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Markets For Non-Storable Commodities

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ABSTRACT

Published empirical studies of simultaneous rational expectations models of spot and futures markets for non-storable commodities are extremely rare. Indeed, only two countries, the US and Australia, have produced data sets for the study of such markets.

This paper develops, and presents estimates of a simultaneous rational expectations model of the live cattle market in Australia, the world's leading beef exporting country. The model contains functional relationships for short hedgers and speculators combined (there is no disaggregation of hedgers' and speculators' commitments in Australian data), long hedgers and speculators, and consumers, and is completed with a spot price equation and market clearing identity. Unit root tests indicate that all variables in the model are stationary, except for consumption of beef and the price of pork, which are I(1). Cointegration tests suggest that these two variables are not cointegrated. The model is estimated by the instrumental variables method of McCallum, which provides consistent estimates. The estimates of all 15 structural parameters have the expected sign, and all are significant at the five per cent level. In a 34 month post-sample period, the model forecasts the spot and futures prices with per cent RMSE's of 3.6% and 2.1% respectively, and in forecasting the spot price, the model outperforms conventional benchmarks such as a random walk and an ARIMA model. The model also outperforms a lagged futures price as a predictor of the spot price, thus providing some evidence against the efficient markets hypothesis.

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Markets for Non-Storable Commodities

I

Introduction

The objective of this paper is to develop and present empirical results for a simultaneous, rational expectations model of the Australian finished live cattle market. Finished live cattle are non-storable, because they can be kept in their finished condition for a period of six to eight weeks only. This model employs information from both spot and futures markets. Only two countries, the United States and Australia, have introduced futures contracts for live cattle, and hence only these two countries have produced data sets for the estimation of such models. While studies of the US live cattle market have been made, comprising simultaneous rational expectations models, none of these studies has been published, as far as the present authors are aware, and no such study has been made of the Australian market, to the best of the present authors' knowledge.

Simultaneous theoretical models of the determination of spot and futures prices have been developed by Peston and Yamey (1960), Stein (1961, 1964), Dewbre (1981) and Kawai (1983), the last of these being specifically for non-storable commodities. Empirical, simultaneous models of (non-storable) livestock markets, without rational expectations, have been developed and estimated by Leuthold and Hartmann (1979) and Leuthold and Garcia (1992) and others, while empirical, simultaneous models, with rational expectations, for storable commodities have been developed by Giles *et al.* (1985), Goss *et al.* (1992) and others. This paper extends the work of Peston and Yamey (1960), Giles *et al.* (1985) and Goss *et al.* (1992) to develop a simultaneous model, with rational expectations, of the Australian live cattle market.

International live cattle markets have attracted considerable attention from researchers, particularly markets in the USA. Leuthold (1972) was reluctant to reject the random walk hypothesis with US live cattle price data, even though some filter rules yielded profits net of transaction costs. Leuthold (1974) did not reject the unbiasedness hypothesis, for US live cattle futures prices as predictors of delivery date spot prices, with lags up to three months from maturity, but did reject that hypothesis with longer lags. Giles and Goss (1980) obtained a very similar result with Australian data. Just and Rausser (1981) compared the predictive performance of various commercial econometric price forecasts with that of the futures price, for a range of commodities. In the case of live cattle they found that only one commercial forecast out of five surpassed the futures price, with a three month lag to maturity, whereas with longer lags several commercial forecasts surpassed the futures price. While Leuthold and Hartmann (1979) refined the model prediction approach to market efficiency (for hogs), Leuthold and Garcia (1992) applied this approach to live cattle, and were unable to reject the efficient markets hypothesis. The latter authors also computed the Stein (1986) social loss measure for cattle and hogs, and found that this measure was smaller for cattle.

Australia, with 22.4 million head of cattle in 1989, is one of the leading beef producing countries in the world, ranking behind, for example, USA (98m head), Brazil (130m head) and Argentina (57m head). In Australia, the main producing states are Queensland, New South Wales and Victoria. In 1989, Australia exported 872,000 tonnes of beef, or 55.4% of production, making it the world's leading exporter of beef. The main export markets served are in USA and Japan; indeed 76.7% of Australia's beef exports goes to these two countries (see ABARE, 1993).

Although a cattle contract was introduced on the Sydney Futures Exchange in July 1975, this contract, which called for the delivery of carcases, traded thinly. Revisions were made to this contract in May 1977, providing for the delivery of 10,000 kg live weight of steers every calendar month (28 steers approx.). This revised contract became relatively successful, with average monthly turnover reaching 16,559 contracts in 1981, and 28,007 contracts being traded in March of that year. By 1985, however, average monthly turnover had fallen to 1190 contracts, and in May 1986 this Trade Steers Contract, as it had become known, was replaced by a live cattle contract providing for mandatory cash settlement. This last contract, although retaining 10,000 kg live weight of cattle as the contract unit, provided that contracts were to be settled at the Live Cattle Indicator price, which is itself an average of cash prices for specified cattle types at specified locations. Although still quoted on the Sydney Futures Exchange, trading in the cash settlement contract became thin after the end of 1988.

The objective of this paper is to develop, present estimates of, and evaluate a simultaneous, rational expectations model of price determination in the Australian live cattle market. Section II of this paper discusses the specification of the model, while Section III discusses the data employed, presents results for tests for unit roots and cointegration, and discusses the methodology employed for estimation of the model. Results for the intra-sample period are presented and discussed in Section IV, while Section V discusses post-sample simulation by the model, compared with various benchmarks. Some conclusions are presented in Section VI.

II

MODEL SPECIFICATION

This model contains four functional relationships and a market clearing identity. The first equation explains the combined futures market commitments of both short hedgers and short speculators, while the second relationship refers to the market commitments of both long hedgers and long speculators in futures. The model contains also, a consumption relationship and a spot price equation, and is completed with a futures market clearing identity.

