A DISEQUILIBRIUM ECONOMETRIC MODEL OF THE AUSTRALIAN RAW WOOL MARKET*

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This paper develops a quarterly disequilibrium model of the Australian wool market. It is postulated that because of inherent market imperfections the market does not clear. The model consists of demand and supply equations for both private and government traders, a minimum condition to determine quantity transacted and a price adjustment equation based on excess demand/supply. Effective demand/supply concepts which recognise the expectation of rationing are employed to model private demand/supply. Supplier price expectations explicitly account for the lower bound imposed by the minimum reserve price scheme (RPS). The estimates suggest that the disequilibrium hypothesis cannot be rejected, as a consequence measures of market imbalance are provided. The model is also used to simulate the effects of the removal of the RPS.

I. INTRODUCTION

Traditionally the majority of economic analysis conducted on trading markets is predicated under the key assumption that markets are efficient and always perfectly clear. The results from these studies underpin policy prescription. Previous economic analysis of the Australian raw wool market is certainly traditional in this sense. As a consequence, it is of clear importance to economists, policy makers and market participants alike, that an examination be undertaken of the robustness of the findings from such analysis to the alternative assumption of market disequilibrium trading. The purpose of this paper is to help examine this robustness of economic argument by developing the first disequilibrium econometric model of the wool market.

The uptake of the 'markets in disequilibrium' modelling approach has been slow since its development by Fair and Jaffee (1972). Part of the reason for the slow acceptance of this alternative modelling methodology may be due to the complexity of its implementation, but is also clearly guided by the philosophical belief of many economists in the perfect operation of the market. We present sufficient accumulated evidence to throw some doubt on the market clearing assumption for the wool market.

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In developing an appropriate disequilibrium model, various modifications to the standard canonical model are made. First, the significantly different behaviour of private and government traders will be recognised. Second, the concept of effective demand/supply based upon expected rationing manipulation possibilities will be employed. That is, the model will recognise that agent behaviour may alter if agents expect to be unsatisfied at the market. Finally, supplier price expectations will be modelled to explicitly recognise the price underpinning provided by the price floor when in operation.

In the next section a brief background description of the wool market is provided. This is followed by an outline of the motivation for the disequilibrium modelling approach. Section III initially discusses some issues pertaining to data. The general specification is then outlined, followed by argument for the preferred regressors. In Section IV the preferred estimates, elasticities, measures of expected rationing and market imbalance, and simulations of policy impacts are provided and discussed. Section V provides a summary and conclusion.

II. BACKGROUND AND MOTIVATION

Given its fundamental importance to both the world wool market and the Australian economy, it is not surprising that the Australian wool industry has been the subject of much description, analysis and debate. Recent comprehensive and lucid descriptions of the industry can be found in Griffith and Farrell (1991) and the AWC (1992). The three principal selling methods for wool are public auction, public tender and private treaty. Over recent times approximately 80 to 95 per cent of sales are through public auction. A key feature of the public auction system was the operation of the reserve price scheme (RPS) which commenced in the early 1970s and ended in February 1991. The RPS was a type of buffer stock scheme where the public authority (the Australian Wool Corporation (AWC)) bought wool at low prices and sold wool at high prices in an effort to support and stabilise prices. Only a price floor was publicly announced and the AWC bought all wool which failed to receive bids above the floor. For detailed discussions and evaluations of the RPS see ABARE (1990), Wool Review Committee (1991) and Don, Gunaskera and Fisher (1992).

Many econometric models of the wool market have been developed. Supply side models include Fisher and Wall (1990) and Agbola (1995). Demand side models include Campbell, Gardiner and Haszler (1980) and O’Donnell (1992). Market (demand and supply) models include Hinchy and Simmons (1983), Fisher (1983) and Connolly (1990). A key feature of all these models is that once the operations of the AWC are incorporated into demand and/or supply the equilibrium assumption is imposed for estimation. That is, it is assumed that markets are efficient and always perfectly clear. We question the relevance of this assumption and turn now to the reasons for modelling the wool market as one in disequilibrium.

1 This analysis does not consider futures trading for the following reasons. First, the overwhelming majority of previous econometric models for the market have ignored futures trading. Second, wool futures trading has been spasmodic and at times negligible, for example, only the equivalent of 15 bales were traded in 1990. Third, there exists argument (Kaldor, 1960) to suggest that trades in the futures and spot markets are fundamentally different in that futures trading is dominated by speculators. Finally, attempts to model futures trading (Goss, 1990), have focused primarily on forecasting and find precise structural parameter estimation difficult.
There is evidence that in the 1960s buying ‘pies’ existed, see WRC (1991, p.24). The existence of pies concentrate market power and is at variance with the pure competition market clearing framework. Even though there is no direct evidence of pies existing in recent times, Hanson and Simmons (1995) argue that the number of buyers is relatively concentrated and that there may be some ‘stable price leadership’ practices in the market.

Secondly, a requirement for the operation of efficient markets is that the flow of information be sufficiently adequate to enable traders to instantly respond to market signals. The unstable and unpredictable nature of the demand for wool is thought to violate this requirement. Wool demand instability and its consequent effects on price variability has been well documented. For example, Motha, Sheales and Saad (1975) find excessive price variation in wool compared to other commodities; Lee and Bui-Lan (1982) point to the practical difficulties in forecasting wool prices; and ABARE (1990, p.44) discuss the unpredictable structural demand shifts due to changing political circumstances in China and the former Soviet Union. It is clear that such variability makes accurate price prediction very difficult implying sub-optimal decision responses by traders. Effectively, prices are constantly adjusting trying to equate demand and supply in response to ever changing demand conditions and agents are continually learning and updating their knowledge of market conditions but necessarily with a lag. For a general discussion on how unpredictable demand shifts and imperfect information results in disequilibrium price dynamics see Gordon and Hynes (1970). Relatedly, Goss (1987) in analysing the relationship between futures and spot wool prices found the existence of some slight information price inefficiency.

