ABARE CONFERENCE PAPER 99.6

Modeling crop area allocations in Australian broadacre agriculture

Intizar Hussain, Alvin Liaw and Ahmed Hafi

Combined 43rd Annual Australian and 6th Annual New Zealand
Agricultural and Resource Economics Society Conference
Christchurch, New Zealand, 20–22 January 1999

A model for forecasting changes in crop areas in response to changes in output prices in Australian broadacre agriculture is outlined in this paper. The crop–livestock interactions and substitution and complementary relationships among crops are modeled as a set of land allocation decisions made simultaneously but at a number of hierarchical stages.

The model developed here is broader in scope than previous models of crop area response in Australian broadacre agriculture in terms of crop coverage. The method employed takes specific account of lagged relationships and producer expectations for prices. In the model, area allocation decisions at the aggregate level are also affected by rainfall. The specified equations are estimated employing the seemingly unrelated regression procedure, over the period 1974-75 to 1995-96 using annual data at the national level. The model is then validated by simulating it over historical and forecast periods. The preliminary results suggest that the model is capable of generating plausible estimates of crop area response.

This work is part of ABARE's
work in progress on commodity model development.

ABARE project 1553

ABARE
Innovation in Economic Research

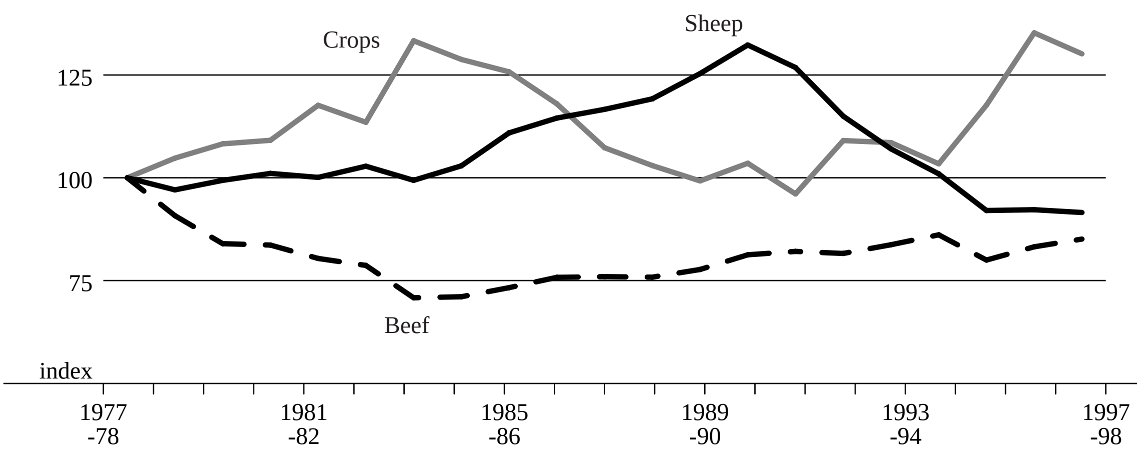
GPO Box 1563 Canberra 2601 Australia
Telephone +61 2 6272 2000 • Facsimile +61 2 6272 2001
or visit our home page at www.abare.gov.au

Introduction and background

Australia's large expanse of farmland has led to the development of what is known as 'broadacre agriculture'. Production alternatives for Australian broadacre industries are generally classified into three major categories — cattle, sheep/wool and cropping. The aggregate area devoted to cropping and improved pasture has expanded significantly over the past three decades, from 41 million hectares in 1970 to 48 million hectares in 1993. However, this expansion has not been uniform across all the broadacre enterprises. The total area planted to crops increased from 13 million hectares in 1970 to a peak level of 22 million hectares in 1983, fell continuously to 16 million hectares in 1991, and has trended upward to reach the 1983 peak level again in 1996. Livestock numbers, on the other hand, have shown trends opposite to that of crops, particularly after 1983, reflecting substitution possibilities between crop and livestock production (figure 1).

