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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.

Keywords: Disequilibrium markets, support prices, Australian wool.

Contributed paper to the 40th AARES conference, February 11-16, 1996, Melbourne.

* The assistance of various people and organisations is acknowledged for providing data: *Wool International*, Gerard Kazakevitch, Robert Pereira, and Frank Agbola. Funding from the ARC small grants scheme is gratefully acknowledged.

1. 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. In part, the motivation for disequilibrium trading stems from the significant demand volatility, which together with information inefficiencies, results in price adjustment towards equilibrium positions which are non-stationary and hence may never be reached.

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.

The output from the estimated model will permit comparisons between the findings from the equilibrium and disequilibrium modelling approaches on key elasticities and simulated impacts of policy removal. Estimated elasticities play an important role in developing optimal wool stockpile disposal policies.

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 three initially discusses some issues pertaining to data. The general specification is then outlined, followed by argument for the preferred regressors. We conclude section three by providing a broad overview of the appropriate estimation method. In section four the preferred estimates, elasticities, measures of expected rationing and market imbalance, and simulations of policy impacts are provided and discussed. Section five provides a summary and conclusion.

2. 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%-95% 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, Gunaskern 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.

Motivation for Disequilibrium Modelling

There are many individual (but related) persuasive reasons for suspecting that the wool market may not always perfectly clear. When taken together, these reasons provide a strong overall motivation for disequilibrium modelling. Motivations include: the existence of buying pies; perverse, excessive or deficient speculation; information inefficiencies and unpredictable demand; the existence of a large single trader (AWC) and its associated floor price; anecdotal empirical evidence; and the public auction system. We discuss each potential motivation in turn.

There is evidence that in the 1960s buying 'pies' existed, see WRC (1991, p24). 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, in the prelude to the introduction of the RPS many authors, for example Lloyd (1965), argued that the degree of speculation by agents was generally inappropriate and that as a consequence prices were not necessarily consistent with equilibrium trades. Beja and Goldman (1980) extensively discuss the role of speculation in markets generally and argue strongly that a disequilibrium framework is a more appropriate framework for modelling markets with speculators.

Thirdly, 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, p44) 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. The lagged learning process implies that disequilibrium trades will occur as the market adjusts to new demand shocks. 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 relation between futures and spot wool prices found the existence of some slight information price inefficiency.

Fourthly, 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 co-ordinating perfectly the activities of the AWC and those of the trade market. These concerns were expressed by those opposed to wool market intervention in the 1960s, for example Parish (1964). Further, the existence of the price floor if set 'too high', by definition, prohibits equilibrium trading.

The fifth 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% 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, p1494). 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 summated 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, p24) 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."

General Disequilibrium Modelling Approaches

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 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. We however, shall modify the model to incorporate some theoretically important features.

First, the concept of effective demand/supply is used. This recognises that the specification of standard notional demand/supply is at variance with the disequilibrium trading assumption. That is, we permit the expectation of rationing to impact upon the demands and supplies expressed to the market. By definition agents on the long side of the market are rationed and unable to fulfil their desires, it is argued that in response to such rationing occurrences behaviour will be modified. The application presented below is the first within a single

market context which employs expected rationing manipulation possibilities. For a discussion of effective demand concepts in single market disequilibrium models, see Oczkowski (1990).

The second modification to the canonical model relates to specifying supplier price expectations. Here we will explicitly recognise the role of the price floor in providing a lower bound for expectations. Finally, the AWC will be simply treated as another trader who buys and sells in the market place, but whose behaviour definitely influences transacted quantity and price. The behaviour of the AWC will however be distinguished from that of private traders by specifying separate demand and supply functions.

3. Econometric Methods and Data

Before describing the econometric specification and estimation technique, it is necessary to discuss some issues pertaining to the data employed. A full description of data sources and construction is provided in the appendix.

Data Issues

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). Initially, unsuccessful attempts were made to get data at an individual micron level and as a consequence aggregated data covering all microns is employed. Quantity data covering all trades is employed, i.e., both public auction sales and private sales. Even though there is significant re-selling, (i.e., private purchases by dealers are often then re-sold at auction) measuring all sales is important because all sales impact upon actual trading prices. 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). Given the focus on modelling actual transactions then for auction sales, the AWC data on all sales rather than the ABS data on previously unsold taxable receivables into brokers' stores is employed. Further, since auctions are conducted on a cents per kg greasy basis, then prices and quantities measured in greasy terms will be employed for modelling and consideration will be given to clean yield regressors in the appropriate equations.