Thirdly, the very significant periodic trading activities of the AWC implies that it possessed occasional market dominance. There is no reason to expect that its activities will perfectly balance the demand and supply forces in the market. As previously alluded to, inappropriate speculation and inaccurate price prediction are two reasons for expecting difficulties in coordinating perfectly the activities of the AWC and those of the trade market see Parish (1964).

The fourth motivation for modelling the wool market as one in disequilibrium comes from the empirical evidence on pass-in rates (i.e. the number of offered but unsold bales as a percentage of sold bales). One method for measuring the ‘degree of disequilibrium’ in a market is to examine associated excess demand market indicators. Rudebusch (1989) employed this concept by assuming that there exists some natural or equilibrium rate for the indicator and significant deviations from this rate imply disequilibrium. Using this concept for the pass-in rate for the period 1976(3)-1993(4), we find a mean of 4.8 per cent and a standard deviation of 3.51, implying a CV of 0.73. These variations exceed those successfully employed by Rudebusch (1989).

Finally, we allude to the public auction system employed to sell wool. Wool is auctioned using the English system where the auctioneer accepts successively higher bids from buyers until the highest bid is reached at which price a sale is made. Auction systems in general have been studied thoroughly by examining their theoretical properties under ideal conditions, see McAfee and McMillan (1987), and through the use of simulation and experimental techniques to simulate actual behaviour, see Whan and Richardson (1969) and Plott (1982). The majority of experimental studies show that prices typically converge to a new equilibrium after two or three trading periods. As such ‘adjustment to a new equilibrium takes time, and ... certainly reflect disequilibrium trades’ (Plott, 1982, p. 1494). These findings are amplified by the imposition of a
price floor. For example, Isaac and Plott (1981) show that a price floor set at the equilibrium level may cause prices to diverge from equilibrium and that even non-binding price floors seem to affect the average level of transacted prices.

All these arguments combined imply that many trades in the wool market may be better characterised by disequilibrium rather than equilibrium. Even if one argues against the market being in a permanent state of disequilibrium never locating a moving equilibrium position, one cannot rule out absolutely the possibility of disequilibrium trades as the market moves from one equilibrium position to the next as a result of a demand shock. If this is accepted then Upcher (1985) provides a strong reason for modelling the market using a disequilibrium framework. Upcher considers the issue of aggregation over time in markets and recognises that typically observed data sets relate to average prices and summed quantities from many trading sessions. It is shown that even if one trading period (during the data measurement period) represents a disequilibrium trade then the equilibrium model is misspecified and that a disequilibrium framework is more appropriate. Effectively, the equilibrium model omits important information about price changes in its demand and supply specifications. Unfortunately, even given more frequent price data relating to individual trading sessions one cannot derive the correct disequilibrium maximum likelihood estimator due to an inherent identification problem. However, it is shown through the use of Monte Carlo simulations, that the disequilibrium formulation with time-aggregated data clearly outperforms its equilibrium counterpart. In general, Upcher (1985, p. 24) argues that ‘if a market is in disequilibrium in any period then there is a strong case for using the disequilibrium estimation approach regardless of the frequency of data.’

We now turn to a discussion of the appropriate disequilibrium modelling framework for the wool market. Econometric techniques for modelling disequilibrium markets are well developed, see Quandt (1988) for the most comprehensive and lucid survey. For a recent discussion of some of the theoretical aspects pertaining to disequilibrium markets see Benassy (1993). The canonical econometric model consists of stochastic demand and supply equations, a minimum condition which determines quantity transacted and a price adjustment equation relating price changes to the level of excess demand/supply. Techniques have also been developed to account for the imposition of price and/or quantity controls, see Oczkowski (1993) for a survey. These latter techniques explicitly recognise how markets may switch between equilibrium and disequilibrium states depending upon whether controls are binding or not. Implicitly, the methods which recognise controls assume that the only cause of disequilibrium trading are institutionally imposed controls.

Even though the wool market operated under the presence of a price floor for a substantial time period, the disequilibrium econometric techniques which recognise controls are considered inappropriate. First, for the time period considered 1976(3)-1993(4) and quarterly observations, in all cases the general market price indicator (averaging over all wool types and weekly prices) was above the price floor. Even when one considers data at the individual ‘integer’ micron levels, averaging over weekly prices still results in actual prices always being above their corresponding

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2 The previously alluded experimental literature implies that equilibrium may be achieved within a quarter (our estimation time span) given daily trading and a single market shock. However, this does not imply that all trades are in equilibrium during the quarter. Further, given numerous shocks there is no guarantee that convergence within a quarter will occur at all.
floor levels. Secondly, we have already alluded to various reasons for disequilibrium trading other
than the existence of a price floor and therefore even given non-binding price floors significant
disequilibrium trading is still expected. As a consequence we shall employ the canonical model
which implies that the price floor may have been set either above, at or below the equilibrium
price level, thereby permitting the occurrence of either excess demand or excess supply.

III. Econometric Methods and Data

Before describing the econometric specification and estimation technique, it is necessary to
discuss some issues pertaining to the data employed.3 Due to the unavailability of certain data
series, quarterly data covering the period 1976(3)-1993(4) is employed. The RPS period covers
1976(3)-1991(1). Quantity data covering all trades is employed, i.e. both public auction sales and
private sales. For the price series, the market indicator from the auction system is employed given
its universal acceptance. The non-use of price information from private sales is not a particular
concern since there is evidence that average auction prices are generally similar to average prices
from private sales, see Samuel, Metcalfe and Combe (1978).

