THE AUSTRALIAN JOURNAL OF AGRICULTURAL ECONOMICS

VOL. 25 APRIL 1981 NO. 1

FUTURES PRICES AS FORECASTS OF COMMODITY SPOT PRICES: LIVE CATTLE AND WOOL*

DAVID E. A. GILES and BARRY A. GOSS
Monash University, Clayton, Vic. 3168

In this paper the foundations on which the predictive interpretation of futures prices rests are discussed, and possible reasons for the differential predictive performance of futures prices as between different commodity markets examined. The predictive performances of futures, and spot prices themselves, are tested empirically, using Australian data for wool (a continuous inventory commodity) and finished live beef cattle (virtually a non-storable commodity), by means of instrumental variables estimation.

Functions of Commodity Futures Markets

Because of their requirement to plan ahead, economic agents seek to forecast commodity prices. Individual and group efforts, both sophisticated and naive, have been directed to this aim. In addition to such initiatives, however, commodity markets themselves, especially those with forward trading facilities, anticipate future prices in their process of current price formation. Commodity markets perform this function because they incorporate current information, including the expectations of economic agents, in the determination of current prices.

Commodity futures contracts are particular specialised cases of forward contracts, being standardised with respect to commodity description, delivery date and delivery location. The contract, therefore, rather than the commodity itself, is the unit of transaction. Futures markets are organised exchanges which deal in these contracts for forward delivery or settlement. A clearing house is interposed between buyer and seller and guarantees all transactions, so that the identity of the buyer or seller is a matter of indifference to the other party. Although delivery is usually, but not always, provided for in such contracts, most traders close out their positions, not by making or taking delivery, but by reversal of the transactions.

* An earlier version of this paper was presented to Section 24, Jubilee ANZAAS Congress, University of Adelaide, May 1980. The research on which this paper is based is part of a wider project entitled 'Price Determination and Storage in International Commodity Markets', supported by the A.R.G.C. Thanks are due to the Sydney Futures Exchange for providing data on cash and futures prices, to Ken Clements and three anonymous referees for their helpful comments, and to Jenny Lau for her careful research assistance. Any remaining errors are the responsibility of the authors.

There are four main functions of futures markets. First, they facilitate risk management because they provide facilities for hedging, which is the holding of a futures position in conjunction with an actuals position of opposite sign, in pursuit of expected gain, subject to a risk constraint. The performance of futures markets as a hedging medium in portfolio selection has been studied by Rutledge (1972), Dusak (1973) and Ederington (1979).

Second, futures markets facilitate stockholding because the price spread (the difference between the futures price and the spot price) acts as a guide to inventory control and may be interpreted as a price of storage (Working 1953). This is because a forward premium which declines results in a gain to short hedgers; hence, when the forward premium is large, economic agents are likely to expand the volume of hedged inventories in the expectation that the forward premium will decline (it must fall to zero at maturity). Similarly, the volume of hedged inventories is likely to be reduced in times of a spot premium, because a decline in the spot premium results in a loss to short hedgers. The holding of hedged inventories at times of spot premium is usually explained in terms of convenience yield.

Third, futures markets are centres for the collection and dissemination of information and, if this information is fully reflected in current prices, these markets may be said to be efficient. Futures markets have been subjected to weak form tests for efficiency and, while a test of the Australian wool futures market found virtually no evidence of dependence (Praetz 1975), the opposite conclusion has been drawn for some U.S. commodities (Cargill and Rausser 1975). Futures markets have also been subject to semi-strong form tests for market efficiency, either by utilisation of 'own' and related forecast errors, or by comparison of the predictive performance of futures prices and other forecasts. The results for U.S. Treasury Bills (Hamburger and Platt 1975) and some currencies (Hansen and Hodrick 1979) have been more favourable than those for U.S. hogs (Leuthold and Hartmann 1979).

Fourth, futures markets perform a forward pricing function, and futures prices have been interpreted as a market anticipation of subsequent cash prices. Empirical evidence tends to support the view that there is a differential performance of this function as between continuous and non-continuous inventory commodities (see especially Tomek and Gray 1970; Leuthold 1974), and it is this issue which is addressed in the present paper. Using instrumental variables regression, the forward pricing function as performed by the Australian wool futures market and by the (finished) live beef cattle futures market in Australia is compared.

