates of α and β in Table 5 add to 1.0171.)

It should be emphasised that the parameter values for the model simulation are estimated for the sample period (February 1974 to December 1980), while the futures price is quoted six months prior to the cash price which it is assumed to predict. Hence for 33 observations of the forecast period the model is on an inferior informational footing compared with the futures price. An attempt was made to equalize the dates of the information inputs to the model and the futures price, by updating the model and re-estimating the parameters, for each successive simulation of the cash price during the forecast period. This procedure resulted in a marginal improvement in the forecasts of A in that the TIC and %RMSE diminished slightly, although the correlation coefficient deteriorated also. The results of simulations with updating are given in Table 6 Section 1 and the contributions to a composite prediction, obtained by estimating (11A), are given in Table 6 Section 2, where

$$A_t = \alpha' AS_{t-6,t} + \beta' P_{t-6,t} + e'_t \qquad (11A)$$

and AS is the model-derived prediction of A with updating. In any case, the model forecasts of the cash price are still inferior to those implicit in the futures price (although again the difference is not significant)

While neither of the model-derived forecasts outperforms the futures price as a prediction of the cash price, it is clear from Figure 6 that each of the prediction series, AS and P, contains information which the other does not. A composite predictor, derived as a weighted average of the two, therefore, could be expected to outperform each of the individual predictors. Two composite predictors were derived, defined as follows:

$$CP_t = 0.5\ E_{t-6,t} + 0.5\ P_{t-6,t} \qquad (12)$$

$$CP'_t = 0.38\ AS_{t-6,t} + 0.62\ P_{t-6,t} \qquad (12A)$$

where the weights are based on the estimation of (11) and (11A) respectively. The performance of these two composite predictors of the cash price is summarized in Table 7. Each of the composite predictors clearly outperforms the futures price as a predictor of the cash price, and CP', the composite predictor which takes account of the updated model, is slightly superior to CP. The difference in predictive performance between CP' and the futures price is significant (see Appendix 3).

What are the implications of these results for the question of market efficiency? It may be tempting to reject the efficient markets hypothesis on the ground that the composite prediction outperforms the futures price as an anticipation of the cash price. In an instantaneous sense it is true that the economic model contains some information not reflected in the futures price. Yet economic agents take time to learn to use information and to revise expectations. The question, therefore, is whether there is evidence that agents in the futures market are using, to an increasing extent, the information contained in the model. Convergence of the composite predictor and the futures price would constitute such evidence, although in this case there is no apparent convergence of these two series. On the other hand, it has been observed that the proportionate contribution of the futures price to a composite predictor during the forecast period, 0.619 (Table 6) is greater than the proportionate contribution of the futures price to a composite predictor during the sample period, 0.254, and a Chow test suggests that these two proportions are significantly different. This suggests that, as time passes, the market is learning to use the information contained in the model, and may provide sufficient caution against rejection of the efficient markets hypothesis.

4. CONCLUSIONS

This paper investigates the semi-strong form efficiency of the Australian wool market, using the model forecasting approach. Tests for unit roots with wool cash price data suggest that the hypothesis of a single unit root cannot be rejected. A simultaneous model of the Australian wool market was developed, with relationships for hedgers, speculators, consumers and unhedged inventory holders; three stage least squares estimation was employed to obtain consistent and asymptotically efficient estimates. This model was used to predict the cash price in a subsequent forecast period, the resulting prediction being compared with the prediction contained in the futures price. The futures price exhibits a higher correlation coefficient, a lower Theil's inequality coefficient and lower per cent root mean squared error than the model predictor, although the difference in performance between the two is not significant.

Nevertheless, each prediction series contains information which is absent from the other, and a composite predictor, derived from the model and the futures price, clearly outperforms the futures price as a predictor of the cash price. It is suggested, however, that the semi-strong form of the efficient markets hypothesis should not be rejected. This is because the contribution of the futures price to a composite predictor during the forecast period, is greater than the contribution of the futures price to such a predictor during the sample period. Hence there is evidence that, over time, agents in the futures market are learning to use information contained in the model.

It is concluded that the results presented here do not favour rejection of the hypothesis that wool prices reflect publicly available information as fully as possible; these results are consistent with those of Goss (1987), in which the same issue was investigated using the forecast errors approach.

TABLE 1

PARAMETER ESTIMATES AND WALD TEST STATISTICS FOR UNIT ROOTS: CASH PRICES*

Equation	$\hat{\mu}$	$\hat{\beta}$	$\hat{\rho}$	$n(\hat{\rho} - 1)$	$\hat{\tau}$
(7)	-	-	1.0018 (0.0048)	0.2412	0.375
				$n(\hat{\rho}_{\mu} - 1)$	$\hat{\tau}_{\mu}$
(8)	9.9213 (8.7635)	-	0.9789 (0.0208	-2.8274	-1.0144
				$n(\hat{\rho}_{\tau} - 1)$	$\hat{\tau}_{\tau}$
(9)	17.572 (9.3709)	0.1575 (0.0742)	0.9344 (0.0293)	-8.7904	-2.2359

* Numbers in parentheses are standard errors.