In developing the demand regressors, measures of industrial production and exchange rates will
be employed. As a consequence it is necessary to use data from two of wool's main buyers, i.e.
China and the former Soviet Union. This poses two problems. First, data from these countries is
generally considered to be of dubious quality. Secondly, for some series quarterly observations are
unavailable. The first problem is unavoidable and results must be interpreted with this in mind. The
second problem is remedied by using BLUE interpolation techniques developed by Chow and Lin
(1971) which maintain the original properties of the annual data. Even though measurement errors
must result from these two problems we consider that these errors are outweighed significantly by
the errors resulting from omitting China and the former Soviet Union completely from the analysis.

The basic econometric specification for the model is given in equations (1)-(10). Equation (11)
specifies the variables based on expectations, while equation (12) relates to the structure of the
error terms.

\[
\begin{align*}
\tilde{Q}_{it}^n &= \bar{Q}_{it}^n + \alpha_1 \max(0, \bar{Q}_{it}^n - \bar{Q}_{it}^y) + u_{1t}, \\
\tilde{Q}_{it}^n &= \bar{Q}_{it}^n + \beta_2 \max(0, \bar{Q}_{it}^y - \bar{Q}_{it}^e) + u_{2t}, \\
\bar{Q}_{it}^y &= X_{it}^\gamma + \alpha_i P_i, \\
\bar{Q}_{it}^y &= X_{it}^\beta + \beta_i P_i, \\
Q_{it}^y &= X_{it}^\gamma + \gamma_i (P_i - P_i^e) + u_{2t}, \\
Q_{it}^e &= X_{it}^\delta + \delta_i (P_i - P_i^e) + u_{4t}, \\
\end{align*}
\]

3 For definitions of the employed data and their summary statistics see the data appendix. For a fuller
description of the data see Oczkowski (1995, pp. 30-33).
\[ \hat{Q}_t^d = \hat{Q}_{tpd} + Q_{tp}^p \] 
\[ \hat{Q}_t^s = \hat{Q}_{tp}^p + Q_{tp}^s \] 
\[ Q_t = \min(\hat{Q}_t^d, \hat{Q}_t^s) \]
\[ \Delta P_t = (1/\lambda) (\hat{Q}_t^d - \hat{Q}_t^s) \]
\[ P_t^e = \max\{P_t^f, P_{t-1} + \theta_1(P_{t-1} - P_{t-2})\} \]
\[ Risk_t = Std_{t-1} + \theta_2(Std_{t-1} - Std_{t-2}) \]
\[ P_t^b = P_t^b_{t-1} + \theta_3(P_t^b_{t-1} - P_t^b_{t-2}) \]
\[ Q_t^{int} = TTP_{t-4} + \theta_4(TTP_{t-4} - TTP_{t-3}) \]
\[ Q_t^{sex} = TTS_{t-4} + \theta_5(TTS_{t-4} - TTS_{t-3}) \]
\[ u_t = \rho_t u_{t-1} + \varepsilon_t \quad (i = 1, \ldots, 4) \]

where \( \hat{Q}_{tpd}^d \) and \( \hat{Q}_{tp}^p \) are effective private demand and supply, 
\( \hat{Q}_{tpd}^d \) and \( \hat{Q}_{tp}^p \) are notional private demand and supply, 
\( Q_{tp}^p \) and \( Q_{tp}^s \) are government (AWC) purchases and sales, 
\( \hat{Q}_t^d \) and \( \hat{Q}_t^s \) are total effective demand and supply, 
\( Q_t^{int} \) is expected available supply to private demanders, 
\( Q_t^{sex} \) is expected available demand to private suppliers, 
\( P_t, P_t^f \) and \( P_t^e \) are transacted, floor and expected wool prices, 
\( Q_t \) is transacted quantity, 
\( Std \) is the standard deviation of weekly wool prices, 
\( P_t^b \) is the price of beef, 
\( TTP \) and \( TTS \) are total trade purchases and sales, 
\( u_t (i = 1, \ldots, 4) \) are AR(1) error terms, 
\( \varepsilon_t (i = 1, \ldots, 4) \) are iid error terms with constant variances \( \sigma_t^2 \), 
\( X_{it} (i = 1, \ldots, 4) \) represent vectors of exogenous regressors, 
\( \alpha, \alpha_1, \alpha_2, \beta, \beta_1, \beta_2, \gamma, \gamma_1, \delta, \delta_1, \lambda \) are estimable parameters, 
\( \rho, \sigma_t^2, \theta_j (i = 1, \ldots, 4, j = 1, \ldots, 5) \) are estimable parameters.
Equations (1) and (2) define the effective demand and supply schedules of private traders. Equations (3) and (4) define the standard 'equilibrium' notional schedules which are derived from choice-theoretic programs under the assumption that the desires of all agents can be satisfied. The notional schedules depend upon exogenous regressors and prices (current for demand and expected for supply). The motivation for the specific form of the effective schedules is based on Oczkowski (1990) and encapsulates notions of expected rationing manipulability and the transactions costs from expressing demands and supplies to the market. For a general discussion on the use of effective demand concepts in disequilibrium models see Oczkowski (1993, pp. 63-70).

For a description of the underlying processes determining effective desires consider supply. If suppliers expect that they can gain their notional desires at the market then \( \bar{Q}^{en} > Q^e \) (i.e. notional supply is less than the expected demand available to private suppliers) and notional desires are expressed \( \bar{Q}^{en} = \bar{Q}^{en} \). On the other hand, if suppliers expect to be rationed \( \bar{Q}^{en} > Q^{de} \), then effective supply differs from notional supply and the difference depends upon an estimable parameter \( \beta_2 \) and the amount of expected rationing. The sign of \( \beta_2 \) depends upon the expected benefits and costs from trying to manipulate more transactions. Clearly, if the supplier takes more wool to the market then it is likely that the chances of selling greater quantities at the desired price are improved. However, there are costs in continually taking wool to the market, i.e. delivery charges, agents' commissions and personal costs in attending sales. A trade off between these costs and benefits ultimately determines whether effective supply exceeds or is less than notional supply. A similar argument applies for effective demand.