Throughout the analysis we assume the absence of money illusion and so all currency based measures are deflated to 1985 prices. 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.

Disequilibrium Model Specification

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

$$\tilde{Q}_t^{pd} = \bar{Q}_t^{pd} + \alpha_2 [\max(0, \bar{Q}_t^{pd} - Q_t^{se})] + u_{1t} \quad (1)$$

$$\tilde{Q}_t^{ps} = \bar{Q}_t^{ps} + \beta_2 [\max(0, \bar{Q}_t^{ps} - Q_t^{de})] + u_{2t} \quad (2)$$

$$\bar{Q}_t^{pd} = X_{1t} \alpha + \alpha_1 P_t \quad (3)$$

$$\bar{Q}_t^{ps} = X_{2t} \beta + \beta_1 P_t^e \quad (4)$$

$$Q_t^{gp} = X_{3t} \gamma + \gamma_1 (P_t - P_t^f) + u_{3t} \quad (5)$$

$$Q_t^{gs} = X_{4t} \delta + \delta_1 (P_t - P_t^f) + u_{4t} \quad (6)$$

$$\tilde{Q}_t^d = \tilde{Q}_t^{pd} + Q_t^{gp} \quad (7)$$

$$\tilde{Q}_t^s = \tilde{Q}_t^{ps} + Q_t^{gs} \quad (8)$$

$$Q_t = \min(\tilde{Q}_t^d, \tilde{Q}_t^s) \quad (9)$$

$$\Delta P_t = (1/\lambda)(\tilde{Q}_t^d - \tilde{Q}_t^s) \quad (10)$$

$$P_t^e = \max[P_t^f, P_{t-1} + \theta_1 (P_{t-1} - P_{t-2})]$$

$$Risk_t = Std_{t-1} + \theta_2 (Std_{t-1} - Std_{t-2})$$

$$P_t^b = P_{t-1}^b + \theta_3 (P_{t-1}^b - P_{t-2}^b) \quad (11)$$

$$Q_t^{se} = TTP_{t-4} + \theta_4 (TTP_{t-4} - TTP_{t-8})$$

$$Q_t^{de} = TTS_{t-4} + \theta_5 (TTS_{t-4} - TTS_{t-8})$$

$$u_{it} = \rho_i u_{it-1} + \varepsilon_{it} \quad (i = 1, \dots, 4) \quad (12)$$

where, \tilde{Q}_t^{pd} and \tilde{Q}_t^{ps} are effective private demand and supply,

\bar{Q}_t^{pd} and \bar{Q}_t^{ps} are notional private demand and supply,

Q_t^{gp} and Q_t^{gs} are government (AWC) purchases and sales,

\tilde{Q}_t^d and \tilde{Q}_t^s are total effective demand and supply,

Q_t^{se} is expected available supply to private demanders,

Q_t^{de} 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_t is the standard deviation of weekly wool prices,

P_t^b is the price of beef,

TTP_t and TTS_t are total trade purchases and sales,

u_{it} ($i = 1, \dots, 4$) are AR(1) error terms,

ε_{it} ($i = 1, \dots, 4$) are i.i.d. error terms with constant variances σ_i^2 ,

X_{it} ($i = 1, \dots, 4$) 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,
 $\rho_i, \sigma_i^2, \theta_j$ ($i = 1, \dots, 4, j = 1, \dots, 5$) 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 $\bar{Q}^s < Q^{de}$ (i.e., notional supply is less than the expected demand available to private suppliers) and notional desires are expressed $\bar{Q}^s = \bar{Q}^s$. On the other hand, if suppliers expect to be rationed $\bar{Q}^s > Q^{de}$, then effective supply differs from notional supply and the difference depends upon an estimable parameter β_2 and the amount of expected rationing. The sign of β_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 λ describes the speed of adjustment, with $\lambda \rightarrow \infty$ implying infinitely slow market clearing and $\lambda = 0$ implying instantaneous adjustment and equilibrium trading.¹ 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, pp21-26, 80-83).

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. Moreover, the specification recognises that the very significant and separate buying and selling activities of the AWC also influence the behaviour of prices.