This structure represents a modification of the original model by Peston and Yamey (1960) and of the approach in the empirical models of Giles *et al.* (1985) and Goss *et al.* (1992), to deal with the case of non-storables. The combined nature of the first two equations arises because Australian futures market data on commitments of traders are not disaggregated into hedging and speculation components, as are data for Reporting Traders provided by the Commodity Futures Trading Commission in the USA.

Although the ideas of Working (1953, 1962) on discretionary hedging were developed for storable commodities, such as grains, his analysis of the motives for hedging is applicable to the case of non-storables. Two of the major types of hedging distinguished by Working (1953, 1962) are carrying charge hedging and selective hedging. On the first hypothesis, the market commitments of short hedgers, who gain from a reduction in the forward premium, can be expected to vary directly with the current forward premium (futures price less spot price), and negatively with the expected forward premium. If, on the other hand, short hedgers are selective hedgers, where a proportion only of their spot market commitments is hedged, then their futures market commitments would be expected to vary directly with the current futures price, and negatively with the expected futures price. Preliminary estimation for short hedgers in this market, such as beef producers, favoured the latter of these two hypotheses.

The market commitments of short speculators, who expect the futures price to fall can be expected to vary directly with the current futures price, and negatively with the expected futures price and marginal risk premium. This specification is based on the equilibrium condition for short speculators (see Goss (1972, p. 23)). The traditional view that the coefficient of the marginal risk premium is negative (e.g. see Kaldor (1953, p. 23) and Brennan (1958, p. 54)), has been challenged recently by Stein (1986, pp. 48-52), who argues, in terms of his "hedging pressure theory", that an increase in the risk premium may have a positive or negative effect on the futures price, and hence on the market commitments of speculators.

The supply of futures contracts by short hedgers and short speculators combined may be expected to be a function of the sum of the influences outlined above. The specification of this function (HSS) is therefore:

$$HSS_t = \theta_1 + \theta_2 P_t + \theta_3 P^*_{t+1} + \theta_4 r_t + e_{1t} \tag{1}$$

where P_t = current futures price;

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

r_t = marginal risk premium;

e_{1t} = error term

and θ_1 = constant; $\theta_2 > 0$; $\theta_3 < 0$; $\theta_4 \gtrless 0$;

This specification suggests a predominance of speculative, rather than hedging, elements.

The rational expectations hypothesis, which is employed in this model, 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). Much has been written on the assumptions, implications and formation of rational expectations, and summaries of this literature can be found in Sheffrin (1985), Minford and Peel (1986), Goss (1991) and Goss *et al.* (1992). While these summaries will not be repeated here, some important points deserve to be emphasized. The first of these is that the rational expectations hypothesis (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 expectations hypothesis and of the appropriateness of the model (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). Second, the question of the likelihood of agents learning to form rational expectations may still be open, although some pessimistic notes (e.g. Frydman, 1983) and some optimistic notes (e.g. Bray and Savin 1986) have been struck. The question of how agents learn to form rational expectations has been discussed by several authors, including Blume *et al.* (1982) who referred to agents using the same forecasting rule for a long period, and Stein (1986) whose asymptotically rational expectations converge to Muth rational expectations with repeated sampling. Third, there is experimental evidence on the convergence of prices to rational expectations equilibrium in futures and asset markets, in the work of Plott and Sunder (1982), Friedman *et al.* (1983) and Harrison (1992). It is the view of the present authors that experimental evidence suggests that a rational expectations equilibrium can be achieved in a comparatively short time, especially with futures markets operating. Finally, support for the REH has been found in models of this type for storable commodities (see Giles *et al.* (1985), Goss *et al.* (1992)).

The market commitments of long hedgers, such as meat processors and beef exporters traditionally, have been regarded as the mirror image of those of short hedgers (e.g. see Stein, 1961). We would expect the positions of these agents, therefore, to vary negatively with the current forward premium, directly with the expected forward premium, and directly with measures of the market commitments of these agents, such as planned consumption and planned exports. The market positions of long speculators, who expect the futures price to rise, can be expected to vary negatively with the current futures price, directly with the expected futures price, and negatively with the marginal risk premium. The combined functional relationship for these two groups of agents could be expected to reflect the sum of these influences. Preliminary estimation suggested that the price spread variables were more important than the level form price variables, and that the planned change in consumption should replace the planned level of consumption. This last change is a consequence of the unit root and cointegration tests reported in Section III. The demand function for futures contracts (HSL), therefore is

$$HSL_t = \theta_5 + \theta_6(P_t - A_t) + \theta_7(P_{t+1} - A_{t+1})^* + \theta_8 \Delta C_{t+1} + \theta_9 X_{t+1} + \theta_{10} r_t + e_{2t} \qquad (2)$$

where A_t = current spot price;

$(P_{t+1} - A_{t+1})^*$ = rational expectation of the forward premium in (t+1) formed in period t;

$\Delta C_{t+1} \equiv C_{t+1} - C_t$ = change in consumption next period, which is a proxy for the planned change, assumed to be realized;

X_{t+1} = exports in period (t+1), which is a proxy for planned exports, assumed to be realized;

r_t = marginal risk premium;

and $\theta_6 < 0$, θ_7, θ_8, $\theta_9 > 0$; $\theta_{10} \gtrless 0$.

This specification contains a mixture of hedging and speculative elements, although it does suggest a predominance of hedging activity. It is, however, consistent with the view that speculators take straddle positions.

The demand for live cattle is derived from the demand for dressed beef. The demand function for live cattle, therefore, can be seen as dependent upon the spot price of live cattle, parameters of the demand for the end product, and parameters of the supply of other inputs. In this case, expected real income next period, and the spot prices of two substitute meats, lamb and pork, have been employed as parameters of the demand for dressed beef. The spot price of oats, a complementary input with live cattle, is used as a proxy for the supply of other inputs. The demand for live cattle, therefore, can be expected to vary negatively with the spot price of live cattle and the price of oats, and directly with expected real income, the price of lamb and the price of pork. It should be noted that the demand for live cattle and the price of pork appear in first difference form in this specification, as a consequence of the unit root and cointegration tests reported in Section III. The resulting specification of this function is

$$\Delta C_t = \theta_{11} + \theta_{12}A_t + \theta_{13}Y_{t+1} + \theta_{14}A_t^L + \theta_{15}\Delta A_t^P + \theta_{16}A_t^o + e_{3t} \tag{3}$$

where $\Delta C_t \equiv C_t - C_{t-1}$ = change in consumption of live cattle in period t.