Wool is a continuous inventory commodity although, around June 1973, which is within the sample period, Australian inventories fell to a very low level. Since early 1975 most Australian wool inventories have been held unhedged by the Australian Wool Corporation (A.W.C.)[1]; nevertheless, wool futures prices determined on the Sydney Futures Exchange are of relevance to economic agents in their forward transactions.

[1] The proportion of Australian wool inventories held by the A.W.C. has varied from 31 per cent in mid-1972 to 40 per cent in mid-1974, reaching 90 per cent early in 1975, and it has remained around this percentage since that time. Our enquiries indicate that the A.W.C. holds around one-third of its inventories abroad, principally in Western Europe, U.S.A. and Japan, although this proportion varies from time to time.

Finished live beef cattle are normally regarded as a virtually non-storable commodity, and our enquiries indicate that such cattle can normally be held in a condition which would satisfy the delivery requirements of the live cattle contract for a maximum period of around six weeks. After this period they lose condition and become a different commodity (although they can, of course, be returned to a finished condition).

The Forward Pricing Function of Futures Markets

If all information, including traders' expectations, is fully reflected in current prices, then both spot and futures prices may be regarded as estimates of subsequent spot prices. Hence, if the market exhibits a forward premium in relation to a future date, this is not a prediction that cash prices will rise, but a market estimated carrying charge (Working 1942). Indeed, arbitrage between spot and futures markets will ensure that the forward premium does not exceed the marginal net cost of storage. Similarly, if the market exhibits a spot premium, this is not a prediction that spot prices will fall, but a market estimated inverse carrying charge. Arbitrage on the spot premium is asymmetrical with that on the forward premium, and cannot be relied upon to reduce the spot premium to any precise level. This at least was the interpretation for continuously storable commodities, based on the price of storage theory (Working 1949). For commodities without continuous inventories, the interpretation is less clear. In these cases, because economic agents cannot give full expression to their expectations about the future in terms of current spot market activities, it would seem that aspects of their expectations will be contained in the futures price (and, hence, in the price spread) which cannot be reflected in the spot price.

The hypothesis that the current futures price is an unbiased estimate of the spot price at the maturity date of the future appears to rest on three assumptions: first, that the market under review is competitive; second, that information is used rationally; and third, that economic agents are risk neutral. If the market is efficient we would expect the hypothesis to be accepted, but it should be emphasised that rejection of the hypothesis does not necessarily imply that the market is inefficient, because the hypothesis is conditional upon the information available at the time the futures price is formed.

The unbiased estimation hypothesis has been tested directly in linear form by regressing maturity date spot prices upon lagged futures prices, and testing the joint hypothesis that the intercept is zero and the slope is unity. Estimation of such a function by ordinary least squares (OLS) is likely to result in autocorrelation among the residuals if the function is under-specified (e.g. if the market is not efficient, or if all factors bearing upon spot price determination are otherwise not fully reflected in the futures price), especially if monthly average data are used.[2] Moreover, with autocorrelated residuals and a lagged endogenous variable (the

[2] A functional relationship representing the forward pricing function of a futures market is *not* a model of the determination of the spot price. Nevertheless, if the market is efficient, and if no new information is received during the interval of the lag on the futures price, then all information bearing upon spot price determination will be summarised in the lagged futures price. If new information appears after the futures price is formed this should not affect the forward pricing performance in a *systematic* way, because true new information is assumed to be random.

futures price), the OLS estimates will be both biased and inconsistent. A more appropriate method of estimation, therefore, is by instrumental variables. This method has been used by Giles and Goss (1980) and Goss (1981), and is employed in this paper.[3]

The evidence to date, summarised by Goss (1980), supports the view that lagged futures prices are unbiased predictors of spot prices for a range of continuous inventory agricultural commodities, some metals on the London Metal Exchange and some currencies. As reported by Leuthold (1974), the list of commodities for which the evidence does not support the unbiased prediction hypothesis includes U.S. potatoes (a non-continuous inventory commodity) and U.S. live beef cattle (with lags greater than three months), although a few continuous inventory commodities also appear on this list. However, the differential performance of the continuous and non-continuous inventory markets has been emphasised in the literature (Tomek and Gray 1970; Kofi 1973). Commodities with non-continuous inventories do not appear in the list of markets for which the unbiased estimation hypothesis has been accepted.