Preferred Regressors

We now turn to the specification of the preferred exogenous regressors, X_{it} ($i = 1, \dots, 4$). 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.²

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 U.S. 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, p32). 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.³

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.⁴

Specification of Expectations

A number of variables in the notional supply equation and the rationing measures in the effective schedules rely on expectations, the preferred specifications are given in equations (11). Extrapolative expectations are employed, for a discussion and other uses of this formulation see Turnovsky (1970), Sulewski, Spriggs and Schoney (1994) and Hey (1994). Given the importance of expectations for model specification considerable theorising and preliminary modelling was undertaken. Recently much effort has been devoted to specifying price expectations in the presence of a price floor through the recognition that the distribution of expected prices is truncated by the floor, see Chavas and Holt (1990) and von Massow and Weersink (1993). To implement the approach an untruncated distribution of 'free market' prices in some other sub-market unaffected by the price floor is required. This appears to be available in voluntary support programs such as U.S. corn, but is unavailable for the wool market where average prices from private sales are clearly influenced by the significantly larger auction sales which operated in the presence of the price floor.

Rational expectations models recognising truncated distributions and disequilibrium trading have also been developed, see Holt (1992). Analytically and computationally this assumption would be extremely difficult to operationalise given the complexity of our model and the extensive use of expectations for other supply regressors and expected rationing. Further, we concur with many of the well known short-comings of the rational expectations assumption, see Maddala (1990, pp31-2) and Hall (1993), and also recognise that the spirit of this assumption is at variance with the information inefficient and non-clearing markets approach of the employed disequilibrium specification.

Three other expectations assumptions were also considered in preliminary modelling but proved to be less appropriate, i.e., naive, moving average and a geometric lag. 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. This switching formulation explicitly allows the price floor scheme to influence expectations not only when the floor is expected to be binding, but also when it is not binding through the use of past actual prices which are determined by the market in the presence of previous price floors. Results indicated that short-term lags of one and two quarters were more appropriate for expected wool and beef prices than longer lags of 4 and 8 quarters, and 8 and 12 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. This is also consistent with the transactions emphasis in modelling as compared to a production emphasis where longer lags were found to be important and sheep shorn is used as the dependent variable, e.g., Malecky (1975). Further, the use of short lags for wool prices better reflects recent structural changes in the market such as the abandonment of the RPS.

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.

Finally, consider the specification of expectations for available demand and supply to private traders, i.e., Q^s and Q^d . Again extrapolative expectations appeared to be more appropriate here, however, given the significant seasonality in quantity transacted, then annual lags of 4

and 8 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.⁵ 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. It appears that this issue requires further research.

We now turn to the regressors for the activities of the AWC, X_{3t} and X_{4t} . 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.⁶

Estimation Procedures

Finally, we consider procedures for estimation. The maximum likelihood method is employed. Given the complexity of the likelihood function we shall only provide a broad overview to its derivation. The function involves the use of endogenous switching regression methods and spline smoothing techniques for the step functions. First consider the use of endogenous switching regressions and equations (9) and (10). From our data set we observe

all variables directly except for \tilde{Q}_t^{ps} and \tilde{Q}_t^{ps} , these are related to the observed Q_t and ΔP_t through equations (9) and (10) and are ultimately determined by (7) and (8). If $\Delta P_t > 0$ (and $\lambda > 0$) then excess demand exists and from equations (9) and (10) $\tilde{Q}_t^s = Q_t$ and $\tilde{Q}_t^d = Q_t + \lambda (\Delta P_t)$, and from (7) and (8) $\tilde{Q}_t^{ps} = Q_t - Q_t^{ps}$ and $\tilde{Q}_t^{pd} = Q_t + \lambda (\Delta P_t) - Q_t^{ps}$. Conversely, if $\Delta P_t < 0$ then excess supply exists and $\tilde{Q}_t^s = Q_t - \lambda (\Delta P_t) - Q_t^{ps}$ and $\tilde{Q}_t^d = Q_t - Q_t^{ps}$. Given known sample separation, we can multiply the associated two joint densities for $(Q_t, P_t, Q_t^{ps}, Q_t^{ps})$ to form the likelihood, for more details see Quandt (1988, pp 31-32).