TABLE 2

LIKELIHOOD RATIO TESTS FOR UNIT ROOTS: CASH PRICES

Hypothesis	Null Model	Alternative Model	Test Statistic (Calc. Value)
(1) $H(\alpha,\rho)=(0.1)$	$A_t = A_{t-1} + e_t$	$A_t = \alpha + \rho A_{t-1} + e_t$	$\phi_1 = 0.0054$
(2) $H(\alpha,\beta,\rho)=(0,0,1)$	$A_t = A_{t-1} + e_t$	$A_t = \alpha+\beta t+\rho A_{t-1}+ e_t$	$\phi_2 = 1.98$
(3) $H(\alpha,\beta,\rho)=(\alpha,0,1)$	$A_t = \alpha+A_{t-1}+e_t$	$A_t = \alpha+\beta t+\rho A_{t-1}+ e_t$	$\phi_3 = 2.782$

TABLE 3
3SLS PARAMETER ESTIMATES : EQUATIONS 1 TO 4

Coefficient	Variable	Estimate	Asym-t value	Equation
θ_1	Const.	-4085.200	-1.524	1
θ_2	NK_t	1.136	1.142	
θ_3	P_t	35.994	0.758	
θ_4	HSS_{t-1}	0.468	4.750	
θ_5	NK_{t-1}	-0.650	-0.666	
θ_6	P_{t-1}	-26.123	-0.543	
θ_7	Const.	726.700	0.484	2
θ_8	P_t-A_t	-54.360	-1.179	
θ_9	X_{t+2}	0.089	1.902	
θ_{10}	HSL_{t-1}	0.724	8.757	
θ_{11}	$P_{t-1}-A_{t-1}$	33.042	0.828	
θ_{12}	X_{t+1}	-0.051	-1.153	
θ_{13}	Const.	34825.000	2.028	3
θ_{14}	A_t	-249.020	-2.676	
θ_{15}	A_{t-1}	176.680	1.760	
θ_{16}	U_{t-1}	0.844	9.297	
ρ_3		0.461	1.632	
θ_{17}	Const.	1.077	1.291	4
θ_{18}	ℓnC_{t-1}	0.894	10.376	
θ_{19}	ℓnY_t	0.029	0.599	
θ_{20}	$\ell n(A/S)_{t-1}$	-0.116	-1.983	
θ_{21}	$\ell n(A/S)_{t-2}$	0.034	0.888	
ρ_4		0.730	3.887	

TABLE 4

INTRA-SAMPLE SIMULATION ASSESSMENT

Variable	Corr.Coeff.	TIC	%RMSE
P	0.9196	0.0812	8.901
A	0.9646	0.0555	6.278
U	0.9963	0.0433	36.045
C	0.9928	0.0028	0.292*
HSS (= HSL)	0.7227	0.3449	64.098

* This is the %RMSE for the difference between simulated and actual values of log C_t. The corresponding figure for the difference between simulated and actual values of C_t is 2.065%.

TABLE 5

SECTION 1 : FORECAST PERIOD PREDICTION OF.CASH PRICE

(MODEL WITHOUT UPDATING)

Source of Prediction	Correl. Coeff.	TIC	%RMSE
Model	0.7240	0.0663	6.5243
Futures Price	0.8069	0.04152	4.0902

SECTION 2 : COMPARATIVE PERFORMANCE OF PREDICTORS*

Equation	$\hat{\alpha}$	$\hat{\beta}$	DW
11	0.5010 (7.2926)	0.5161 (8.1199)	1.7930

* Estimation is by OLS; asymptotic t values are in parentheses.

TABLE 6

SECTION 1 : FORECAST PERIOD PREDICTION OF CASH PRICE (MODEL WITH UPDATING)

Source of Prediction	Corr.Coeff.	TIC	%RMSE
Model	0.6884	0.06128	6.0252
Futures Price	0.8069	0.04152	4.0902

SECTION 2 : COMPARATIVE PERFORMANCE OF PREDICTORS*

Equation	$\hat{\alpha}'$	$\hat{\beta}'$	DW
11	0.3831 (4.8577)	0.6191 (8.3432)	1.482

* Estimation is by OLS; asymptotic t values are in parentheses.

TABLE 7

FORECAST PERIOD PREDICTION OF CASH PRICE BY COMPOSITE PREDICTIONS

Predictor	Correl. Coeff.	TIC	%RMSE
CP	0.9036	0.0278	2.732
CP'	0.8705	0.0270	2.636

FOOTNOTES

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1. The delivery months for wool on the SFE are March, May, July, October and December. In order to generate a continuous series of futures prices the following rule was applied:

   when the month is January, February, the future is July;
   when the month is March, April, the future is October;
   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.