Figure 1: **Indexes of Australian crop areas and livestock numbers**

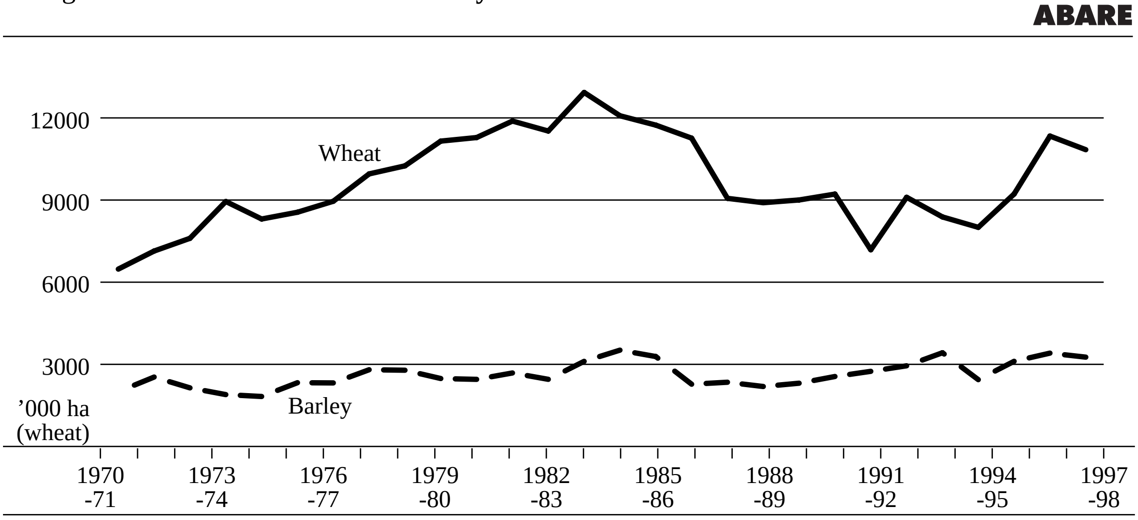
ABARE



Over the past two and a half decades Australian broadacre cropping industries have become much more diversified. While wheat and barley still remain the dominant crops (with areas averaging 9.4 million hectares and 2.4 million hectares respectively in the five years to 1997-98 — figure 2), the area planted to oilseeds (mainly canola) and pulses (mainly lupins) has increased significantly. This has mainly reflected favorable prices and the recognition of the important role of oilseeds and pulses in crop rotations through their capacity to improve soil structure and provide a break in cereal disease cycles (Martin et al. 1998).

The aggregate expansion in cultivated area and the changes in cropping patterns since the mid 1970s leads to the questions of whether the estimates of area planted responses based on earlier or mixed data series are currently valid and whether forecasts of future area trends based on these estimates are likely to be biased. The major objective in this study is to provide updates of estimates of crop area responses in the Australian broadacre

Figure 2: **Australian wheat and barley areas**



agriculture and to develop an area forecasting model, using time series data from the mid-1970s.

Modeling approaches and previous studies

There are a number of alternative approaches to estimating supply response. These approaches may be broadly classified into two categories — structural and reduced form approaches.

Structural form approaches involve estimating a system of output supplies and factor demand equations such as production or profit function approaches. The system of supply equations in these approaches needs to satisfy various restrictions such as homogeneity, symmetry, monotonicity and convexity of the underlying profit function. These approaches are theoretically attractive in terms of economic rigor, but are demanding in data and are analytically complex. For applications of these approaches to model Australian broadacre supply response, see McKay, Lawrence and Vlastuin (1983); Wall and Fisher (1987); Hall, Fraser and Purtill (1988); Lawrence and Zeitsch (1989); Fisher and Wall (1990); Low and Hinchy (1990); and Kokic, Beare, Topp and Tulpulé (1993).

Reduced form approaches involve direct estimation of supply response such as direct specification of supply equations as unknown functions of variables selected on the basis of economic theory. These latter approaches are practically appealing as they are less complex and relatively less demanding of data. Moreover, adjustments and expectation formulations are explicitly considered in these approaches.

Crop production decisions in area responses are generally modeled using the approaches in the reduced form category. Most previous area response studies have estimated response functions separately for individual crops using a Nerlovian framework of partial adjustment and adaptive expectations (Nerlove 1956; Askari and Cummings 1977). Binkley and McKinzie (1984) criticised the single equation approach, arguing that crop area response analyses in a multiuse context can provide much more information about interactions among a set of uses and the results from an individual equation could be potentially deceptive. The system approach was further extended by Krakar and Paddock (1985) and Bewley, Young and Colman (1987) who used a multinomial logit approach in studying the allocation of fixed resources between alternative uses. More recently, Coyle (1993) developed an approach where he modeled a system of crop area demands (in western Canada) as conditional on total crop area planted and used separability and dynamic specifications to reduce the effects of multicollinearity in the system.