The suggested reasons why some markets perform the forward pricing function better than others and, in particular, why non-continuous inventory markets perform less well, have been summarised by Goss (1980). Two of the reasons discussed in that paper warrant mention in the context of the present study. First is the suggestion that non-continuous and non-inventory markets perform the forward pricing function less well because they are newer, with relatively smaller trading volumes. Giles and Goss (1980) tested this hypothesis by comparing the predictive performance of Sydney wool futures prices for 1963-67 (a youthful period for the exchange) with that for 1968-78, and found the former to be inferior. The second is that the absence of inventories increases the possibility of expectational error by reducing the opportunities for arbitrage between the spot and futures markets. On this reasoning, non-continuous inventory markets cannot be expected to perform the forward pricing function as well as their continuous inventory counterparts, other things being equal. It is consistent with the reasoning underlying the first suggestion, however, that with the passage of time and the subsequent expansion of trading volumes, the two categories of market may be expected to perform equally well, other things being equal. To the best of our knowledge, the second hypothesis has not been tested directly.

A Comparative Empirical Study

Method and data

In order to compare the power of futures prices to predict subsequent spot prices in commodity markets where continuous inventories are held and where inventories are not held at all, the wool futures market and the

[3] The efficiency with which futures markets utilise the information contained in past prices has been addressed by regressing the current forecast error (the difference between the current spot price and a lagged futures price) upon lagged forecast errors for the same commodity. This procedure is a test for dependence on past prices (weak form test of market efficiency). If the market is efficient in this sense the parameter estimates should not be significantly different from zero.

live beef cattle futures market on the Sydney Futures Exchange have been investigated. This role of futures prices in the wool market was investigated by Giles and Goss (1980), at which time the data necessary for the present inter-commodity comparison were unavailable to the authors. Such a comparative study is now both feasible and potentially interesting. Gellatly (1980) investigated the predictive quality of futures prices in the Australian live beef cattle market. However, he used a different estimation technique from that described below, and so direct comparisons are difficult.

The forward pricing function of futures markets is examined on the basis of simple regression relationships of the form:

$$p_t^s = \alpha + \beta p_{t-i}^f + u_t, \qquad (1)$$

where p_t^s is the spot price in month t;
p_{t-i}^f is the futures price, quoted in period $t-i$ for maturity in period t;
α and β are unknown parameters; and
u_t is a stochastic disturbance term.

If $\alpha = 0$ and $\beta = 1$, then p_{t-i}^f may be referred to as an 'unbiased' predictor of p_t^s.

The hypothesis of unbiased prediction may be examined through the statistical testing of the joint hypothesis $H: \alpha = 0$ and $\beta = 1$, or of the two simple hypotheses $H_\alpha: \alpha = 0$ and $H_\beta: \beta = 1$. If the parameters α and β in (1) are estimated by ordinary least squares (OLS), then the appropriate test statistic in the former case is:[4]

$$F_{2,T-2} = (\sum_t (p_t^s - p_{t-i}^f)^2 - \sum_t \hat{u}_t^2)(T-2)/(2\sum_t \hat{u}_t^2),$$

if H is true. The usual t-test suffices for the separate hypotheses. Often it is helpful to test H_α and H_β separately. For example, rejection of H_α and acceptance of H_β is consistent with the Keynesian hypothesis of normal backwardation. In such a case, the futures price is a downward-biased predictor of the maturity date spot price, because the latter includes a risk premium but the former does not.

Allowing for the possibility that futures prices may be endogenous, and because preliminary OLS estimation of (1) revealed autocorrelated residuals[5], equation (1) is augmented by:

$$u_t = \varrho u_{t-1} + e_t, \qquad (2)$$

where e_t is a 'well-behaved' error term associated with month t; and
ϱ is an additional unknown parameter.

Hendry's (1976) General Instrumental Variables Estimator (GIVE) was used to estimate α, β and ϱ consistently and (in a limited information sense) asymptotically efficiently.[6]

[4] Here T is the sample size and $\hat{u}_t$ is the OLS residual from (1).

[5] If p_{t-1}^f were an efficient predictor for p_t^s, then the residuals from equation (1) should be random. In this case, the residuals associated with equation (1) for $i > 1$ might be expected to follow a moving average process.