In addition to this basic structure we must also consider the switching behaviour of the effective schedules and the P^e variable. These are deterministic switches because they involve only regressors and parameters and not error terms. Depending upon the signs of expected rationing $(\tilde{Q}_t^{ps} - Q_t^{ps})$ and $(\tilde{Q}_t^{ps} - Q_t^{ps})$, four possible combinations for the $(\tilde{Q}_t^{ps}, \tilde{Q}_t^{ps})$ pair exist. This results in four joint densities for $(Q_t, P_t, Q_t^{ps}, Q_t^{ps})$ for each sample separation $\Delta P_t > 0$ and $\Delta P_t < 0$. To permit conventional gradient optimisation of the log-likelihood function, these two deterministic step functions determining the signs of expected rationing must be replaced by some continuous approximation. We employ the Tishler and Zang (1979) spline approximation which uses a 5th degree polynomial. This approximation appears to work well in disequilibrium models, see Sneessens (1985) and Oczkowski (1990). Operationally, the approximation coefficient is initially set high to smooth out the function and then it is taken arbitrarily small to avoid any approximation error. This spline approximation is also employed for P^e in the RPS period and the deterministic switching between extrapolative expectations and the price floor.

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, i.e., equations (12). Unfortunately, this enormously complicates estimation and requires the use of techniques developed by Laffont and Monfort (1979). The likelihood must be modified to describe the complete one period lagged dynamic history of the model. In our case, all potential combinations of the signs between

$(\bar{Q}_t^{pd} - Q_t^{pe})$, $(\bar{Q}_t^{ps} - Q_t^{de})$, $(\bar{Q}_{t-1}^{pd} - Q_{t-1}^{pe})$ and $(\bar{Q}_{t-1}^{ps} - Q_{t-1}^{de})$ must be recognised for the effective schedules (16 possibilities) and combinations of the signs between ΔP_t and ΔP_{t-1} must be recognised for sample separations (4 possibilities). Combined this results in $(16)(4) = 64$ separate joint densities to make up the likelihood function.⁷

4. Results and Discussion

Estimates

Maximum likelihood estimates and associated summary statistics for the preferred specification are presented in tables 1 and 2. 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 heteroscedasticity for all equations at a 10% level of significance.⁸ The majority of parameter estimates in table 2 align with our expectations. Definite signs were not expected for all the extrapolative expectations coefficients, some of the structural change coefficients and all of the auto-regressive coefficients. The majority of estimates also appear to be reasonably precisely estimated given the relatively large t-ratios.

Table 1: Summary Statistics

| Variable | Static Simulations (Squared Correlations) | Historical Simulations (Squared Correlations) | Heteroscedasticity |
|---------------|--|--|-----------------------------------|
| AWC Purchases | 0.717 | 0.701 | $(\sigma_1^2) \chi^2(9) = 13.99$ |
| AWC Sales | 0.308 | 0.328 | $(\sigma_2^2) \chi^2(12) = 13.97$ |
| Price | 0.950 | 0.765 | $(\sigma_3^2) \chi^2(4) = 0.64$ |
| Quantity | 0.754 | 0.758 | $(\sigma_4^2) \chi^2(2) = 0.14$ |