2. The instruments used to obtain initial values for the coefficients of (2) were: $(P_t - A_t)$, $(P_{t-1} - A_{t-1})$, X_{t+2}, X_{t+1}, HSS_{t-2}.

3. The instruments employed to obtain initial values of the parameters for (3) were: A_{t-1}, A_{t-2}, U_{t-2} while those employed to obtain initial values for (4) were as follows: $\ln(A_{t-3}/S_{t-3})$, $\ln(A_{t-4}/S_{t-4})$, $\ln Y_{t-1}$, $\ln C_{t-2}$. The values of the estimated autocorrelation coefficients for (3) and (4) obtained with IV estimation ($\hat{\rho}_3$ and $\hat{\rho}_4$ respectively, t statistics in parentheses)

are as follows:

$\hat{\rho}_3 = 0.214$ (1.952) $\qquad$ $\hat{\rho}_4 = 0.366$ (3.497)

4. The instruments employed were NK_{t-1}, NK_{t-2}, $(P_{t-1} - A_{t-1})$, $(P_{t-2} - A_{t-2})$, HSS_{t-2}, X_{t+1}, X_t, ℓnY_{t-1}, $\ell n(A_{t-3}/S_{t-3})$, $\ell n(A_{t-4}/S_{t-4})$. Experiments were conducted with various instruments, but no other set of instruments resulted in improved significance of the parameter estimates, and improved intra-sample and post-sample simulation simultaneously, nor did any other instrument set provide results comparable with those reported in Tables 1 to 4.

5. An evaluation of the post-sample simulation of the other endogenous variables is presented in Appendix 2. It will be seen that the model predicts unhedged inventories and the consumption of raw wool extremely well, and predicts the futures price and sales (and purchases) of futures contracts only moderately well. Given that the spot market is currently far more important than the futures market for wool, and that the equations for U and C are both spot market relationships, these results are helpful.

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APPENDIX 1

SYDNEY FUTURES EXCHANGE: AVERAGE MONTHLY TURNOVER OF WOOL CONTRACTS (LOTS)

1960	2,720	**1969**	3,087	**1978**	2,272
1961	2,740	**1970**	5,422	**1979**	6,291
1962	2,378	**1971**	3,733	**1980**	14,442
1963	6,836	**1972**	8,607	**1981**	5,555
1964	10,891	**1973**	15,500	**1982**	2,583
1965	6,453	**1974**	12,702	**1983**	1,859
1966	5,189	**1975**	7,250	**1984**	771
1967	5,549	**1976**	8,440	**1985**	566
1968	4,694	**1977**	5,143		

Source: Sydney Futures Exchange and International Commodities Clearing House.

APPENDIX 2

FORECAST PERIOD: SIMULATION ASSESSMENT
OF VARIABLES P, U, C, HSS(=HSL)

Variable	Corr.Coeff.	TIC	%RMSE
P	0.4774	0.2001	19.803
U	0.9990	0.0208	4.432
C	0.9206	0.0013	0.0000*
HSS (=HSL)	0.6612	0.4800	68.033

* This is the per cent RMSE for $\ell n\ C_t$; the corresponding figure for the difference between actual and simulated values of C_t is 0.964%.

APPENDIX 3

SIGNIFICANCE OF DIFFERENCE IN PERFORMANCE OF MODEL AND P AS PREDICTORS OF A

For each time period of post-sample forecasts define

$e_1 = A - E$, which is the forecast error for the model;

$e_2 = A - P$, which is the forecast error for the futures price.

With 34 observations and $\bar{e}_1 = 28.964$ ($SE_{\bar{e}_1} = 19.707$), $\bar{e}_2 = -10.697$ ($SE_{\bar{e}_2} = 19.244$), the hypotheses $H(\mu_{\bar{e}_1} = 0)$ and $H(\mu_{\bar{e}_2} = 0)$ must each be rejected.

Define $u = e_1 + e_2$ and $v = e_1 - e_2$; then the variances of e_1 and e_2, and hence the expected squared errors of the model and the futures price, will be equal if and only if u and v are uncorrelated (Granger and Newbold (1986) p.279). The relevant formula for the sample correlation coefficient between u and v, given that neither E nor P is an unbiased forecast, is