Y_{t+1} = real income in period (t+1), used as a proxy for planned real income;

A_t^L = spot price of lamb;

$\Delta A_t^P = A_t^P - A_{t-1}^P$ = change in price of pork in period t;

A_t^o = spot price of oats;

and $\theta_{12}, \theta_{16} < 0$; $\theta_{13}, \theta_{14}, \theta_{15} > 0$.

The model contains also a spot price equation, in which the spot price of live cattle is specified first, as a direct function of the current futures price, on the ground that changes in these two prices are expected to be closely correlated. Secondly, it is postulated that the spot price is negatively related to the number of store cattle in current yardings for sale, because an increase in yardings can be expected to lead to an increase in the number of finished live cattle, and hence to a decline in the spot price. The spot price equation is written as

$$A_t = \theta_{17} + \theta_{18}P_t + \theta_{19}N_t + e_{4t} \tag{4}$$

where N_t = number of cattle in current yardings; and $\theta_{18} > 0$; $\theta_{19} < 0$.

This model, with five endogenous variables (HSS, HSL, ΔC, P, A) and four equations, is completed with the futures market clearing identity

$$HSS_t \equiv HSL_t \tag{5}$$

Conventional identification conditions do not apply to linear multi-equation models with forward rational expectations (Pesaran, 1987, p. 119). The model developed here, however, fulfils the identification conditions developed by Pesaran (1987, pp. 156-60) for such models.

III

DATA, UNIT ROOTS, COINTEGRATION TESTS AND ESTIMATION

Data

The sample period for the results reported in this paper, after allowance for leads and lags, is 1980(05) to 1985(12), comprising a total of 68 monthly observations; the post-sample forecast period, again after allowance for leads and lags, is 1986(03) to 1988(12), which is a total of 34 observations. Data are discussed in this section under the headings "Endogenous Variables" and "Exogenous Variables".

Endogenous Variables

Futures price data (P) are futures prices of live steers, on the median trading day of the month, for a contract two months prior to delivery (the most heavily traded contract), in Australian cents per kg live weight from the Sydney Futures Exchange *Statistical Yearbook* 1980-88.

Spot price data (A) for the period 1980(05) to 1986(06), during which time the Trade Steer Contract (deliverable) traded on the SFE, are prices in Australian cents per kg live weight, for "futures type steers", on the median trading day of the month, provided by the New South Wales Meat Industry Authority. Data on spot prices for the period 1986(07) to 1988(12), when the Live Cattle (cash settlement) Contract replaced the previous contract, are SFE Live Cattle Indicator prices, on the median trading day of the month, in Australian cents per kg live weight, provided by the SFE. The Live Cattle Indicator price is a five day average of cash prices for specified cattle types at specified selling centres. At maturity, positions in the Live Cattle Contract are settled at the Indicator price.

The total supply of, and total demand for futures contracts (HSS $\equiv$ HSL) are measured by the open positions (or commitments) of traders, in number of contracts, on the median trading day of the month, for a futures contract two months from maturity. The data on commitments of traders, therefore, are synchronized with the data on spot and futures prices.

Data on consumption (C) are Australian consumption of beef and beef meat products, per quarter, in thousand tonnes, from Australian Bureau of Statistics (ABS) *Livestock and Livestock Products* (Catalogue 7221.0). These data were interpolated to monthly observations using the program TRANSF (Wymer 1977).

Exogenous Variables

Exports of beef (X) are measured by exports of beef meat, fresh chilled or frozen, in tonnes per month, from ABS *Exports, Australia, Monthly Summary Tables* (Cat. 5432) and ABS *Exports of Major Commodities and Their Principal Markets* (Cat. 5403). Exports of live beef cattle from Australia are insignificant and are not included.

Real income (Y) is Australian household disposable income per quarter in million Australian dollars from ABS, divided by the Consumer Price Index (quarterly), also from ABS. These data were interpolated to monthly observations.

The marginal risk premium (r) is the monthly average 90 day bank accepted bill rate, in per cent per annum, minus the monthly average 90 day Treasury Bill rate, in per cent per annum; observations on both these rates are taken from the Reserve Bank of Australia *Statistical Bulletin*. This treatment of the risk premium is consistent with Stein (1991, p. 39).

The spot price of lamb (A^L) is the monthly average saleyard price, in Australian cents per kg for lambs (16kg to 19kg) on a dressed weight basis. Similarly, the spot price of pork (A^P) is the monthly average saleyard price, in Australian cents per kg for pigs (60kg to 70kg) on a dressed weight basis. Observations on both these prices were taken from Australian Meat and Livestock Corporation, *Statistical Review of Livestock and Meat Industries*, and ABARE (1993). The spot price of oats (A^o) is the monthly average price, in Australian dollars per tonne, from ABARE *Situation and Outlook: Coarse Grains*.

The number of cattle in current yardings (N) is the total number per month of beef cattle in current yardings listed for sale from ABS *Livestock and Livestock Products*.

UNIT ROOTS AND COINTEGRATION TESTS

To obtain meaningful estimates of the parameters of the model, it is necessary that the residuals of the estimating equations are stationary. This condition will be fulfilled if all the variables in these equations are stationary (i.e. integrated of order I(0)), or alternatively, if some of these variables are integrated of order I (1) or higher order, this condition will be fulfilled only if the non-stationary variables are integrated of the same order and are cointegrated. The first step in this procedure is to determine the order of integration of the variables in the model.