Table 2: Parameter Estimates

| | Coefficient | T-Ratio | | Coefficient | T-Ratio |
|--|-------------|---------|--------------------------------|-------------|---------|
| <u>Demand</u> | | | <u>AWC Purchases</u> | | |
| Constant | 36.758 | 36.44 | Constant | 6.061 | 5.47 |
| Exchange Rate | -0.0625 | -4.22 | March Qrt | -2.279 | -3.57 |
| Industrial Production | 0.0681 | 2.21 | June Qrt | -2.255 | -2.93 |
| Cotton Price | 0.0260 | 3.39 | September Qrt | -1.769 | -3.00 |
| March Qrt | -2.328 | -3.63 | 91(1) Dummy | -10.024 | -5.25 |
| June Qrt | -8.058 | -11.43 | $P_t - P_t'$ | -0.0258 | -2.42 |
| September Qrt | -8.923 | -15.11 | | | |
| 87(1)-88(2) Dummy | 9.299 | 7.61 | <u>AWC Sales</u> | | |
| AWC Stocks | -0.111 | -4.33 | Constant | 1.159 | 2.85 |
| 91(2)-93(3) * Price | 0.0145 | 2.61 | March Qrt | 1.086 | 3.58 |
| Price | -0.0398 | -4.04 | 91(2)-93(4) Dummy | -5.680 | -4.28 |
| $\bar{Q}_t^{rd} - \bar{Q}_t^{re} (\alpha_2)$ | 0.543 | 2.90 | 91(2)-93(4) * Price | 0.0197 | 2.71 |
| | | | $P_t - P_t'$ | 0.0074 | 1.62 |
| <u>Supply</u> | | | | | |
| Constant | 41.488 | 39.28 | Price Adjustment (λ) | 0.0146 | 7.81 |
| Rainfall | 0.0483 | 2.03 | | | |
| Time | 0.215 | 9.25 | <u>Error Variances</u> | | |
| March Qrt | -8.110 | -8.43 | Private Demand | 16.293 | 11.02 |
| June Qrt | -10.203 | -9.70 | Private Supply | 6.324 | 7.11 |
| September Qrt | -6.790 | -5.82 | AWC Purchases | 5.011 | 4.65 |
| Input Prices | -0.302 | -9.39 | AWC Sales | 1.583 | 6.34 |
| Beef Prices | -0.0287 | -1.71 | | | |
| Risk | -0.077 | -2.49 | <u>AR(1) Coefficients</u> | | |
| 91(2)-93(3) Dummy | -28.510 | -27.35 | Private Demand | 0.154 | 1.89 |
| 91(2)-93(3) * P^e | 0.101 | 12.38 | Private Supply | -0.233 | -2.96 |
| Expected Price (P^e) | 0.0304 | 4.32 | AWC Purchases | 0.904 | 8.87 |
| $\bar{Q}_t^{rs} - \bar{Q}_t^{de} (\beta_2)$ | -0.426 | -5.25 | AWC Sales | 0.493 | 4.46 |
| | | | | | |
| <u>Expectations Coeff.</u> | | | | | |
| Price (P^e) | | | | | |
| Risk | -1.232 | -3.08 | | | |
| Beef | -0.296 | -0.71 | | | |
| Private Supply (Q_t^s) | 1.121 | 1.09 | | | |
| Private Demand (Q_t^{de}) | -0.800 | -11.69 | | | |
| | -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 α_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, pp164-166) 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 β_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.⁹

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% of the quarters and private suppliers 77.1% of the quarters. When rationing is expected, private effective demand exceeds notional demand by 8.3% on average, while private effective supply is less than notional supply by 8.5% 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.

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. 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. For both P^e and Q^e these rationales are pure conjectures.¹⁰

Elasticities

The elasticities for the key variables, from the preferred specification, are presented in table 3. 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 Wohlgenant (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, p264) [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 Sutcliffe (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, p60).

Table 3: Elasticities

| | 1976(3)-1991(1) | 1991(2)-1993(4) | 1976(3)-1993(4) |
|-----------------------|-----------------|-----------------|-----------------|
| <u>Private Demand</u> | | | |
| 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 |
| <u>Private Supply</u> | | | |
| Expected Price | 0.258 | 0.431 | 0.340 |
| Input Prices | -0.645 | -0.364 | -0.585 |
| Beef Prices | -0.060 | -0.031 | -0.054 |
| <u>Total Demand</u> | | | |
| Price | -1.021 | -0.332 | -0.971 |
| <u>Total Supply</u> | | | |
| Price | 0.357 | 0.653 | 0.472 |

Measures of Market Imbalance

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.

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% of the time with an average magnitude of 11.9%, while excess supply occurred 56% of the time with an average magnitude of 12.5%. In stark contrast, for private traders (figure 2) excess demand occurred 46% of the time with an average magnitude of 23.8%, while excess supply occurred 54% of the time with an average magnitude of 33.9%.

Simulation of RPS Removal

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 $Q^{sp} = Q^{ps} = 0$, $P^f = -\infty$ 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.