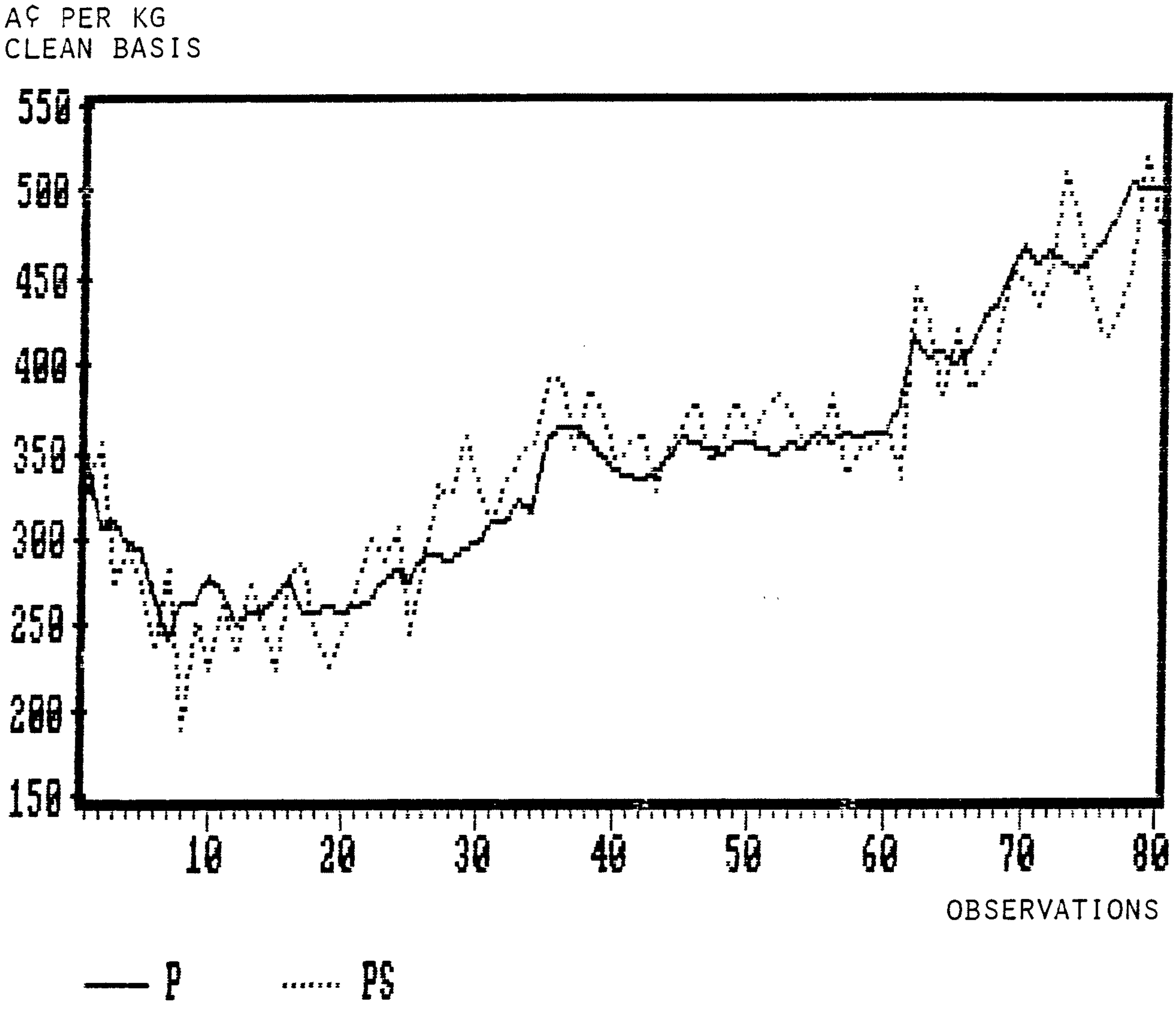
$$r = \frac{\Sigma[(e_1 + e_2) - (\bar{e}_1 + \bar{e}_2)]\ [(e_1 - e_2) - (\bar{e}_1 - \bar{e}_2)]}{\sqrt{\Sigma[\ e_1 + e_2) - (\bar{e}_1 + \bar{e}_2)]^2\ \Sigma[(e_1 - e_2) - (\bar{e}_1 - \bar{e}_2)]^2}}$$

The sample value of r calculated according to this formula is 0.02491, which is not significant. This result suggests that there is no significant difference in the performance of the model and the futures price as predictors of the cash price.

When the performance of the composite predictor CP' is compared with that of the futures price, the sample value of r calculated according to the formula above is -0.42047, which is significant. Hence the predictive performance of CP' is significantly better than that of the futures price (see also Tables 6 and 7).