In the autoregressive representation of the time series

$$Z_t = \rho Z_{t-1} + e_t \tag{6}$$

where Z is an economic variable, ρ is a real number, and e_t is $N1D(0,\ \sigma^2)$, if $|\rho| < 1, Z_t$ converges to a stationary series as $t \rightarrow \infty$. On the other hand, if ρ = 1, there is a single unit root and Z_t is non-stationary, while if $|\rho| > 1$, the series is explosive.

Tests of the hypothesis H(ρ = 1) in (6), and for variations of this model with constant and time trend, were developed by Dickey and Fuller (1979, 1981). Critical values for these tests are given in Fuller (1976) and Dickey and Fuller (1981). These tests were extended by Said and Dickey (1984) to accommodate autoregressive processes in e_t of higher but unknown order. In this latter case the model is augmented by lagged first differences in Z to render e_t as $N1D(0,\ \sigma^2)$, and the hypothesis H(ρ = 1) is tested by the Augmented Dickey-Fuller Test (ADF).

In this paper the following models were estimated by ordinary least squares (OLS) to test the hypothesis of a unit root in all endogenous and exogenous variables in the structural model:

$$\Delta Z_t = \mu + \gamma Z_{t-1} + \phi \Delta Z_{t-1} + e_t \tag{7}$$

$$\Delta Z_t = \mu + \gamma Z_{t-1} + \phi \Delta Z_{t-1} + \phi_2 \Delta Z_{t-2} + e_t \tag{8}$$

$$\Delta Z_t = \mu + \beta t + \gamma Z_{t-1} + \phi \Delta Z_{t-1} + e_t \tag{9}$$

$$\Delta Z_t = \mu + \beta t + \gamma Z_{t-1} + \phi \Delta Z_{t-1} + \phi_2 \Delta Z_{t-2} + e_t \tag{10}$$

where μ = constant;

β, ϕ, ϕ_1, ϕ_2, are coefficients to be estimated;

e_t is assumed to be $N1D(0,\ \sigma^2)$.

Models (9) and (10) contain a time trend, (7) and (9) contain a single lagged value of ΔZ_t, and (8) and (10) contain two such lagged values.[1] In each case, (7) was estimated first, the other models being estimated as necessary to whiten e_t. The hypothesis H(ρ = 1) is addressed by testing the hypothesis H(γ = 0) in (7) - (10). This is executed by the ADF test, although it is now preferable to refer to critical values of MacKinnon (1991), which are based on more replications than the original Dickey-Fuller tables. Calculated ADF statistics, together with 5 per cent and 10 per cent critical values from MacKinnon (1991), are provided in Appendix 1 for all variables in the model. Notwithstanding the low power of these tests (see Evans and Savin, 1981), it will be seen that for only two variables (consumption of beef C and the spot price of pork A^P) is it not possible to reject the hypothesis of a single unit root; these tests support the view that all other variables in the model are stationary.[2]

In equations (1) and (4) of this model there are no non-stationary variables, and hence it can be assumed that the residuals of these equations will be stationary. In equation (2), there is one non-stationary variable, C_{t+1}, and in order to render the residuals in (2) stationary, the first difference of this variable is taken. In equation (2), therefore, the planned consumption proxy employed for long hedgers' commitments is ΔC_{t+1}.

In equation (3) there are two I(1) variables only, C_t and A_t^P, all other variables being I(0). While C_t and A_t^P are non-stationary, it is possible that a linear combination of these variables may be stationary, i.e. they may be cointegrated, in which case the residuals of (3) will be stationary. To investigate whether these I(1) variables are cointegrated, the cointegration test analysed by MacKinnon (1991), which is based on the work of Engle and Granger (1987), was employed. The Engle-Granger technique is adequate in this case, because the question of cointegration refers to two variables only.[3] This test requires first that a relationship between the I (1) variables, such as the following, be estimated by OLS.

$$C_t = \alpha_0 + \alpha_1 A_t^P + \alpha_2 t + u_t \tag{11}$$

The hypothesis of no cointegration in (11) is addressed by testing the hypothesis that the series of estimated values of residuals $(\hat{u}_t)$ from (11) contains a unit root. To test the hypothesis of a unit root in $\hat{u}_t$ the following model was estimated

$$\Delta \hat{u}_t = \gamma \hat{u}_{t-1} + \phi \Delta \hat{u}_{t-1} + v_t \tag{12}$$

and the hypothesis H(γ = 0) was tested, using the Augmented Engle-Granger (AEG) test. As the information in Appendix 2 shows, this hypothesis is not rejected at the 10 per cent level, and hence the hypothesis of no cointegration in (11) is not rejected. Stationarity of the residuals in the consumption relationship equation (3), therefore, can be achieved by employing first differences of the two I(1) variables in this equation, C_t and A_t^P.

Estimation

Full information estimators of simultaneous models with forward rational expectations, while potentially more efficient, are less robust to specification errors, and are computationally more demanding than limited information methods (Pesaran, 1987, p. 162). For these reasons the model presented here is estimated by the instrumental variables (IV) method of McCallum (1979). This requires that an instrument is obtained, by OLS, for the unobservable expectation of an endogenous variable, such as P^*_{t+1} in (1), as a fitted value on the information set at time t (θ_t) comprising all exogenous and predetermined variables (including lagged endogenous variables) in the model. That is

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

$$P_{t+1} = E\left(P_{t+1} / \phi_t\right) + \eta_t \tag{13}$$

where $E(\eta_t) = 0$ and η_t is uncorrelated with the variables in ϕ_t, under rational expectations. $E\left(P_{t+1} / \phi_t\right)$ is taken to be linear in the elements of ϕ_t. The structural equations can then be estimated by IV, and if the residuals of those equations are not serially correlated, this method will produce consistent estimates. This procedure is discussed in McCallum (1979) and is summarized in Giles *et al.* (1985, pp. 754-55). This procedure has been used for equation (2) in this model.[4]

When serial correlation is present, however, a simple autoregressive (AR) correction with IV estimation will not produce consistent estimates, as Flood and Garber (1980) pointed out. In this case an AR transformation has been made, and each of the variables in the transformed equation was regressed on the elements of the relevant information set, using OLS. The fitted values so obtained were substituted in the transformed equation (see McCallum (1979, p. 67-68)), and consistent estimates of the parameters in that equation were obtained by non-linear least squares, using the option LSQ in TSP (Hall *et al.*, 1993). This method, which is discussed by Cumby *et al.* (1983), has been employed for equation (1) in this model.