In Australia, numerous studies are available on estimating crop area responses. However, the majority of these are either regionally focused or analyse an individual crop. Coelli (1992) provides a brief review of most of these studies. There are very few studies analysing area responses for multiple crops, the most notable being Foster and Dewbre (1983), Dewbre, Shaw, Corra and Harris (1985) and Gunasekera et al. (1992). These latter studies cover only a few major crops and the estimates of parameters in these studies are based on data series going back to the 1950s which, as mentioned earlier, raises questions on the current validity of these estimates. The present study, in addition to updating parameter estimates, attempts to develop a model to improve on the framework, level of disaggregation and crop coverage of previous crop area response models.

The model

Theoretical framework

Consider a farm with fixed amount of land *L* that can be allocated among m alternative uses, so that

(1) $$\ell^1 + \ell^2 + \ell^3 + \ldots + \ell^m \leq L$$

or $$\sum_{i=1}^{m} \ell^i \leq L$$

Assuming profit maximising and price taking producers, the objective function of a producer is to maximise profit from alternative enterprises. Thus a producer’s decision problem is to

(2) $$\max \sum_{i=1}^{m} p^i y^i - \sum_{j=1}^{n} c^j x^j$$
$$\text{s.t.} \sum_{i=1}^{m} \ell^i \leq L \quad \text{and } y \geq 0;\ x \geq 0;\ \ell \geq 0$$

where $y = (y^1, ..., y^m)$ and $p = (p^1, ..., p^m)$ are vectors of outputs and prices for m enterprises, $x = (x^1, ..., x^n)$ and $c = (c^1, ..., c^n)$ are vectors of variable input quantities and input prices for n inputs, $l = (l^1, ..., l^m)$ is a vector of area planted allocations to m alternative uses.

Following Coyle (1993), the farm's dual profit function conditional on area allocation vector l may be written as

(3) $$\pi = \pi(p, c, K, l)$$

where K is the level of quasifixed capital inputs.

Recent developments in the duality theory suggest that crop area demands can be incorporated into duality models of multicrop output supplies and input demands. The multioutput profit function, using output specific profit functions conditional on area allocation vector l, can be obtained as

(4) $$\pi = \pi(p,c,K,L) = max\left(\sum_{i=1}^{m} \pi^i\left(p^i, c, k, l^i\right) \ \ s.t. \ \sum_{i=1}^{m} l^i \leq L\right)$$

with standard first-order conditions for an interior solution

(5) $$\partial\pi\left(p,c,K,l^*\right)/\partial l^i = \partial\pi\left(p,c,K,l^*\right)/\partial l^j \qquad i,j = 1, \ldots, m$$

(for details see Chambers and Just 1989; Paris 1989; Coyle 1993).

Expression (5) implies that optimal allocation of land is determined by equating its shadow prices between alternative enterprises. Output supply and variable input demand equations conditional on land allocation vector are obtained by Hotelling's lemma and crop area demands are implied by (5). Paris (1989) has demonstrated that land allocation vector l can be recovered explicitly from the multioutput profit function using the concept of purified profit function (imputed profit obtained by netting out the imputed cost of the fixed input). Coyle (1993) proved that the multioutput technology can be recovered from the profit function $\pi(p, c, l)$, thus establishing the duality between the two.

The crop area demand functions implied by the above theoretical general models may be written as

(6) $$l^i = f(p, c, k, L) \qquad i = 1,2, \ldots, m$$

Equation (6) indicates that each area demand is a function of prices of all outputs, prices of all variable inputs, level of quasifixed capital and total available land.

Empirical considerations

Since area demand for each enterprise depends, in principle, on the prices of all outputs and inputs and, given the fact that much of Australian broadacre land is used for a large number of crop and noncrop outputs, the multicollinearity between price variables and the problem of degrees of freedom are quite obvious. However, these problems may be reduced by assuming a multistage allocation process, where decisions on area planted are viewed as a sequence of hierarchical allocation stages. This allocation process is generally similar to the consumer budget allocation process. The producers are assumed to adopt this allocation process in order to simplify their decision making for allocating their total area planted.

The hierarchical structure of the model is presented in figure 3. Each stage in this structure represents an area allocation to a group of enterprises. In this framework, it is assumed that the total available land, at the most aggregate level, is first allocated between crops and livestock groups. Given this allocation, the total crop land is allocated between winter and summer crops at the second level. At the next level, winter and summer land is allocated among winter and summer cereals, oilseeds and pulses. At the bottom level, land in these aggregate categories is allocated to individual crops. Area demand equations in a group are dependent on total area allocation to the group determined in a group immediately above the group under consideration. The conditional area demand equations in a group then may be specified as functions of prices of outputs and inputs for the group and the total area allocated to that group. The prices of outputs outside the group enter the conditional area demand equations in the group only through their effect on the total area allocated to that group. This restriction to simplify the model is similar to the assumption of weak separability between groups of commodities in consumer theory.[1] The broad structure of the model, though similar, is more disaggregated and includes more crops than that of the crops supply module in ABARE's EMABA model of broadacre agriculture (Dewbre 1983).