FIGURE 1

FUTURES PRICE

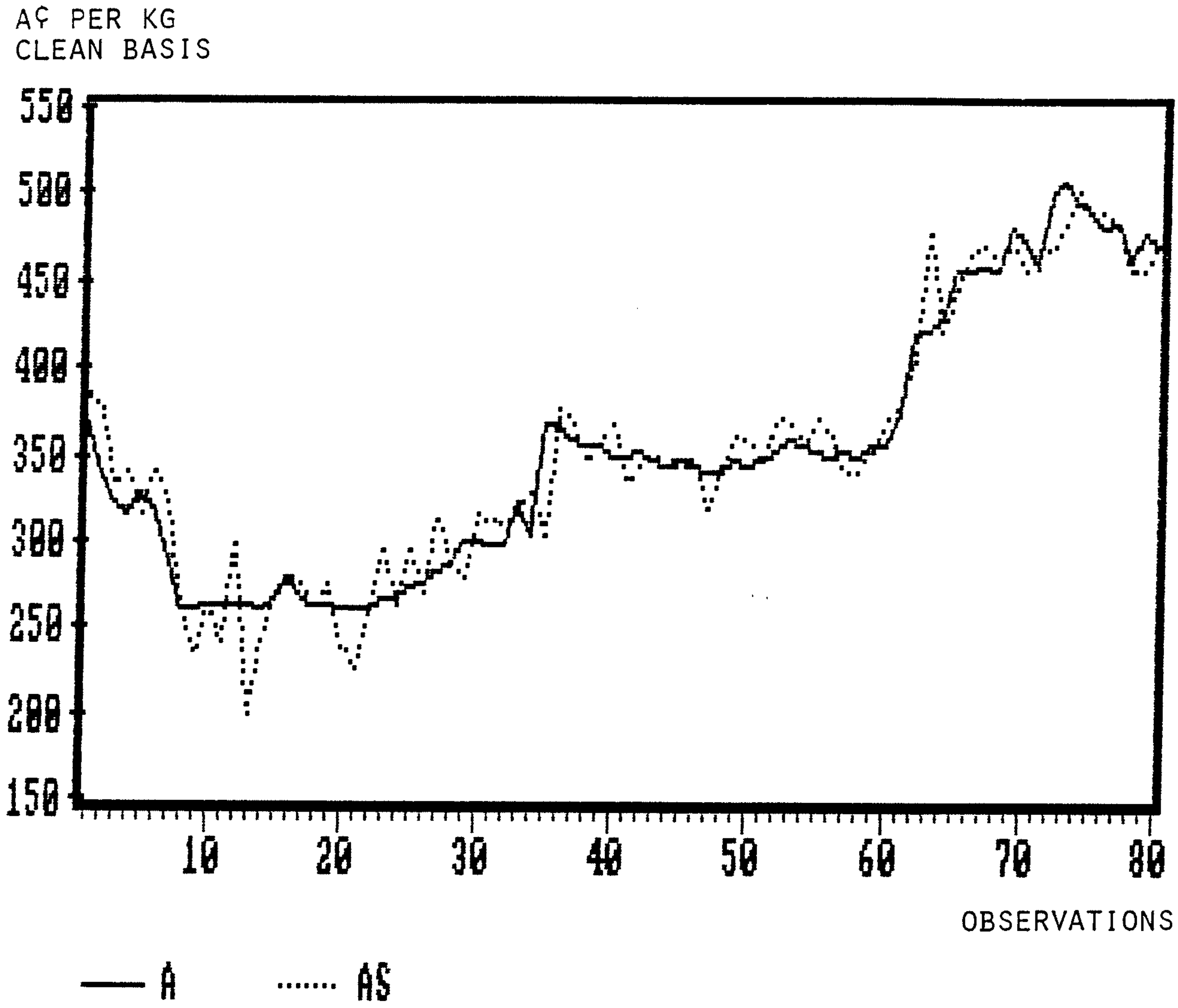


P = ACTUAL FUTURES PRICE

PS = SIMULATED FUTURES PRICE

FIGURE 2

CASH PRICE

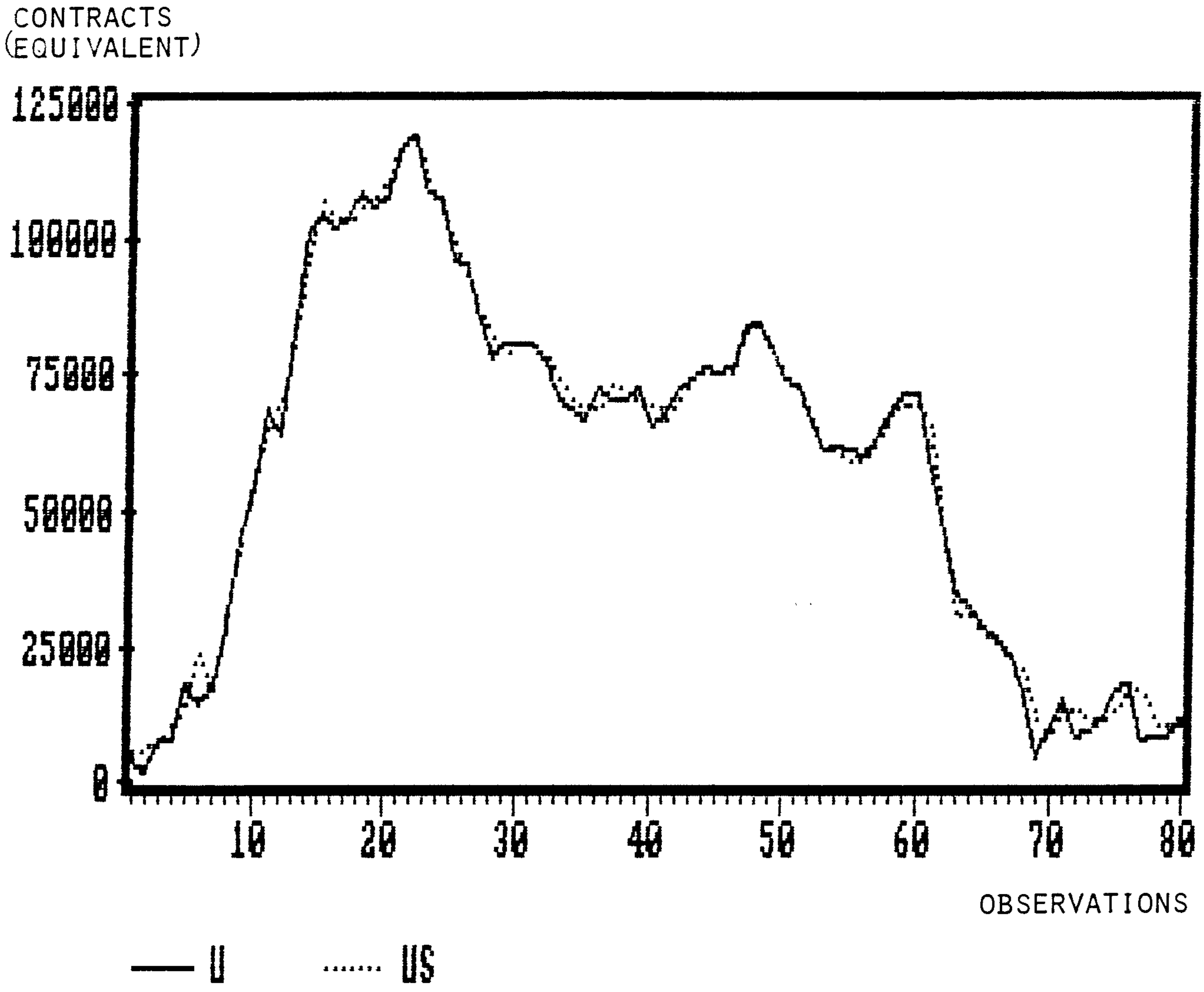


A = ACTUAL CASH PRICE