Equations (5) and (6) define the purchasing and buying behaviour of the AWC. Rather than specifying net AWC purchases as done in some previous models, purchases and sales are treated separately given the clear asymmetry in buying and selling behaviour with respect to prices differences from the floor, that is, we expect \( \gamma_1 < 0 \) and \( \delta_1 > 0 \). Equations (7) and (8) define total effective demand and supply as the sum of private desires and AWC sales/purchases. Given the associated complexities and the lack of a theoretical motivation, we abstract from using effective demand concepts for the activities of the AWC and assume that their purchases and sales reflect actual desires.

Equations (9) and (10) describe the disequilibrium trades and price dynamics. Equation (9) represents the standard minimum condition suggesting that the minimum of total effective demand and supply is the quantity transacted, while equation (10) describes how the change in prices depends upon the level of total effective excess demand and supply. The price adjustment parameter \( \lambda \) describes the speed of adjustment, with \( \lambda \to \infty \) implying infinitely slow market clearing and \( \lambda = 0 \) implying instantaneous adjustment and equilibrium trading. That is, the equilibrium assumption is a testable hypothesis (H\(_0\): \( \lambda = 0 \)) within this disequilibrium framework. For details on the motivation for equations (9) and (10) and for testing the equilibrium assumption see Quandt (1988, pp. 21-26, 80-83).

\(^4\) An alternative disequilibrium model with price adjustment is to append an error term to equation (10). Unfortunately this results in an unbounded likelihood function which complicates the estimation procedure. Given the inherent complications already in our model this extension was not considered. We did however consider asymmetric price adjustment coefficients for price rises and falls, see Quandt (1986, p. 23), the asymmetry proved to be unimportant.
Overall, the basic structure of the model recognises that the determinants of price changes depend not only upon actual amounts transacted but also upon unsatisfied notional desires and attempts to manipulate expected rationing. Intuitively, one expects that all attempts to sell and buy wool even if unsuccessful, should influence the behaviour of observed prices. Anecdotal evidence does suggest that high pass-in rates are generally related to low transacted prices. For our estimation period the simple correlation between pass-in rates and real wool prices is a highly significant -0.52.

We now turn to the specification of the preferred exogenous regressors, $X_{it}$ ($i = 1,...,4$). The preferred regressors are primarily based upon findings from previous models (e.g. Fisher, 1983; Hinchy and Simmons, 1983 and Connolly, 1990) but also recognise structural changes due to the effects of deregulation. The final regressors are chosen with regard to data availability, degrees of freedom considerations and preliminary modelling results.

For notional demand ($X_{1t}$) we employ a real wool trade weighted exchange rate index (expected - sign) as an individual regressor to account for additional general equilibrium effects, see Chambers and Just (1979). The level of economic activity in wool using countries is measured by a wool trade weighted industrial production index (expected + sign). The real US cotton price (expected + sign) is employed to capture fibre substitution possibilities. Three quarterly seasonal dummy variables were found to have important impacts on demand. The level of AWC stocks (expected - sign) is used to represent the general availability of wool stocks, the reduced form demand equation in Fisher (1983) employs this, and it is important as it may help explain the extreme buying behaviour (in response to low stocks) during 1987(1)-1988(2), see WIRC (1993, p.32). Variables measuring structural changes were also employed. A dummy variable for the period 1987(1)-1988(2) reflecting the above mentioned extreme buying behaviour and an interaction between price and a dummy variable for the non-RPS period 1991(2)-1993(4), proved to be important. 5

For notional supply ($X_{2t}$) a rainfall index (expected + sign) reflecting the suitability of weather conditions for producing wool was employed. A time trend (expected + sign) was included to capture technological advances in production. Three quarterly seasonal dummies were found to be important. Real input costs (expected - sign) and real expected beef prices (expected - sign) reflecting substitution possibilities are employed. A crucial motivation for the introduction of the RPS was to help reduce the impact of price variation on wool producers, consequently an expected risk variable (expected - sign) is also specified for the supply equation. Structural change variables which proved important are a constant dummy for the non-RPS period and an interaction between expected wool prices and the dummy for the non-RPS period. 6

5 Other variables unsuccessfully tried in the demand equation included: the clean wool yield; Japanese textile prices which were highly correlated with the US cotton price; and various structural shift dummies including, a dummy for the non-RPS period and a dummy for the period 1988(2)-1991(1) reflecting the substantially reduced demand from China and the former Soviet Union.

6 Other variables unsuccessfully tried in the supply equation included: the clean yield and the real expected price of wheat as another substitution possibility. The relative importance of expected beef prices compared to expected wheat prices is consistent with results from other studies, see Reynolds and Gardiner (1980).
A number of variables in the notional supply equation and the rationing measures in the effective schedules rely on expectations. Four expectations assumptions were considered in preliminary modelling, i.e. extrapolative, naive, moving average and a geometric lag (adaptive).\(^7\) Table I compares the predictive performance of these expectations assumptions for the two key variables, price and quantity transacted. Extrapolative expectations dominates in all cases except for per cent RMSE and quantity. Moreover, extrapolative expectations produced theory consistent parameter estimates to a greater extent than the other formulations.