Equation (3), which contains no expectational variables, but does contain an endogenous regressor, was estimated by IV without a correction for serial correlation.[5]

Equation (4), which again does not contain any expectational variables but includes an endogenous regressor, was estimated also by IV, although in this case a correction for first order serial correlation was necessary.[6]

IV

RESULTS: INTRA-SAMPLE PERIOD

Estimates of the parameters of the model are provided in Table 1, together with their asymptotic *t* values. It will be seen that estimates of all 15 structural parameters have the expected signs and all are significant at the five per cent level (one tail test), thereby providing strong support for the model specification discussed above. There are, however, several features of the results for individual equations, which deserve comment. First, the clear significance of $\hat{\theta}_3$ and $\hat{\theta}_7$, the coefficients of the expected futures price and expected price spread respectively, provides support for the rational expectations hypothesis. Moreover, the results for equation (1) support the view that HSS is essentially a speculative relationship. Similarly, the results for equation (2) suggest that commitments on the long side of the market are a combination of hedging and speculative elements, with a strong discretionary component in the hedging activities.

Second, the positive estimates of θ_4 and θ_{10}, the coefficients of the marginal risk premium in equations (1) and (2) respectively, support an interpretation different from the Kaldor (1953) - Brennan (1958) view of the risk premium. In equation (1) the positive sign of $\hat{\theta}_4$ can be explained as follows: an increase in the marginal risk premium *cet par* will lead to an increase in the equilibrium futures price, and hence to an increase in the market commitments of short speculators. In equation (2), an increase in the marginal risk premium *cet par* will lead to a decrease in the equilibrium futures price, and hence to an increase in the market commitments of long speculators. These explanations are similar to the "hedging pressure theory" of Stein (1986, pp. 48-52), although Stein's argument is directed to the effect of a change in the risk premium on price alone.

Thirdly, in equation (3), the consumption relationship, the positive sign of $\hat{\theta}_{14}$ is consistent with a substitution relationship between beef and lamb in the sense that a rise in the price of lamb will lead to an increase in the rate of change of consumption of beef. This is not the usual sense of substitutability, however, and it is possible that the equilibrium value of ΔC_t, in the period in question, may still be negative. Again, the positive sign of $\hat{\theta}_{15}$, which relates a change in the price of pork to a change in the consumption of beef, is consistent with substitutability between these two meats. This is not the same as the conventional view of such a relationship, however, because the equilibrium value of ΔA_t^P may be positive while that of ΔC_t may be negative. Indeed, similar qualifications must be attached to the interpretation of $\hat{\theta}_{16}$, which suggests that live cattle and oats are complementary inputs, as well as to the interpretation of the price and income coefficients.

A further test of the appropriateness of this model is the ability of the model to forecast the endogenous variables within the sample period, according to specified criteria. Table 2 presents an evaluation of the (static) intra-sample simulation of the two key variables, P and A, according to the correlation coefficient, Theil's inequality coefficient, and per cent root mean square error.[7] These simulations are illustrated in figures 1 and 2. Concentrating on the per cent RMSE criterion, it will be seen that the better forecast is that of the futures price of live cattle (P). The simulation errors of the other variables (not reported here) are somewhat larger than those for the futures and spot prices. This may be due, in part, in the case of ΔC_t, to the inherent difficulty in predicting the magnitudes of first differences, and in the case of HSS (= HSL), to the thinness of the market in the latter part of the sample period.

V

POST-SAMPLE SIMULATION

A more stringent test of model performance is the ability of the model to forecast key endogenous variables, against pre-determined criteria, outside the sample period, especially in comparison with alternative forecasts. Table 3 presents an evaluation of (dynamic) two months ahead forecasts of the futures and spot prices, for the post-sample forecast period 1986(03) to 1988(12), comprising 34 monthly observations. Concentrating on the per cent RMSE criterion, it will be seen first, that again the better forecast is that of the futures price, and second, and more important, the accuracy of both forecasts has improved significantly compared with the intra-sample simulation of these variables. Indeed, for P and A the per cent RMSE's are each less than half of their corresponding values for intra-sample simulation. This latter outcome provides substantial support for the validity of the model.

The question is then how does the model perform, compared with alternative price forecasts. Table 4 presents an evaluation of post-sample forecasts of the spot price, two months ahead, by the model (AS: the same as A in Table 3), compared with three alternative forecasts. The first of the alternative forecasts is the futures price lagged two months prior to maturity (P_{t-2}), the second is a random walk forecast two months ahead,[8] and the third is a complex ARIMA model of MA terms with lags of one and five months, and an AR term with a lag of five months. The two latter forecasts are conventional benchmarks in assessing the forecasting performance of economic models. Table 4 shows that the model developed in this paper clearly outperforms all the alternative forecasts of the spot price, according to the per cent RMSE criterion. Moreover, the difference between the per cent RMSE's for the model (AS) and the random walk (AWALK 2), which is the best of the alternative forecasts on this criterion, is statistically significant, at the five per cent level, according to the test proposed in Granger and Newbold (1986, pp. 278-79).