FIGURE 1: Total Market Excess Demand

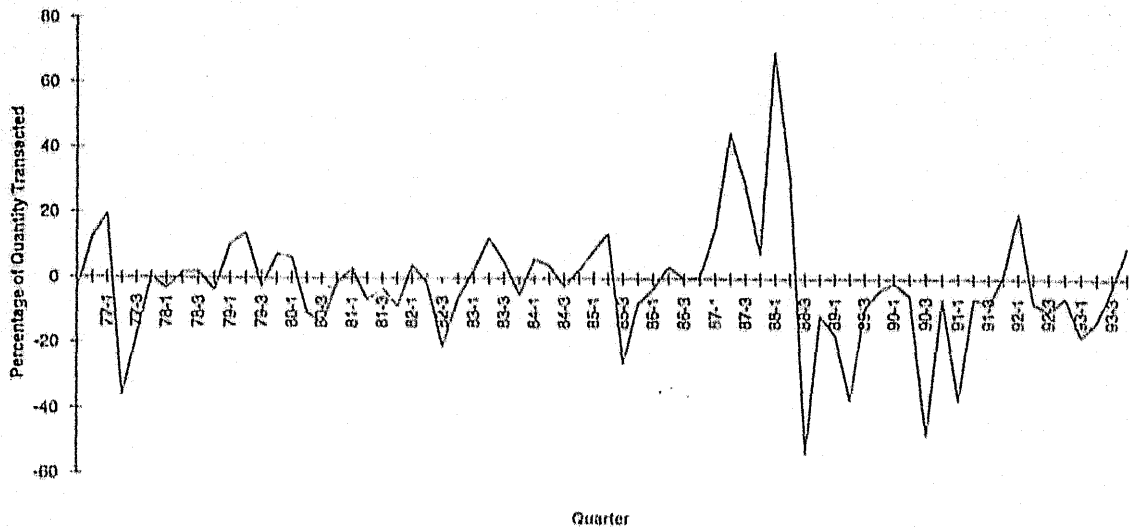
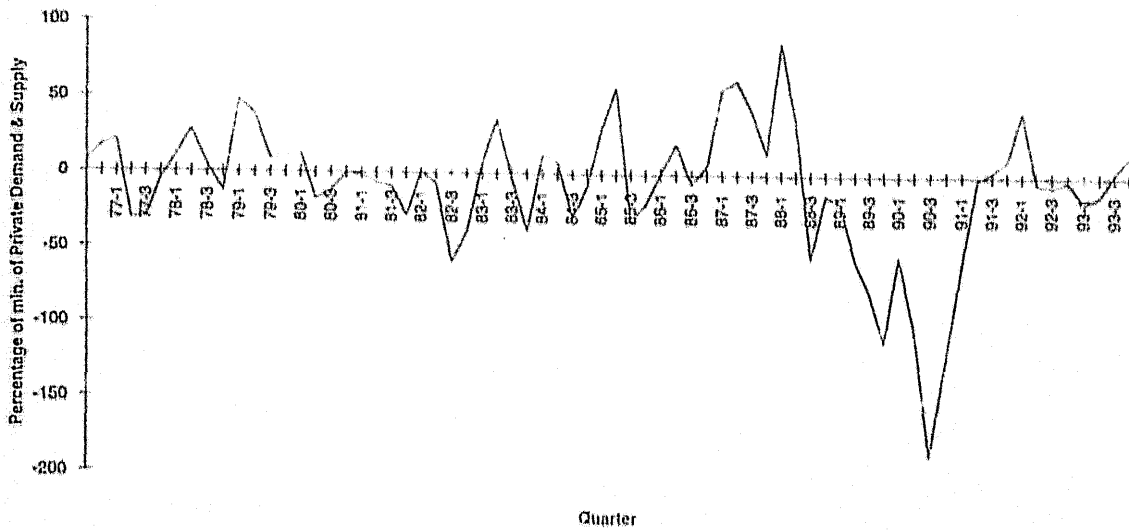