<table>
<thead>
<tr>
<th>Table I</th>
<th>Squared Correlations</th>
<th>Theil’s U</th>
<th>%RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Price</td>
<td>Quantity</td>
<td>Price</td>
</tr>
<tr>
<td>Extrapolative</td>
<td>0.825</td>
<td>0.747</td>
<td>0.101</td>
</tr>
<tr>
<td>Naive</td>
<td>0.733</td>
<td>0.710</td>
<td>0.146</td>
</tr>
<tr>
<td>Moving average</td>
<td>0.807</td>
<td>0.738</td>
<td>0.104</td>
</tr>
<tr>
<td>Geometric</td>
<td>0.725</td>
<td>0.709</td>
<td>0.130</td>
</tr>
</tbody>
</table>

As a consequence, extrapolative expectations are employed (equation 11), for a discussion and other uses of this formulation see Turnovsky (1970), Sulewski, Spriggs and Schoney (1994) and Hey (1994). Various time lags were also considered. For supplier price expectations ($P^s$) and the RPS period, switching between the expectations formulation and the price floor is permitted. If extrapolative expectations exceed the floor then extrapolative expectations are employed, if not, the floor is used as the expectation. Results indicated that short-term lags of one and two quarters were more appropriate for expected wool and beef prices than longer lags of four and eight quarters, and eight and twelve quarters. These results are reasonably consistent with the findings from Connolly (1990) that short-term marketing considerations may be more important than longer-term production considerations.

In determining expectations for the risk variable, preliminary modelling with Just’s (1974) measure of risk, based on the difference between actual and expected prices, proved unsuccessful. In part this may be due to the additional complexity of the estimation procedure. Consistent with the short-term outlook for price expectations, the standard deviation of actual weekly prices from the previous two quarters proved to be more important than longer lags.

\(^7\) Rational expectations were not considered given that the spirit of this assumption is at variance with the information inefficient noncoring markets approach of the employed disequilibrium specification. Moreover, this assumption is extremely difficult to computationally implement even in simpler disequilibrium models, see Holt (1992). In fact, debate still exists as to the correct expression for rational expectations in the standard disequilibrium model with minimum prices, see Donald and Maddala (1992), and Pesaran and Samiei (1992).
Finally, consider the specification of expectations for available demand and supply to private traders, i.e. $Q^u$ and $Q^d$. Again extrapolative expectations appeared to be more appropriate here, however, given the significant seasonality in quantity transacted, then annual lags of four and eight quarters are used in the expectation formulation. The information employed in determining these expectations is based on what agents actually traded in previous periods. For example, expected available demand for private suppliers is based on previous private sales.\(^8\) In some cases this assumption may however underestimate available demand since if excess demand was experienced in previous periods then more demand than previous private sales was available to private suppliers. One possible remedy to this deficiency is to supplement the expectation with previous price information which may reflect whether excess demand was experienced and its extent. Modelling efforts with additional price information proved unsuccessful, the likelihood function continually failed to converge. It appears that this issue requires further research.

We now turn to the regressors for the activities of the AWC, $X_3$, and $X_4$. The majority of previous studies modelling the activities of the AWC have employed the relation between the observed and floor prices in some form as the principal regressor, see Connolly (1990, ch. 7) for a survey of previous studies. It would appear that other exogenous regressors are generally irrelevant given the charter of the AWC. We gave consideration, however, to seasonal dummy and structural change regressors. For AWC purchases, three quarterly seasonal dummies are employed as well as a dummy for the 1991(1) quarter reflecting the abandonment of the RPS. This quarter has unusual characteristics of both the RPS and the non-RPS period. For AWC sales only a March quarter seasonal dummy proved important. For structural change a constant dummy for the non-RPS period and an interaction between price and the non-RPS dummy were employed.\(^5\)

Finally, we consider procedures for estimation. The maximum likelihood method is employed. The likelihood function involves the use of endogenous switching regression methods and spline smoothing techniques for the step functions, see Quandt (1988, pp. 31-33, 110-112). In our preliminary modelling, LM tests based on generalised residuals, indicated significant degrees of first-order error auto-correlation. As a consequence the preferred specification assumes an AR(1) error structure (equation 12), and estimation requires the use of techniques developed by Laffont and Monfort (1979). The resultant likelihood function consists of 64 separate joint densities, see Oczkowski (1995, pp. 17-19).\(^10\)

\(^8\) In this example for $Q^u$, previous private purchases are inappropriate as such purchases are made from both private sellers and the AWC.

\(^5\) For the non-RPS period, equation (5) for $Q^d$ does not exist and $P^t = P^f$ for equation (6) and $Q^d$.

\(^10\) Numerical optimisation of the log-likelihood function was carried out using the Davidon-Fletcher-Powell algorithm and GQOPT. A local optimum was reached without computational failure. Numerical derivatives were employed and the reported standard errors are from the estimated Hessian. The approximation coefficient in the spline function was set to 1.E-05 in the second step, and accuracy in optimisation results to 1.E-10. For starting values we employed ordinary least squares recognising price change information in demand and supply, assuming expected rationing for all observations, and naive expectations. The attainment of consistent estimates for starting values from least squares is not obvious given that the switching in effective schedules and $P^*$ depends upon unknown parameters which cannot be estimated directly.
IV. RESULTS AND DISCUSSION

Maximum likelihood estimates and associated summary statistics for the preferred specification are presented in Tables II and III. The summary statistics indicate reasonably good predictive performance for all variables except AWC sales. This is somewhat expected given the lack of announced price ceiling selling policies during the RPS period and the changing selling policies during the non-RPS period. The decline in the predictive performance of price as we move to the historical simulations is expected given its greater dependence on lagged variables. The tests indicate a lack of heteroskedasticity for all equations at a ten per cent level of significance.\(^{11}\) The majority of parameter estimates in Table III align with our expectations. The majority of estimates also appear to be reasonably precisely estimated given the relatively large t-ratios.\(^{12}\)

### Table II

**Summary statistics**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Static simulations (squared correlations)</th>
<th>Historical simulations (squared correlations)</th>
<th>Heteroskedasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWC purchases</td>
<td>0.717</td>
<td>0.707</td>
<td>(\sigma^2) (\chi^2(9)=13.99)</td>
</tr>
<tr>
<td>AWC sales</td>
<td>0.308</td>
<td>0.309</td>
<td>(\sigma^2) (\chi^2(12)=13.97)</td>
</tr>
<tr>
<td>Price</td>
<td>0.950</td>
<td>0.825</td>
<td>(\sigma^2) (\chi^2(4)=0.64)</td>
</tr>
<tr>
<td>Quantity</td>
<td>0.754</td>
<td>0.747</td>
<td>(\sigma^2) (\chi^2(2)=0.14)</td>
</tr>
</tbody>
</table>

\(^{11}\) The heteroskedasticity tests are likelihood ratio tests which assume that the error variances are related linearly to the exogenous variables in their own respective equations. Endogenous price is omitted from these regressors, but all variables based on expectations are included.