Turning to a comparison of the spot price forecasts provided by the model (AS) and by the lagged futures price $\left(P_{t-2}\right)$, it should be noted that in executing the model-derived post-sample forecasts, the parameter estimates of the model were updated by one month following each forecast. Hence, the model and the futures price were placed always on the same informational footing during the post-sample period. Since the model significantly outperforms the futures price in making a two month ahead forecast of the spot price, it can be inferred that this comparison provides some evidence against the semi-strong efficient markets hypothesis (EMH). The reason for this inference is that the model evidently contains some publicly available information not reflected in the futures price (see Leuthold and Hartmann (1979), Leuthold and Garcia (1992) and the summary in Goss (1992, pp. 4-7)) (see also Figure 3).

Any temptation to reject the EMH on the basis of this evidence, however, should be resisted. While forecasting performance by an alternative model, superior to that of the futures price, is a necessary condition for market inefficiency, it is not sufficient. The EMH should not be rejected until it can be shown that the model under consideration can be employed, in a trading strategy, to produce significant profits net of transaction costs (this is a sufficient condition: see Leuthold and Garcia (1992, pp. 62-71)).

The main features of post-sample simulation, then, are first, that the accuracy with which the model forecasts the key variables, the futures and spot prices of live cattle, has improved substantially compared with the accuracy of the intra-sample forecasts of these variables. Second, in post-sample forecasts of the spot price, the model developed in this paper significantly outperforms three alternative predictors, comprising a lagged futures price, a random walk model and a complex ARIMA model. Both these outcomes must be regarded as positive in assessing the performance of the model presented here.

VI

CONCLUSIONS

This paper develops and presents estimates of a simultaneous rational expectations model of the Australian finished (non-storable) live cattle market, using information from both spot and futures markets. Published studies of simultaneous rational expectations models of such markets are extremely rare, and only two countries, Australia and the US, have produced data sets for the estimation of such models.

Australia is the world's leading beef exporting country. The model developed in this paper contains functional relationships for short hedgers and short speculators combined (there is no disaggregation of hedging and speculative positions in Australian market commitments data), long hedgers and long speculators combined, and consumers. The model contains also a spot price equation, and is completed with a futures market clearing identity.

Unit root tests indicate that all variables in this model are stationary except the consumption of beef and the spot price of pork (an exogenous variable in the consumption equation), these latter two variables being integrated of order I(1), i.e. first difference stationary. Cointegration tests of the Engle-Granger (1987) type, which are adequate with only two I(1) variables, suggest that these two non-stationary variables are not cointegrated. These properties are taken into account in model specification.

The model developed in this paper was estimated by the instrumental variables method of McCallum (1979) in the absence of serial correlation, and by non-linear least squares for equations where correction for serial correlation was required. This methodology will produce consistent estimates, as explained in detail in Section III. All parameter estimates have the expected signs, and all are statistically significant at the five per cent level. The signs and significance of the estimated coefficients of the price and expected price variables in the combined hedger-speculator relationships for the futures market, provide support for the rational expectations hypothesis. Moreover, the parameter estimates for the equation referring to short market commitments suggest that this relationship is essentially speculative; furthermore, there is support for a rival hypothesis of the risk premium, of the type discussed by Stein (1986, pp. 48-52). Parameter estimates suggest also that market commitments on the long side of the futures market are predominantly those of discretionary long hedgers in the sense of Working (1953), probably beef exporters and meat processors.

Estimated coefficients in the consumption relationship should be interpreted with caution, because the dependent variable in that equation appears in first difference form; hence changes in the level of explanatory variables such as the spot price of beef are linked to the rate of change of consumption of beef.

Intra-sample the model simulates the futures price of beef with a per cent RMSE of 4.5% and the spot price with per cent RMSE of 8.7%, while post-sample these forecast errors decline to 2.1% and 3.6% respectively. In post-sample forecasting of the spot price, the model thus significantly outperforms rival predictors such as a random walk model (% RMSE 5.3%), an ARIMA model (% RMSE 6.7%) and a lagged futures price (% RMSE 5.8%). This last comparison means that this study provides some evidence against the semi-strong efficient markets hypothesis (EMH), although the EMH should not be rejected until there is evidence that this model can be used to generate significant profits net of transaction costs.

Endnotes

1. Fuller (1976) has shown that the limit distribution of the t statistic for $\hat{\gamma}$ is independent of the number of lags of ΔZ in the equation.

2. For three variables (A, A°, Y) this rejection is made at the 10 per cent level, using the most appropriate model from the group (7) - (10).

3. In the case of three or more I(1) variables a procedure such as the maximum likelihood procedure of Johansen and Juselius (1990) would be necessary to identify all cointegrating relationships.

4. The instruments employed for the IV estimation of equation (2) are:

$$X_{t-2},\ Y_{t-2},\ r_{t-2},\ r_{t-1},\ \Delta A^{P}_{t-1},\ A^{L}_{t-1},\ A^{o}_{t-1},\ N_{t-1},\ (P-A)_{t-2},\ \left(\widehat{P-A}\right)_{t+1},\ \Delta C_{t-1},$$

$$HSL_{t-1},\ HSL_{t-2}.$$

5. The instruments for the IV estimation of equation (3) are:

$$X_{t-2},\ \hat{Y}_{t+1},\ A^{o}_{t-2},\ A^{L}_{t-2},\ \Delta A^{P}_{t-1},\ r_{t-2},\ N_{t-1},\ \Delta C_{t-1},\ HSS_{t-2},\ (P-A)_{t-1},\ A_{t-2}.$$

6. The instruments for the IV estimation of equation (4) are:

$$X_{t-1},\ X_{t-2},\ Y_{t-2},\ r_{t-2},\ r_{t-1},\ A^{o}_{t-1},\ N_{t-1},\ \Delta A^{P}_{t-1},\ A^{L}_{t-1},\ \Delta C_{t-1},\ P_{t-2},\ P_{t-3},$$

$$A_{t-1},\ A_{t-2},\ A_{t-3},\ HSS_{t-1},\ HSS_{t-2}.$$

7. Theil's inequality coefficient and per cent RMSE are defined in Pindyck and Rubinfeld (1981, pp. 362, 364).

8. Random walk forecasts of the spot price two months ahead were obtained by estimating the following model by OLS:

$$A_t = \alpha + \beta A_{t-2}$$

where α, β are constants. From these estimates fitted vales $\hat{A}_t$ were obtained, which acted as forecasts.