[6] With fully informed expectations, we would expect seasonal variations to be completely taken into account in current prices. Since the GIVE estimator is not limited to first order autoregressive error structures, higher order processes were investigated, but the estimates of ϱ were found to be generally insignificant in these cases.

This estimator choice was motivated by the fact that the combination of a lagged endogenous variable and autocorrelated errors results in inconsistent and biased OLS estimates. Further, the OLS standard errors will be biased and the tests of the hypotheses of central interest here will be invalid. The use of the GIVE estimator permits the construction of legitimate tests of these hypotheses, at least in asymptotic terms. In the cases of H_α and H_β, these tests are based on the GIVE point estimates, α^* and β^*, and their asymptotic standard errors (ase) by noting that $(\alpha^* - \alpha)/\text{ase}(\alpha^*)$ is asymptotically standard normal, and similarly for β^*. An asymptotic test of the joint hypothesis H can be constructed from the GIVE estimates in the manner described by Giles (1980). This Lagrange Multiplier test results in a test statistic which is asymptotically χ^2, in this case with two degrees of freedom, and is described in the Appendix.

In the case of an efficient continuous inventory commodity market, spot prices should, on average, serve as well as futures prices in predicting subsequent spot prices. This point was examined for Australian wool by Giles and Goss (1980), and it is interesting to compare those results with the results obtained for the beef futures market, where the non-inventory nature of the commodity suggests, *a priori*, that beef spot prices will *not* perform as well as those for wool as predictors of subsequent spot prices.

The comparison is based on the relationship:

$$p_t^s = \alpha' + \beta' p_{t-i}^s + u_t', \tag{3}$$

with u_t' as in (2), and GIVE estimation is used for the reasons noted above. Gellatly (1980) also compared the predictive powers of spot and futures prices in the live beef cattle market, but his comparison was based on sample mean squared errors of these prices, rather than on instrumental variables regression estimates.

The price data used here are monthly averages of daily observations. The wool market data cover the period 1968 to 1978 and those for the live beef market cover 1975 to 1979. In the former case the available sample size is reduced slightly because of gaps in the spot price data, such as when some July auctions were not held. In the wool futures market the delivery months are March, May, July, October and December, while in the beef futures market they are January, March, May, July, August, September and November. Accordingly, the number of observations available for the estimation of equations (1) and (3) ranges from 31 to 48 in the case of wool, and 21 to 32 for beef, the precise number depending upon the lag length being considered.

In the case of the wool prices, lag lengths from one to six months, and of 12 months, were examined. This choice was made because, in interviews with 25 floor members and associate members of the Sydney Futures Exchange in 1970/71, the second author found that, on average, hedges in the greasy wool futures market were held for about 18 weeks. The most popular hedging medium was a futures contract six months from maturity, and the next most popular was a future 12 months from maturity (Goss 1977). No such information was available for the live beef cattle market so, in this case, lag lengths in equations (1) and (3) ranging from one to six months were tested.[7]

TABLE 1

Greasy Wool Spot Prices Regressed on Futures Prices[a] *(1968-1978)*

i	α^*	β^*	ϱ^*	$\bar{R}^2$	DW	W	T
1	224.72 (156.49)	0.19 (0.54)	0.84 (0.11)	0.98	2.53	1.51	48
2	59.18 (29.06)	0.79 (0.10)	0.27 (0.18)	0.83	1.80	1.83	45
3	245.62 (95.10)	0.14 (0.24)	0.88 (0.10)	0.82	1.25	1.88	38
4	93.11 (209.62)	0.66 (0.74)	0.75 (0.57)	0.89	1.96	2.23	38
5	85.59 (212.19)	0.67 (0.81)	0.74 (0.62)	0.87	1.95	2.20	31
6	61.17 (130.57)	0.77 (0.46)	0.77 (0.26)	0.86	1.42	2.16	31
12	274.69 (160.84)	0.02 (0.52)	0.86 (0.11)	0.73	2.49	1.56	47

[a] T = the number of observations after allowance is made for autocorrelation; DW and W are the Durbin-Watson and Wallis test statistics, respectively; and $\bar{R}^2$ = the coefficient of determination (obtained as one minus the ratio of the residual variance to the sample variance), corrected for degrees of freedom.
Asymptotic standard errors are in parentheses.