\(^{12}\) We did not perform unit root and cointegration tests for the following reasons. First, the employed economic theoretical disequilibrium framework provides no motivation for performing such tests, that is, it is not clear that cointegration relationships would have any useful theoretical meaning within the employed framework. Second, many unit root tests are unreliable and often contradictory, results depend crucially upon what is assumed to be the null model, Cochrane (1991) and Silvapulle (1996). Third, Bardsley and Olekalns (1996) find no evidence of unit roots for wool prices using the KPSS test. Finally, dynamics are adequately catered for in the employed specification through quantity and price expectations, the price adjustment equation and the AR(1) error structure.
<table>
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</table>

**Expected coefficients**

| AR(1) coefficients       |             |         |             |         |
| Price $(P^*)$             | -1.232      | -3.08   | Private demand | 0.154  | 1.89   |
| Risk                     | -0.296      | -0.71   | Private supply | -0.233 | -2.96  |
| Beef                     | 1.121       | 1.09    | AWC purchases | 0.904  | 8.87   |
| Private supply $(Q_t^{ps})$ | -0.800  | -11.69  | AWC sales    | 0.493  | 4.46   |
| Private demand $(Q_t^{en})$ | -0.005   | -0.13   |             |         |        |
We now briefly comment on some of the less obvious results from each equation. For demand there is significant seasonality with the control December quarter having the greatest impact on demand. The extreme buying behaviour during 1987(1)-1988(2) had a clear positive impact on demand. The price impact on demand was significantly reduced in the non-RPS period. Most interestingly the coefficient for expected rationing \( \alpha_2 \), indicates that when rationing was expected, effective demand exceeds notional demand. This implies that agents expected significant benefits from trying to manipulate more transactions compared to the associated costs. This could reflect the notion that buyers expend low costs when expressing higher demands. As argued by Benassy (1977, pp. 164-166) once a demander is at the market then she can express unlimited demands, being only constrained by the number of actual purchases made. Essentially, a single lump sum cost is expended for any level of demand expressed at any one given trading session. It is clear however, that as agents trade over many weeks and locations then 'personal' accommodation and travel costs do increase. These costs still appear to be relatively small compared to the wide range of opportunities to express high demands.

For supply once again the December quarter has the greatest seasonal impact. The dummy variable for the non-RPS period implies a significant 'constant' reduction in supply after deregulation, however, this is offset by the significantly increased expected price impact during the non-RPS period. The coefficient for expected rationing for supply \( \beta_2 \), indicates that when rationing was expected effective supply was less than notional supply. This contrasts to the results for demand and may result from the relatively high costs in expressing supply. That is, wool bales must be physically brought to the market each time a supplier wishes to express a supply. The consequential organisation, delivery and related costs are clearly greater than those relating to demand expression.\(^{13}\)

It is interesting to examine the frequency of expected rationing and the extent of the deviations between effective and notional desires in some greater detail. At the preferred estimates, private demanders expect to be rationed for 64.3 per cent of the quarters and private suppliers 77.1 per cent of the quarters. When rationing is expected, private effective demand exceeds notional demand by 8.3 per cent on average, while private effective supply is less than notional supply by 8.5 per cent on average. The only obvious pattern in the time series behaviour of expected rationing occurs with demand where significant rationing was expected in the period 1987(1)-1988(2), and no rationing was expected in the period 1988(3)-1991(1).

The equation for AWC purchases also indicates that the December quarter has the greatest seasonal impact. The 1991(1) dummy clearly indicates that buying behaviour for the quarter during which the RPS was abandoned was unlike the immediately preceding quarters. For AWC sales there is little seasonality with only the March quarter standing out. There is a significant constant downward shift in the non-RPS period but this is offset in part by a greater price impact in the non-RPS period. The price impact during the RPS period is not particularly strong.

\(^{13}\) It appears erroneous to interpret the existence of the RPS scheme and its guaranteed floor price sales as an indication that rationing manipulation is relatively easy for suppliers (with \( \beta_2 > 0 \) expected). In disequilibrium models expected rationing and consequent manipulation relates to quantities at expected supplier prices, which in most cases are above floor prices. That is, during the RPS period suppliers could sell as much as they like at the price floor but were rationed at prices above the floor.
As indicated previously the price adjustment coefficient allows us to test the equilibrium hypothesis. Given a $t$-ratio of 7.81 then the equilibrium hypothesis ($\lambda = 0$) is clearly rejected.\textsuperscript{14} The error variances point to greater unpredicted demand variation and the strongest error autocorrelation occurs for AWC purchases.