Table 1

PARAMETER ESTIMATES

Equation	*Coefficient*	*Variable*	*Estimate*	*Asymp. t Value*
(1)	θ_1	Constant	1014.54	2.275
	θ_2	P_t	20.053	2.611
	θ_3	P^*_{t+1}	-29.691	-2.946
	θ_4	r_t	88.870	2.029
	ρ_1		-0.511	-4.410
(2)	θ_5	Constant	65.201	0.183
	θ_6	$P_t - A_t$	-28.801	-1.823
	θ_7	$P^*_{t+1} - A^*_{t+1}$	53.002	3.320
	θ_8	ΔC_{t+1}	0.634	3.083
	θ_9	X_{t+1}	0.014	1.798
	θ_{10}	r_t	292.866	3.089
(3)	θ_{11}	Constant	-11009.5	-2.605
	θ_{12}	A_t	-12.929	-1.773
	θ_{13}	Y_{t+1}	0.562	2.202
	θ_{14}	A_t^L	15.283	2.795
	θ_{15}	ΔA_t^P	73.887	3.031
	θ_{16}	A_t^O	10.139	2.850
(4)	θ_{17}	Constant	23.703	1.162
	θ_{18}	P_t	1.003	5.165
	θ_{19}	N_t	-0.501×10^{-4}	-2.917
	ρ_4		0.643	6.873

Table 2

INTRA-SAMPLE SIMULATION

Variable	*Correlation Coefficient*	*Theil's IC*	*% RMSE*
P	0.9312	0.0214	4.5354
A	0.8868	0.0379	8.6996

Table 3

POST-SAMPLE SIMULATION: SPOT AND FUTURES PRICES

Variable	*Correlation Coefficient*	*Theil's IC*	*% RMSE*
P	0.9197	0.0099	2.0793
A	0.8999	0.0171	3.5546

Table 4

POST-SAMPLE SPOT PRICE FORECASTS

Variable	*Correlation Coefficient*	*Theil's IC*	*% RMSE*
AS	0.8999	0.0171	3.5546
P_{t-2}	0.7608	0.0270	5.7983
AWALK 2	0.7696	0.0249	5.3242
ARIMA*	0.7992	0.0298	6.6541

* This is a complex ARIMA model: see text.

Appendix 1

UNIT ROOT TESTS

Variable	*Model*	*Calculated ADF Statistic*	*5% Critical Value*	*10% Critical Value*	*Integration Order*
P	9	-3.8095	-3.4527	-3.1516	I(0)
A	9	-3.3090	-3.4527	-3.1516	I(0)
HSS (= HSL)	9	-4.7421	-3.4527	-3.1516	I(0)
C	9	-1.8444	-3.4527	-3.1516	I(1)
(P - A)	7	-3.1357	-2.8889	-2.5812	I(0)
X	8	-3.6586	-2.8892	-2.5813	I(0)
Y	9	-3.3182	-3.4527	-3.1516	I(0)
r	10	-5.2094	-3.4531	-3.1519	I(0)
A^L	7	-5.1816	-2.8889	-2.5812	I(0)
A^P	8	-2.1550	-2.8892	-2.5813	I(1)
N	7	-3.7352	-2.8889	-2.5812	I(0)
A^O	7	-2.7462	-2.8889	-2.5812	I(0)

Appendix 2

COINTEGRATION TEST

Equations	*Variables*	*Calculated AEG Statistic*	*10 % Critical Value*	*Durbin-Watson Statistic*
(11), (12)	C_t , A_t^P	-0.4987	-3.1064	2.2150