Results

The GIVE regression results for equations (1) and (2) appear in Tables 1 and 2 for the wool and live beef cattle futures markets, respectively. In both tables, the predictive power of the futures prices within the sample periods is quite high when measured by $\bar{R}^2$. It should be noted that the way in which $\bar{R}^2$ is defined for the GIVE estimates ensures that this measure is bounded above by unity. Certainly it is the case that these $\bar{R}^2$ values are at least as large as those reported in similar studies (based on OLS estimation) of other futures markets.

A priori, one might expect the $\bar{R}^2$ values to decrease as i increases. In Table 2 this occurs monotonically over the range of i values considered, and it is generally true in Table 1. In Table 1, however, we find that the $\bar{R}^2$ values for $i=4$, 5 and 6 are greater than those for $i=2$ and 3, a result which is consistent with the average duration of hedging (18 weeks) for wool.

The Durbin-Watson and Wallis test statistics reported in these two tables can, of course, be interpreted only approximately, as the tabulated critical values are valid only under OLS (and not GIVE) estimation, and with non-stochastic regressors. However, these statistics are reported for informal interpretation, and the tabulated values suggest that, in most cases, the residuals are free of first and/or fourth-order autocorrelation.

[7] We have limited the lag lengths in this way to preserve reasonable sample sizes—an important consideration in view of the asymptotic justification for our statistical tests. Gellatly (1980) considered i = 1 to 9.

TABLE 2

Live Beef Cattle Spot Prices Regressed on Futures Prices[a] *(1975-1979)*

i	α^*	β^*	ϱ^*	$\bar{R}^2$	DW	W	T
1	−26.25	1.11	0.23	0.96	1.93	1.89	32
	(23.87)	(0.06)	(0.20)				
2	−67.21	1.27	0.52	0.95	1.57	1.87	32
	(53.73)	(0.13)	(0.20)				
3	−157.16	1.58	0.68	0.94	1.52	2.11	30
	(101.36)	(0.24)	(0.18)				
4	−315.57	2.06	0.59	0.92	1.58	2.23	30
	(97.14)	(0.25)	(0.16)				
5	−568.73	2.80	0.65	0.88	1.47	2.51	27
	(181.92)	(0.47)	(0.16)				
6	−783.88	3.50	0.28	0.83	1.69	1.74	21
	(164.20)	(0.47)	(0.22)				

[a]The notation is as in Table 1.

In Table 1, the hypothesis of unbiased prediction is upheld, in the sense that neither H_α nor H_β can be rejected at the five per cent level, for $i=1$, 4, 5, 6 and 12. This is also true at the one per cent level for $i=2$. For $i=3$, the results suggest the rejection of both simple hypotheses at the five per cent significance level, but in overall terms, these results favour the unbiased prediction hypothesis. At the one per cent significance level, the same is true in Table 2 for $i=1$, 2, or 3, but for longer lags the results imply the rejection of both H_α and H_β and, hence, of the hypothesis that beef futures prices are unbiased predictors of subsequent spot prices in that market.

The GIVE estimates of equations (2) and (3) for the two futures markets under study can be compared with Tables 3 and 4. Relatively high $\bar{R}^2$ values again emerge, declining (generally in the case of Table 3, and uniformly in the case of Table 4) as i increases, and the residuals again appear to be free of simple autocorrelation. Comparing $\bar{R}^2$ values across Tables 1 and 3 (for wool prices), we see that the lagged spot prices perform marginally better than the futures prices, except when $i=1$, 3 or 12. In contrast, except when $i=1$, the $\bar{R}^2$ values obtained when lagged spot prices are the regressors are smaller than those associated with lagged futures prices in the beef cattle market (Tables 2 and 4).

Considering H_α and H_β separately (or, for that matter, the joint hypothesis, H), we see that the hypothesis of unbiased prediction cannot be rejected at the one per cent significance level in Table 3, except for $i=3$. At the five per cent significance level the only difference is that this hypothesis is then also rejected when $i=12$. In the beef market results in Table 4, the unbiased prediction hypothesis is uniformly rejected at the five per cent level. With only two exceptions (H_α is accepted when $i=1$ and 5), this is also true at the one per cent significance level. The latter exceptions are interesting, as in these cases H_β is *rejected* at the same significance level. That is, it is not clear whether or not the joint