Finally, consider the extrapolative expectations coefficients. For risk, beef and private demand the coefficients are not significant and so naive expectations appear relevant here. For $P^e$ and $Q^e$ negative signs were estimated. This implies some type of expected short term cyclical behaviour in these variables. Sulewski, Spriggs and Schoney (1994) find a similar result for Canadian canola prices. For both variables the RPS is thought to dominate these expectations. For expected wool prices, a rationale provided by Dalton and Taylor (1975) may be modified and adopted. It could be argued that if the price floor is set too high with large price increases, then suppliers may revise expectations downwards anticipating that a price reduction in the floor may follow as the AWC tries to avoid accumulating excessive stocks. For expected available supply to private demanders, if there is a large increase in available supply, part of which stems from AWC sales, then expectations might be revised downward in anticipation of a decline in AWC sales due to diminished stocks.\textsuperscript{15}

\begin{table}
\centering
\caption{Table IV}
\label{tab:elasticities}
\begin{tabular}{llll}
\hline
\hline
\textit{Private demand} & & & \\
Price & -0.685 & -0.332 & -0.637 \\
Exchange rate & -0.300 & -0.425 & -0.321 \\
Industrial production & 0.308 & 0.579 & 0.347 \\
Cotton price & 0.110 & 0.081 & 0.108 \\
\textit{Private supply} & & & \\
Expected price & 0.258 & 0.431 & 0.340 \\
Input prices & -0.645 & -0.364 & -0.585 \\
Beef prices & -0.060 & -0.031 & -0.054 \\
\textit{Total demand} & & & \\
Price & -1.021 & -0.332 & -0.971 \\
\textit{Total supply} & & & \\
Price & 0.357 & 0.653 & 0.472 \\
\hline
\end{tabular}
\end{table}

\textsuperscript{14} Even though testing ($\lambda = 0$) does test whether total demand equals total supply, in such an equilibrium model there would also be no need for effective demand/supply specifications and hence $z_2 = \beta_3 = \beta_4 = \theta_3 = 0$ also. An appropriate LR test ($\chi^2(5)$) was performed to test these five joint restrictions, the resulting test statistic (86.7) was highly significant.

\textsuperscript{15} For the switching behaviour of the expected price of wool, it is interesting to note that only during four quarters (77(1), 83(2), 83(3) and 87(3)) was the price expectation set equal to the price floor. This represents only 6.8 per cent of the RPS quarters.
The impact elasticities for the key variables, from the preferred specification, are presented in Table IV. These are evaluated at the sample means of the observed and predicted data for the RPS period, the non-RPS period and the entire sample. In all but one case inelastic responses are reported. The majority of elasticities are within the ranges of previous estimates, see Mullen, Alston and Wohlgemant (1989) and Fisher and Wall (1990). One key difference however, is the relatively low own price demand elasticity when compared to those reported by Beare and Meshios (1990) (ranging from −1.0 to −2.0) and Connolly (1990, p. 264) (ranging from −1.2 to −3.5). Our model’s most recent demand elasticity estimate of −0.33 is also well below the −1.0 employed by Beare, Fisher and Sutcliff (1991) and Hertzler (1994) in deriving optimal stock-pile disposal policies. On the other hand, our estimates are broadly consistent with O’Donnell’s (1992) −0.53 estimate produced by a demand model which recognises endogenous switching. Further, our estimates are consistent with the general notion that disequilibrium models tend to produce lower demand elasticities compared to their equilibrium counterparts, see Oczkowski (1993, p. 60).

Disequilibrium models also provide important measures of market imbalance. Conditional (on observed transactions) predictions of excess demand and excess supply are presented for all traders in Figure 1 and for only private traders in Figure 2. Both figures indicate varying periods of excess demand and excess supply. Two significant periods stand out. Significant excess demand is predicted during 1987 and early 1988 and significant excess supply is predicted from late 1988 until the abandonment of the RPS in early 1991. This clearly reflects the extreme buying behaviour in response to low stocks and the subsequent excess supply behaviour as China and the former Soviet Union withdrew from the market and the price floor was maintained at relatively high levels.

FIGURE 1
Total market excess demand
FIGURE 2
Private market excess demand

It is clear from Figures 1 and 2 that the market imbalance between private traders was reduced significantly in the overall market by the activities of the AWC. In particular for the overall market (Figure 1) excess demand occurred 44 per cent of the time with an average magnitude of 11.9 per cent, while excess supply occurred 56 per cent of the time with an average magnitude of 12.5 per cent. In stark contrast, for private traders (Figure 2) excess demand occurred 46 per cent of the time with an average magnitude of 23.8 per cent, while excess supply occurred 54 per cent of the time with an average magnitude of 33.9 per cent.

One important use of the model is to simulate the consequences of removing the RPS during its period of operation. Simulations were performed by setting $Q^{fp} = Q^{fs} = 0$, $P^f = -\infty$ and adjusting the risk variable such that the average coefficient of variation for the RPS period is the same as that for the non-RPS period. The latter adjustment recognises that the RPS did reduce the risk impact from price variability, i.e. the ratio of the average CV for the non-RPS period to the RPS period is 2.62.

The impact on prices of removing the RPS is depicted in Figure 3. This figure measures percentage deviations of the simulated price without the RPS from the observed price with the RPS in place. Prices were kept relatively low by the RPS during the period 1980(1)-1983(2) and the year 1987. During 1987 extensive net selling by the AWC did occur. This however, was not the case for the former period where there was moderate net buying by the AWC. The cause of the relatively low prices in this period is unclear and is a function of the complex disequilibrium dynamics underpinning the simulations. Prices were kept relatively high by the RPS after 1988(2) and this is clearly the result of the significant net buying activities of the AWC and high price floors.
FIGURE 3
Price: simulated removal of RPS less observed RPS

FIGURE 4
Private suppliers' revenue: simulated removal of RPS less observed RPS
The simulation results for private suppliers' total revenue are presented in Figure 4. Compared to the price effects, there is greater variability in revenue changes and less obvious systematic patterns apart from the significant revenue losses after 1988(2). The total sum of private suppliers' revenues, for the period 1976(3)-1991(1), are simulated to fall by 8.2 per cent given the removal of the RPS. This translates to an average fall of $60.9 million (1985 prices) per quarter. This gross revenue impact appears to be greater than previous estimates which point to 'small' gross impacts both negative and positive, see ABARE (1990, p28). For example, Myers, Pigott and Tomek (1990) simulate a 0.7 per cent fall in revenue as a result of removing stockpiling. Our greater estimated revenue impacts are principally due to the inclusion of the post 1988(2) period, which was not considered in the above cited evaluations. On the other hand, part of the difference could be due to the disequilibrium modelling methodology employed in our study.