AS = SIMULATED CASH PRICE

FIGURE 3

UNHEDGED INVENTORIES

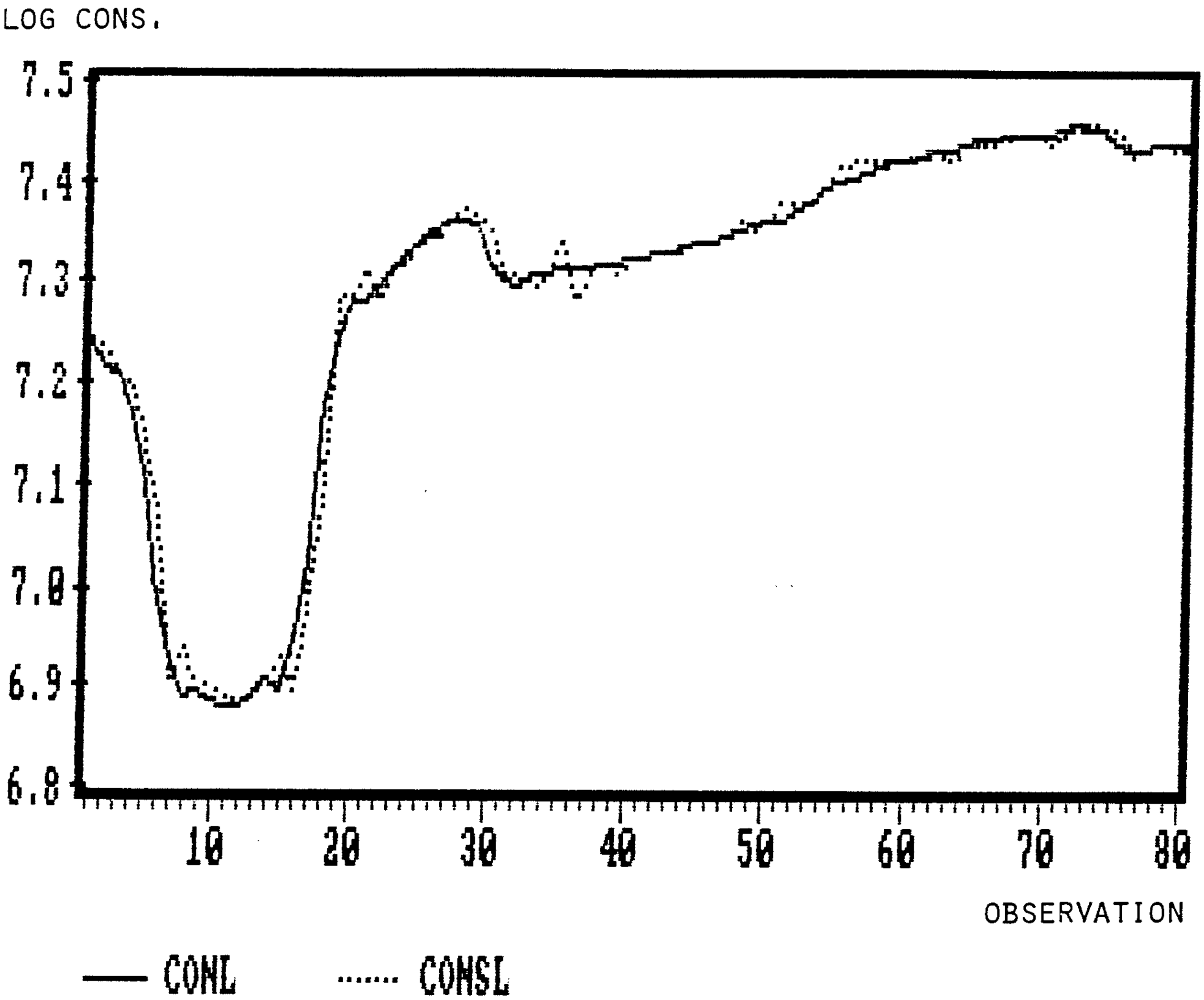


U = ACTUAL UNHEDGED INVENTORIES

US = SIMULATED UNHEDGED INVENTORIES

FIGURE 4

CONSUMPTION

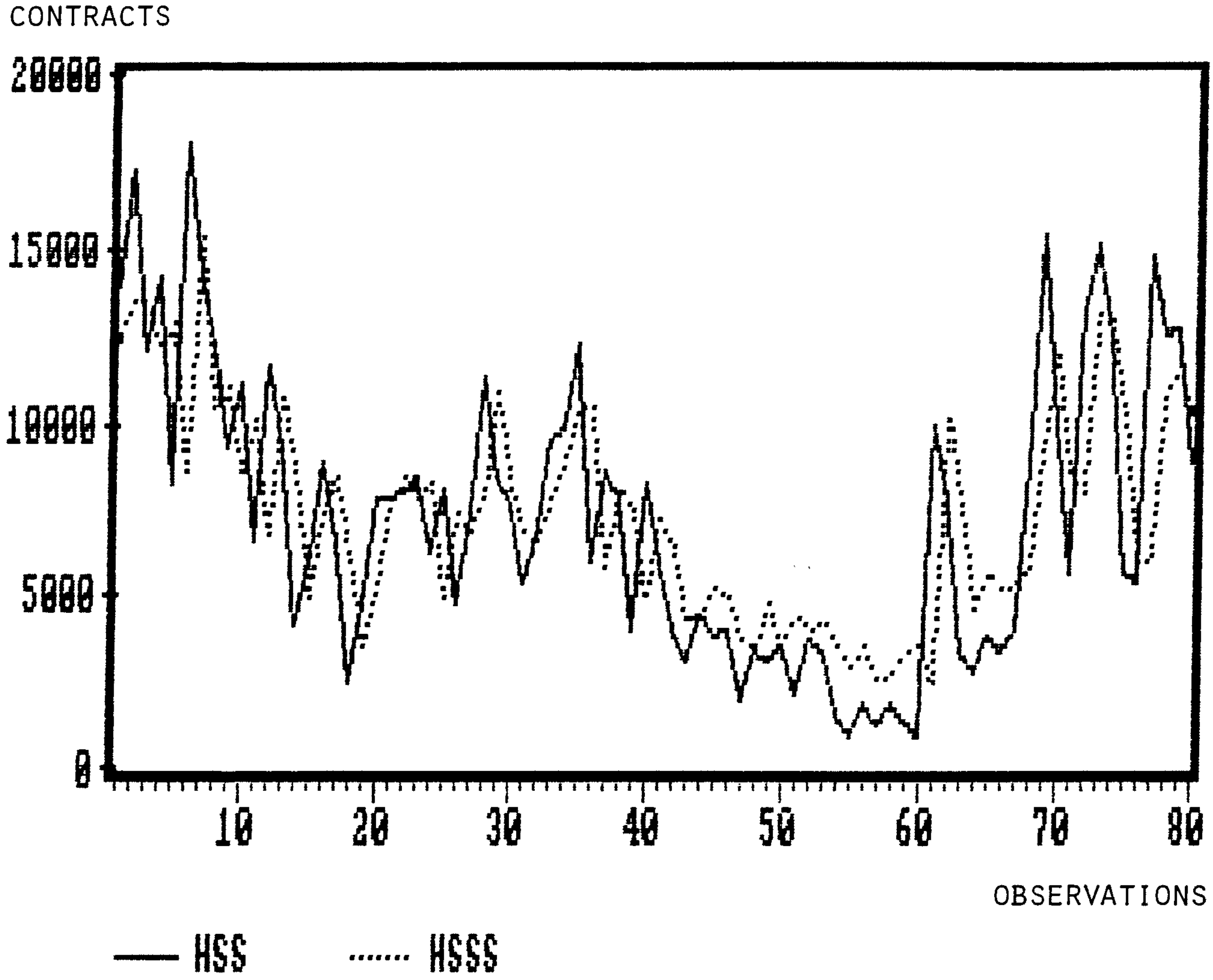