TABLE 3

Greasy Wool Spot Prices Regressed on Lagged Spot Prices[a] *(1968-1978)*

i	α'^*	β'^*	ϱ'^*	$\bar{R}^2$	DW	W	h_1	h_4	T
1	4.56	1.00	0.13	0.93	2.04	1.78	−0.16	0.82	48
	(15.58)	(0.06)	(0.17)						
2	15.36	0.94	−0.42	0.99	1.58	1.94	1.47	0.21	45
	(11.74)	(0.04)	(0.15)						
3	234.23	0.23	0.86	0.74	1.91	2.36	0.30	−1.16	38
	(72.03)	(0.16)	(0.12)						
4	123.04	0.54	0.80	0.90	1.78	2.35	–	–	38
	(100.57)	(0.32)	(0.26)						
5	61.96	0.75	0.65	0.90	1.81	2.06	–	–	31
	(101.52)	(0.36)	(0.48)						
6	78.92	0.71	0.75	0.86	1.40	2.40	–	–	31
	(147.96)	(0.50)	(0.39)						
12	274.71	0.02	0.86	0.73	2.50	1.56	−2.93	2.60	47
	(129.69)	(0.40)	(0.12)						

[a] The notation is as in Table 1. h_1 is Durbin's asymptotically standard Normal statistic for testing for first-order autocorrelation in the presence of a lagged dependent variable. h_4 is analogous to h_1, with W replacing DW in its calculation. The h statistics cannot be calculated in some cases. Strictly, this test statistic applies only to OLS residuals and it is only approximate in the context of GIVE estimation.

hypothesis H should be rejected. In fact, when the approximate test discussed in the Appendix is applied, χ^2 values of 30.5 and 115.2 are obtained when $i=1$ and 5, respectively, implying the rejection of the joint unbiased prediction hypothesis.[8] This further strengthens the general conclusion to be drawn from the results in Table 4. These $\bar{R}^2$ comparisons and the outcomes of the hypothesis tests point to the strength of spot prices as predictors of subsequent spot prices in the wool market, and their weakness in this role in the beef market.

The overall results are consistent with the conclusion which emerges from the U.S. studies referred to earlier, namely, that lagged futures (and spot) prices of continuous inventory commodities perform better as predictors of subsequent spot prices than do those of non-continuous inventory commodities. Moreover, the conclusions of Praetz (1975) and Fisher and Tanner (1978), that the Australian wool (spot) market is efficient, give rise to a presumption that the hypothesis of unbiased prediction will be accepted, and we have seen that this presumption is justified.

To the best of our knowledge, there is no such evidence of the efficiency of the Australian live beef spot market. However, it is interesting to compare our results for the beef futures market with those obtained by Gellatly (1980). He also found that, in this market, futures prices out-performed spot prices as unbiased predictors of subsequent spot prices. This stands in contrast to the results obtained with U.S. live

[8] The five per cent and one per cent critical values for the χ^2 distribution with two degrees of freedom are 5.99 and 9.21, respectively.

TABLE 4

Live Beef Spot Prices Regressed on Lagged Spot Prices[a] *(1975-1979)*

i	α'^*	β'^*	ϱ'^*	$\bar{R}^2$	DW	W	h_1	h_4	T
1	−39.65	1.16	−0.13	0.97	1.99	1.84	0.20	0.34	32
	(16.20)	(0.04)	(0.20)						
2	−97.90	1.39	0.24	0.93	1.83	1.96	1.78	0.54	32
	(35.68)	(0.09)	(0.19)						
3	−208.56	1.78	0.46	0.91	1.78	2.06	—	—	30
	(70.26)	(0.18)	(0.18)						
4	−282.62	2.06	0.44	0.87	1.82	2.05	—	—	30
	(89.33)	(0.24)	(0.18)						
5	−420.70	2.56	0.58	0.84	1.55	1.84	—	—	27
	(163.47)	(0.45)	(0.18)						
6	−468.21	2.86	0.35	0.79	1.67	1.63	—	—	21
	(157.43)	(0.49)	(0.25)						

[a] The notation is as in Table 3.

beef data by Leuthold (1974). He found that, for lags in excess of approximately 15 weeks, spot prices out-performed futures prices in this predictive role. Gellatly expressed surprise at finding that futures prices are unbiased spot price predictors, even for lags of eight or nine months. The latter finding differs from our own results which, like those of Leuthold, suggest that such unbiased predictions hold only for lags of up to three months.[9]