V. SUMMARY AND CONCLUSION

This paper has provided new insights into the well researched Australian raw wool market. The recognition of disequilibrium trading possibilities and expected rationing manipulation activities have been investigated for the first time. Some of the main results are novel and particularly revealing.

In response to expected rationing, private demanders were predicted to express higher demands than otherwise, while private suppliers expressed lower supplies than otherwise. The relative costs of demand/supply expression are thought to motivate this behaviour. Supplier price expectations were predicted to be only seldomly bounded by the price floor. Measures of the significant excess demand behaviour during 1987(1)-1988(2) and the significant excess supply behaviour of 1988(3)-1991(1) are provided. The latter behaviour clearly describes the events leading up to the ultimate abandonment of the RPS. The activities of the AWC were found to significantly reduce the market imbalances stemming from the behaviour of private traders.

The gross revenue impacts of the RPS appear to be significant once the excess supply period of 1988(3)-1991(1) is considered. When this period is ignored however, the RPS impact is negligible and similar to that found in other studies. Estimated elasticities are similar to previous findings except for relatively low own price demand elasticities. This may imply that some previously suggested stockpile disposal policies, using larger elasticities, may be sub-optimal. More importantly, however, is that such stockpile disposal policies and related discussions, e.g. Edwards (1993), are still predicated on the assumption that observed transactions lie on both the demand and supply curves. These simulation models and policies may need reworking to account for disequilibrium trading possibilities, rationing manipulation practices, and price dynamics related to market imbalances.

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16 When the 1988(3)-1991(1) period is excluded from our calculations, there is a 0.3 per cent predicted rise ($2.3 million per quarter in 1985 prices) in revenue as a consequence of removing the RPS. This result appears to be consistent with the small revenue impacts reported by previous studies. It is not clear however, that these other 'equilibrium' methods would estimate similar large revenue impacts for the 1988(3)-1991(1) excess supply period.

17 For example, statements such as 'if the elasticity of demand is less than unity... wool industry gross revenue is reduced by sales from the stockpile', Edwards (1993, p106) implicitly assume that transactions lie on the demand curve. This is not the case given an excess demand situation and the minimum condition.
In conclusion, this paper further illustrates the utility of modelling using a 'markets in disequilibrium' framework. The method has been shown to be relevant and important for a market where it is often argued that the extreme price variability illustrates the market mechanism keeping supply and demand in balance, see WIRC (1993, pp. 46-7). Our final advice concurs with Upcher (1985), that the disequilibrium modelling framework may be more widely applicable than generally considered. Practically, would-be equilibrium market modellers should be encouraged to test for 'market disequilibrium' as part of their routine specification error checking.

DATA APPENDIX

Wool Quantity Transacted (Mean = 21.80 Std = 6.02) Greasy weight of all raw wool transactions, per 10 kts (kilotonnes).

Real Wool Price (Mean = 349.99 Std = 83.34) Real AWC market indicator, cents per kg of greasy, deflated by Australian CPI (1985 prices).

Demand regressors

Real Wool Trade Weighted Exchange Rate Index (Mean = 105.92 Std = 17.45) Index base: 1985(1) =100. Based on five major export destinations: France, Italy, China, (former) Soviet Union and Japan. Annual weights determined by export shares based on previous five years trade (excluding the current year).

Wool Trade Weighted Industrial Production Index (Mean = 105.20 Std = 23.14) Index base: 1985 = 100. Countries and weights as for the exchange rate. Data collected are seasonally adjusted.

US Real Cotton Price (Mean = 85.44 Std = 30.46) US cents per lb (1985 prices) Deflated by US CPI. UK cif price from American Memphis Territory.

AWC Wool Stocks (Mean = 24.87 Std = 25.71) Greasy weight per 10 kts. Average of weekly closing stocks. Lagged one quarter.

Total Trade Wool Purchases (Mean = 19.35 Std = 5.58) Greasy weight per 10 kts.

Supply regressors

Rainfall (Mean = -1.757 Std = 14.72) Percentage deviation from long-run (80 year) average. Four quarter moving average lagged one year. Based on readings from three zones; pastoral, wheat-sheep and high rainfall, weighted by sheep numbers.

Time (Mean = 43.5 Std = 20.35) 1976(3) = 9, 1976(4) = 10, ...... 1993(4) = 78.

Real Input Prices (Mean = 93.91 Std = 4.19) Index base: 1985 = 100. ABARE Index of Prices Paid, Total Australia (1985 prices). Deflated by Australian CPI.
Real Beef Prices (Mean = 90.43 Std = 18.23) Index base: 1985 = 100. ABARE Index of prices received for beef (for earlier periods cattle and sheep) (1985 prices). Deflated by Australian CPI.

Standard Deviation of Real Wool Prices (Mean = 10.22 Std = 12.66) Standard deviation of weekly market indicator closing quotations. Real greasy cents per kg.

Total Trade Wool Sales (Mean = 20.05 Std = 6.00) Greasy weight per 10 kts.

Other variables

AWC Purchases (Mean = 2.91 Std = 4.01 for RPS period only) Greasy weight per 10 kts.

AWC Sales (Mean = 1.75 Std = 1.54) Greasy weight per 10 kts.

Real Wool Price Floor (Mean = 331.11 Std = 39.57 for RPS period only) Real minimum reserve price associated with market indicator (1985 prices). Deflated by Australian CPI.


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