CON L = LOG ACTUAL CONSUMPTION

CONS L = LOG SIMULATED CONSUMPTION

FIGURE 5

SALES (AND PURCHASES) OF FUTURES CONTRACTS

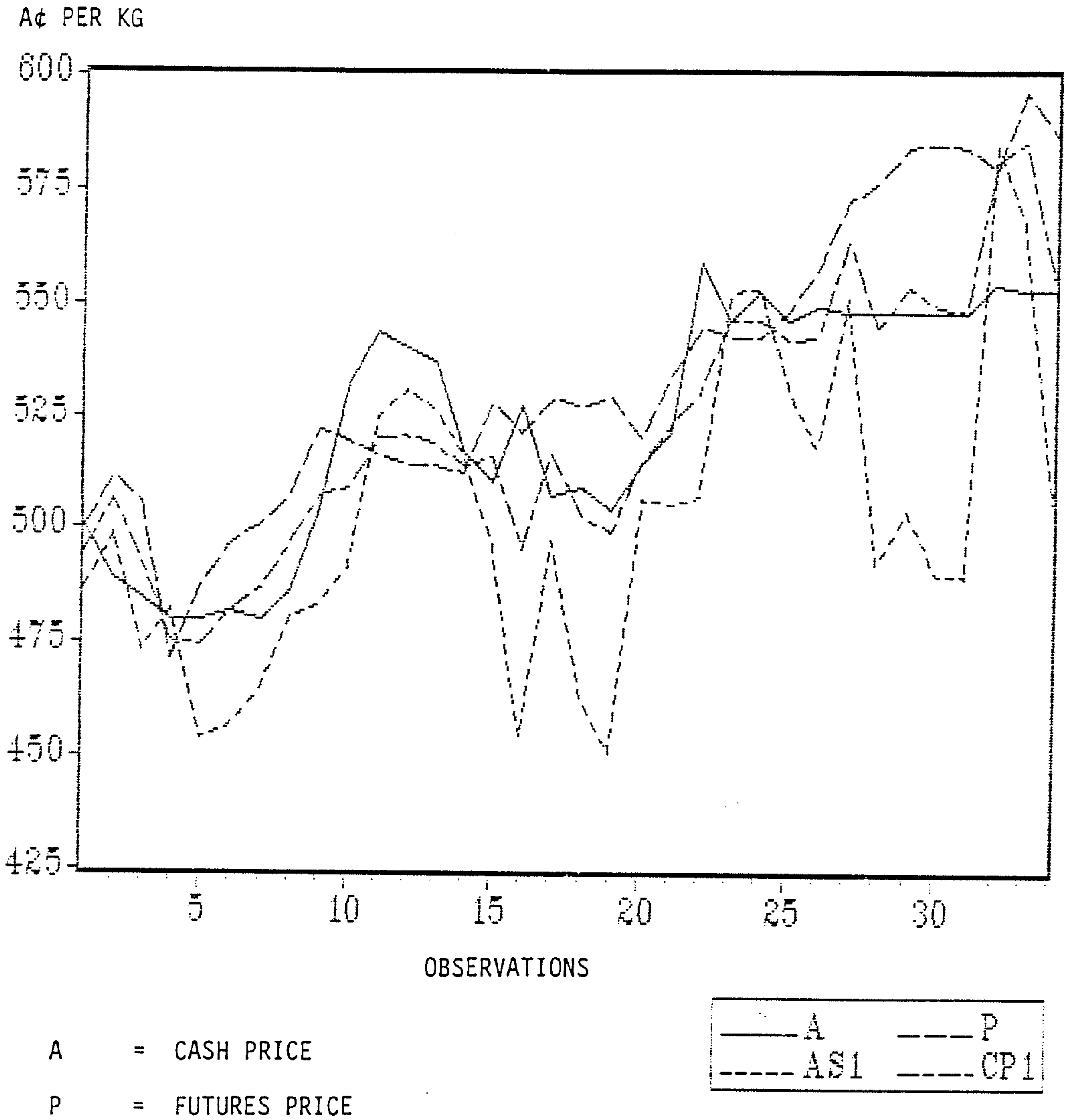


HSS = ACTUAL SALES (AND PURCHASES) OF FUTURES CONTRACTS

HSSS = SIMULATED SALES (AND PURCHASES) OF FUTURES CONTRACTS

FIGURE 6

FORECAST PERIOD PREDICTION OF CASH PRICE



A = CASH PRICE

P = FUTURES PRICE

AS1 = MODEL PREDICTOR WITH UPDATING

CP1 = COMPOSITE PREDICTOR (EQUATION (12A))