Conclusions

The hypothesis that futures prices are unbiased estimates of maturity date spot prices for Australian wool, a continuous inventory commodity, and Australian finished live beef cattle, a virtually non-storable commodity, was investigated. The hypothesis rests on the argument that, if all relevant information, including traders' expectations, is fully reflected in current futures prices, then those prices can be interpreted as unbiased market anticipations of maturity date spot prices, given the information set at the time the futures prices were formed, and assuming that economic agents are risk neutral. Rejection of this hypothesis, however, does not necessarily imply that the market is not efficient, because of the assumptions on which the hypothesis rests.

This hypothesis has been represented by a linear relationship between delivery month spot prices and lagged futures prices, and the parameters estimated by instrumental variables regression. With one or two exceptions, the results support the view that lagged futures prices are unbiased estimates of delivery date spot prices for wool with lags from one to 12

[9] Some of the differences between our results and those in other comparable studies might be attributed to our use of an appropriate estimation procedure. The inappropriate use of ordinary least squares estimation in some of these studies casts doubt on the validity of the results obtained.

months, and for live beef with lags from one to three months. We have also tested the subsidiary hypothesis that lagged spot prices are unbiased anticipations of subsequent spot prices, an hypothesis which is presumed to follow for an efficient market. This hypothesis is generally accepted for wool (except for lags of three or 12 months) and is rejected for beef.

Hence, these results are similar to those for the U.S. commodities referred to earlier, in that lagged futures prices for the continuous inventory commodity perform better than those for the non-continuous inventory commodity as predictors of delivery month spot prices. This difference may be due to the comparative youthfulness (and consequent smaller turnover) of the Australian beef futures market, rather than to factors of risk premium or market imperfections. This viewpoint is supported by results for the wool futures market reported by Giles and Goss (1980), where the choice of sample period is found to have an important bearing on the outcome of tests of the unbiased prediction hypothesis. The results for the beef futures market are similar in some respects to those obtained by other authors who have studied this market and its American counterpart, but different in other respects.

Finally, it appears that the Australian wool futures market is performing its forward pricing function better than the Australian live beef futures market, so that economic agents who use wool futures prices for forward contract pricing, or for tendering for such business, have access to a more effective instrument than do those agents who use live beef cattle futures prices for the same purposes.

APPENDIX

Instrumental Variables Estimation with Linear Restrictions

Consider the single linear relationship:

(A.1) $$y = x\beta + u;\ u \sim N(O, \sigma^2 I),$$

where y and u are $(T \times I)$;
X is $(T \times k)$ and of rank k; and
β is $(k \times I)$.

Suppose that q independent linear restrictions are imposed on the elements of β:

(A.2) $$R\beta = r,$$

where R is $(q \times k)$, of rank q $(\leq k)$ and non-stochastic; and
r is $(q \times 1)$ and non-stochastic.

In the absence of the restrictions (A.2), the usual Instrumental Variables Estimator of β is:

(A.3) $$\beta^* = [X'Z(Z'Z)^{-1}Z'X]^{-1}X'Z(Z'Z)^{-1}Z'y,$$

where Z is a $(T \times g)$ matrix of instruments, with rank $(Z) = g \geq k$. Some of the columns of X may appear in Z, and the latter matrix typically is stochastic.

It is known that if:

$$plim\ (T^{-1}X'Z) = \Sigma_{xz};\ \text{finite and of rank } k;$$
$$plim\ (T^{-1}Z'Z) = \Sigma_{zz};\ \text{finite, non-singular; and}$$
$$\text{(A.4)} \qquad (T^{-\frac{1}{2}}Z'u)^{d} \rightarrow N(O,\Omega);$$

then β^* is consistent and $T^{\frac{1}{2}}(\beta^* - \beta)^{d} \rightarrow N(O, Q\Omega Q')$, where $Q = (\Sigma_{xz}\Sigma_{zz}^{-1}\Sigma_{xz}')^{-1}\Sigma_{xz}\Sigma_{zz}^{-1}$. The usual situation is where $\Omega = \sigma^2\Sigma_{zz}$, and Giles (1980) shows that if assumptions (A.4) hold with this Ω, then when $H_O : R\beta = r$ is true, the statistic:

$$C^* = (r - R\beta^*)'(R[X'Z(Z'Z)^{-1}Z'X]^{-1}R')^{-1}(r - R\beta^*)/s^{*2},$$

is asymptotically distributed as $\chi^2(q)$, where $s^{*2} = (y - X\beta^*)'(y - X\beta^*)/T$.