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Figure 1
Futures Prices

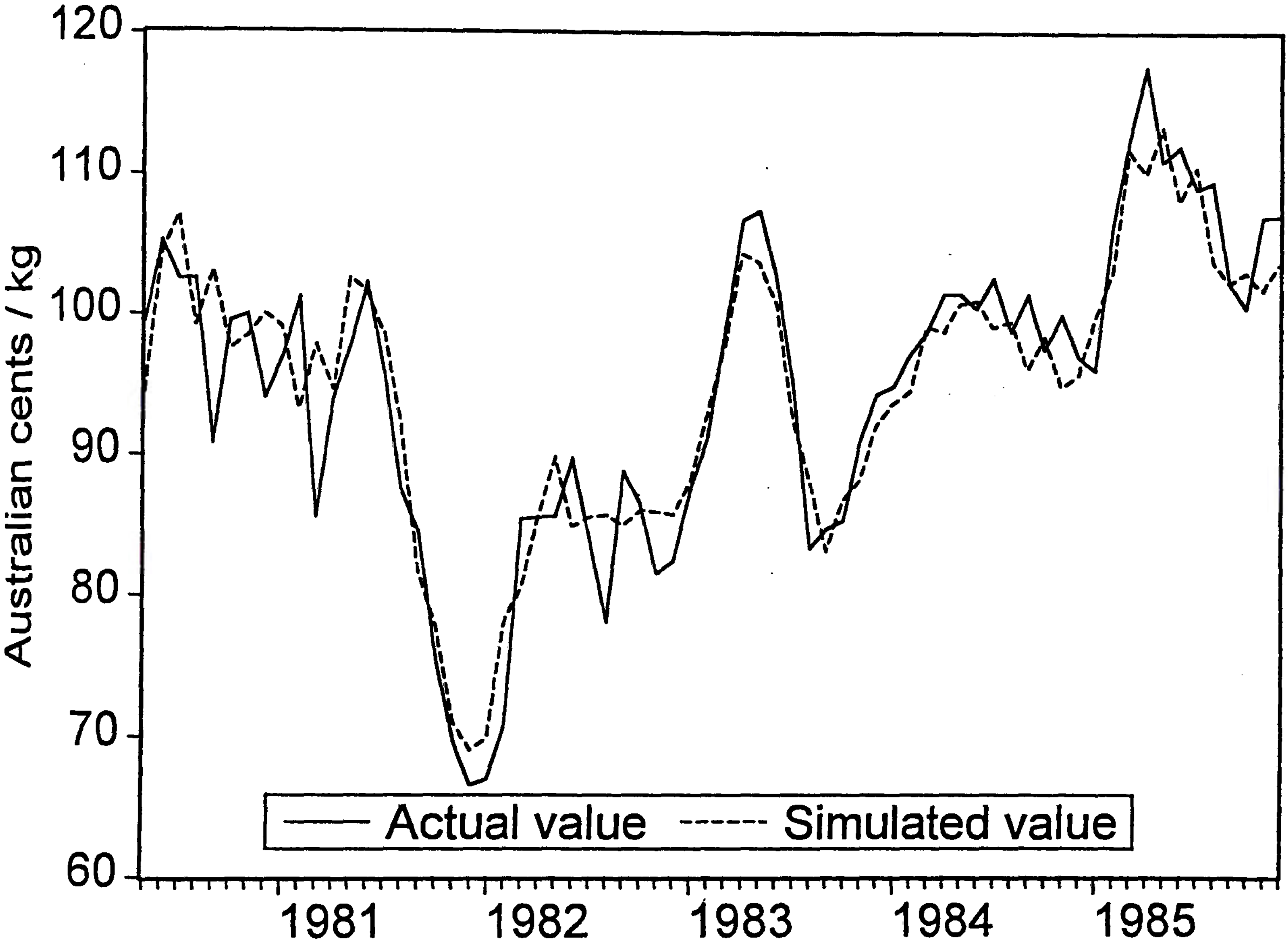

Figure 2
Cash Prices

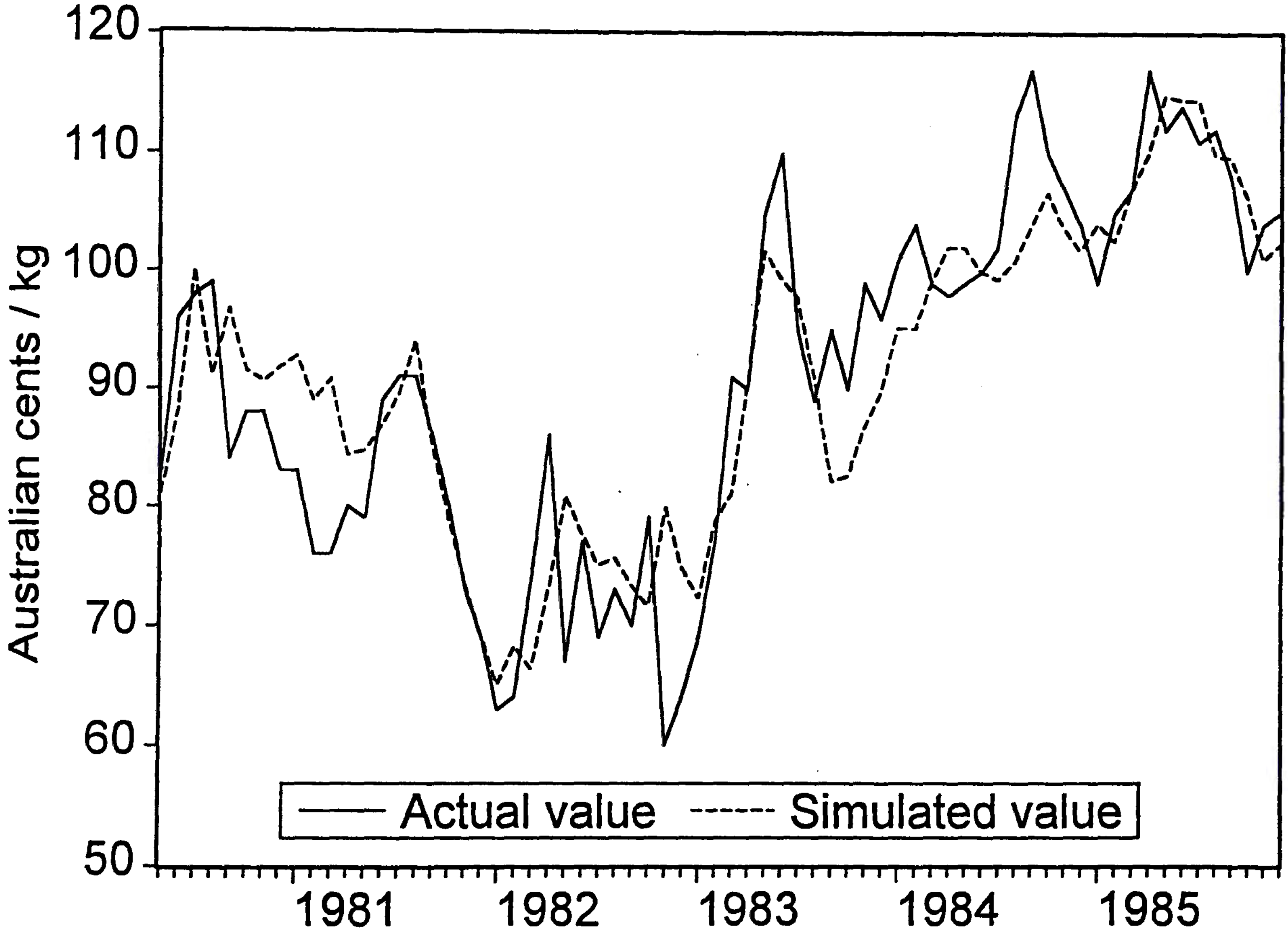

Figure 3
Post Sample Forecasts of Spot Price