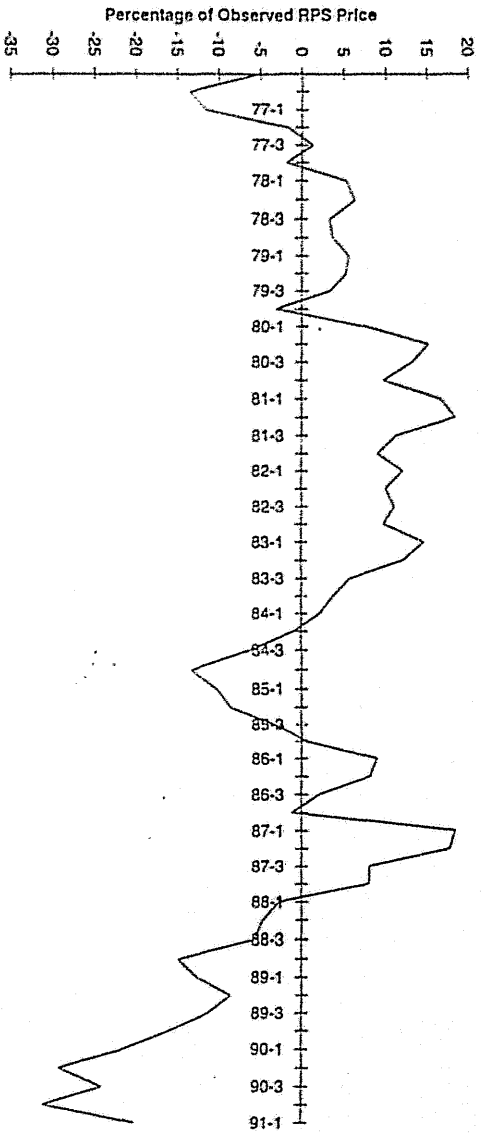
FIGURE 2: Private Market Excess Demand



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.

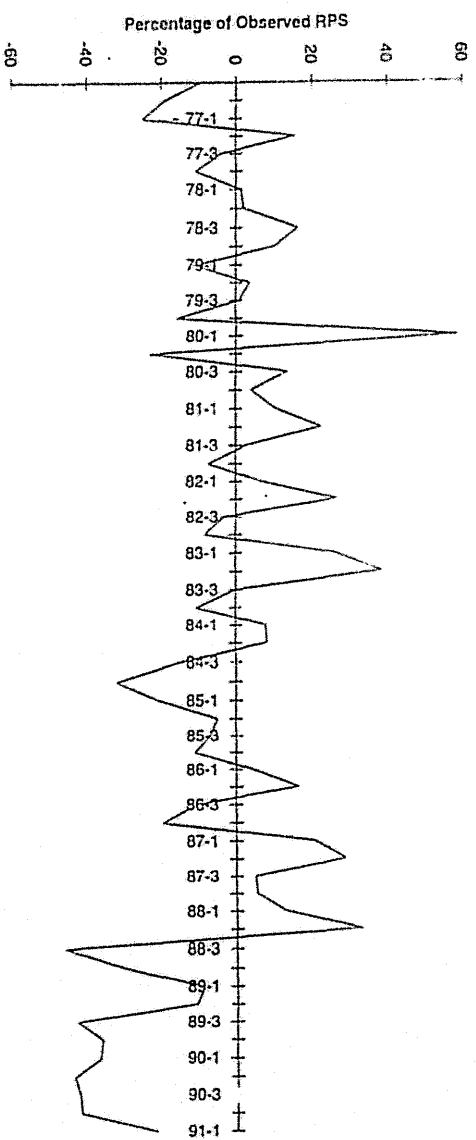
The simulation results for private suppliers' total revenue are presented in figure 4. Compared to the price effects, there is greater variability in revenue changes and less obvious systematic patterns apart from the significant revenue losses after 1983(2). The total sum of private suppliers' revenues, for the period 1976(3)-1991(1), are simulated to fall by 8.2% 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% 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.¹¹ On the other hand, part of the difference could be due to the disequilibrium modelling methodology employed in our study.

FIGURE 3 Price: Simulated Removal of RPS less Observed RPS



Quarter

FIGURE 4 Private Suppliers' Revenue: Simulated Removal of RPS less Observed RPS



Quarter

5. 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.¹² These simulation models and policies may need reworking to account for disequilibrium trading possibilities, rationing manipulation practices, and price dynamics related to market imbalances.

In conclusion, this paper further illustrates the utility of modelling using a 'markets in disequilibrium' framework. Even though the associated estimation techniques are complex, the resulting estimates provide theoretically meaningful information typically unavailable from standard analyses. 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, pp46-7). 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

For some variables listed below the time series were incomplete. In some cases extrapolation to outside the available data range was needed, while in other cases only annual data was available and distribution to quarterly data was required. For both situations we employed the BLUE technique based on related series developed by Chow and Lin (1971). For distribution this method maintains the original properties of the annual data, e.g., quarterly totals add up to annual amounts. In specifying the relevant related series seven different time trends were considered, in all cases the cubic trend proved to be most accurate. The data series for which this technique is employed are identified below. All distributions are from annual to quarterly, unless otherwise stated.