This result is obtained ignoring equation (2) in the text, so the application of this test in the presence of autocorrelation will be only approximately valid. Even when the instrumental variables estimates (α^* and β^*) are obtained by taking account of this autocorrelation (as with GIVE) so that they are consistent, this test is still only approximately valid. In applying this test, we have taken account of the additional instruments generated and used by the GIVE algorithm as a consequence of the autocorrelated errors.

References

Cargill, T. F. and Rausser, G. C. (1975), 'Temporal behavior in commodity futures markets', *Journal of Finance* 30(4), 1043-53.

Dusak, K. (1973), 'Futures trading and investor returns: an investigation of commodity market risk premiums', *Journal of Political Economy* 81(4), 1387-406.

Ederington, L. H. (1979), 'The hedging performance of the new futures markets', *Journal of Finance* 34(1), 157-70.

Fisher, B. S. and Tanner, C. (1978), 'In search of Hunt's short-run price cycles in the Sydney wool futures markets', *Australian Journal of Agricultural Economics* 22(2), 129-34.

Gellatly, C. (1980), Analysis of price and volume movements in the live beef cattle futures market, Paper presented to the 24th Annual Conference of the Australian Agricultural Economics Society, Adelaide, February.

Giles, D. E. A. (1980), Instrumental variables estimation with linear restrictions, Working Paper No. 4/80, Department of Econometrics and Operations Research, Monash University.

——— and Goss, B. A. (1980), 'The predictive quality of futures prices, with an application to the Sydney wool futures market', *Australian Economic Papers* 19(35), 291-300.

Goss, B. A. (1977), 'La coppertura del rischio: teoria ed applicazioni', *Rivista di Economia e Politica Industriale* 3(3), 401-16.

——— (1981), 'The forward pricing function of the London metal exchange', *Applied Economics*, 12 (in press).

——— (1980), 'Aspects of hedging theory', *Australian Journal of Agricultural Economics* 24(3), 210-23.

Gray, R. W. (1972), 'The futures market for Maine potatoes: an appraisal', *Food Research Institute Studies* 11(3), 313-41.

Hamburger, M. J. and Platt, E. N. (1975), 'The expectations hypothesis and the efficiency of the Treasury Bill market', *Review of Economics and Statistics* 57(2), 190-9.

Hansen, L. P. and Hodrick, L. R. (1979), Forward exchange rates as optimal predictors of future spot rates: an econometric analysis (mimeo), Graduate School of Industrial Administration, Carnegie-Mellon University.

Hendry, D. F. (1976), General instrumental variable estimation of linear equations with endogenous and lagged endogenous regressors and auto-regressive errors (mimeo), London School of Economics.

Kofi, T. A. (1973), 'A framework for comparing the efficiency of futures markets', *American Journal of Agricultural Economics* 55(4), 584-94.

Leuthold, R. M. (1974), 'The price performance on the futures market of a nonstorable commodity: live beef cattle', *American Journal of Agricultural Economics* 56(2), 313-24.

——— and Hartmann, P. A. (1979), 'A semi-strong form evaluation of the efficiency of the hog futures market', *American Journal of Agricultural Economics* 61(3), 482-89

Praetz, P. D. (1975), 'Testing the efficient markets theory on the Sydney wool futures exchange', *Australian Economic Papers* 14(25), 240-9.

Rutledge, D. J. S. (1972), 'Hedgers' demand for futures contracts: a theoretical framework with applications to the United States soybean complex', *Food Research Institute Studies* 11(3), 237-56.

Tomek, W. G. and Gray, R. W. (1970), 'Temporal relationships among prices on commodity futures markets: their allocative and stabilizing roles', *American Journal of Agricultural Economics* 52(3), 372-80.

Working, H. (1942), 'Quotations on commodity futures as price forecasts', *Econometrica* 10(1), 39-52.

——— (1949), 'The theory of price of storage', *American Economic Review* 39(6), 1254-62.

——— (1953), 'Futures trading and hedging', *American Economic Review* 43(3), 314-43.