Wool Quantity Transacted (Mean = 21.80 Std = 6.02)

Greasy weight of all raw wool transactions, per 10 kts (kilotonnes). Determined as: AWC purchases + Private trade auction purchases + Transactions conducted by private dealers + AWC non-auction sales. For auction purchases and AWC non-auction sales, bales converted to greasy weight using average nett weight of bales sold. Extrapolation required for: proportion of total AWC sales at auction for 81/2, 83/4, 84/5 and 89/90. Distribution required for: proportion of total AWC sales at auction and average nett weight per bale sold (half-yearly to quarterly).

Sources: *Wool International* personal communication, ABS (1994a), NCWSBA (1994), and AWC (1993a)

Real Wool Price (Mean = 349.99 Std = 83.34)

Real AWC market indicator, cents per kg of greasy, deflated by Australian CPI (1985 prices). Simple average of weekly closing quotations. Clean based indicator converted to greasy basis using average clean yields. Distribution required for: clean yield.

Sources: AWC (1993b), WI (1994), ABARE (1994a) and ABS (1994b).

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 5 years trade (excluding the current year). Modelling with 1, 3 and 7 year export share weights was also considered. The index construction follows RBA (1988, pp21-23). For each country deflating based on consumer price indices and 1985 prices. Distribution required for: China CPI 1979-1992, Soviet Union CPI 1970-1989, Soviet Union exchange rate 1970-1991.

Sources: IMF (1995), OECD (1992), PlanEcon Inc. (1994), UN (1993), RBA (1994), ABS (1993a, 1993b, 1985)

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. Extrapolation for China and 1992, 1993. Distribution for: China 1980-1993 and Soviet Union 1971-1993.

Sources: IMF (1995), OECD (1992), PlanEcon Inc. (1994) and UN (1993)

U.S. Real Cotton Price (Mean = 85.44 Std = 30.46)

U.S. cents per lb (1985 prices). Deflated by U.S. CPI. U.K. c.i.f. price from American Memphis Territory. Average of monthly prices.

Sources: FAO (1994), RBA (1994).

AWC Wool Stocks (Mean = 24.87 Std = 25.71)

Greasy weight per 10 kts. Average of weekly closing stocks. Lagged one quarter. Bales converted to greasy weight by using average nett bale weight.

Sources: *Wool International* personal communication, NCWSBA (1994).

Total Trade Wool Purchases (Mean = 19.35 Std = 5.58)

Greasy weight per 10 kts Total quantity transacted less AWC purchases. Other details as per quantity transacted.

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. Extrapolation required for: total sheep numbers in zones 1977/8, 84/5 and 85/6. Distribution required for: total sheep numbers in each zone 1975-1993.

Sources: *Bureau of Meteorology* National Climate Centre, ABARE (1993), BAE (1985)

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.

Sources: ABARE (1994b), ABS (1994b)

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.

Sources: ABARE (1994b), ABS (1994b).

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. Other details as for the real wool price.

Total Trade Wool Sales (Mean = 20.05 Std = 6.00)

Greasy weight per 10 kts. Total quantity transacted less AWC sales. Other details as per quantity transacted.

Other Variables

AWC Purchases (Mean = 2.91 Std = 4.01 for RPS period only)

Greasy weight per 10 kts. Other details as per quantity transacted.

AWC Sales (Mean = 1.75 Std = 1.54)

Greasy weight per 10 kts. Other details as per quantity transacted.

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.

Sources: AWC (1993b), WI (1994), ABARE (1994a) and ABS (1994b).

Endnotes

1. 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 (1988, p23), the asymmetry proved to be unimportant.
2. For a full description of the variables used, their lags, weights, constructions and sources see the data appendix.
3. Other variables unsuccessfully tried in the demand equation included: the clean wool yield; Japanese textile prices which were highly correlated with the U.S. 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.
4. 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).
5. In this example for Q^{pr} , previous private purchases are inappropriate as such purchases are made from both private sellers and the AWC.
6. For the non-RPS period, equation (5) for Q^{wp} does not exist and $P^J = 0$ for equation (6) and Q^{rs} .

7. 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.

8. The heteroscedasticity 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.

9. 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.

10. 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% of the RPS quarters.

11. When the 1988(3)-1991(1) period is excluded from our calculations, there is a 0.3% 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.

12. 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.

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