Related issues

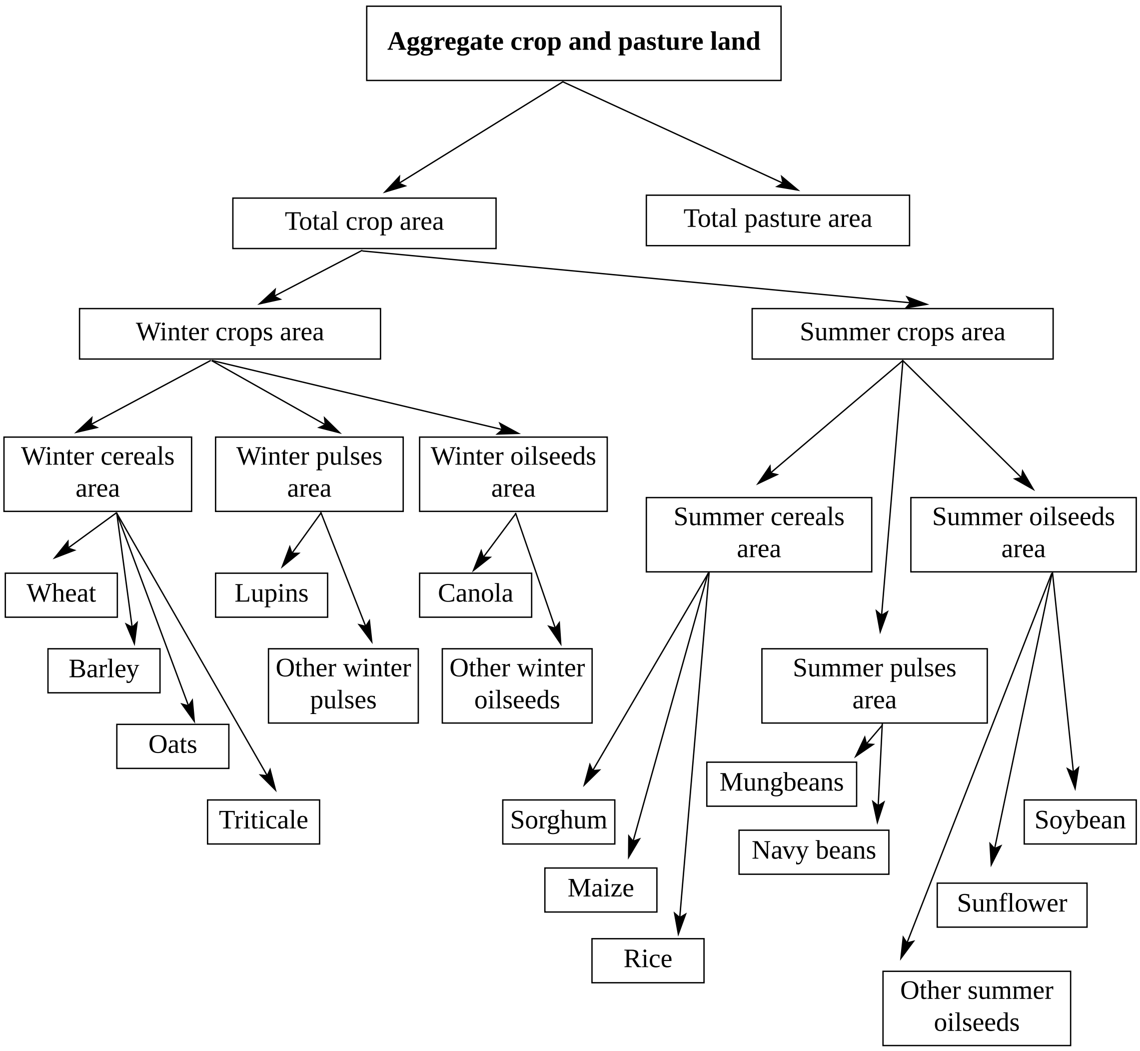
Studies in estimating crop area response models generally raise three important issues in specifying response equations: adjustment lags, producer price expectations and technological changes.

• *Adjustment lags*

Previous area response research suggests that producers may follow a partial adjustment process in moving into or out of enterprises in response to economic conditions. The reasons generally advanced for a partial adjustment hypothesis include 'asset fixity', and

1 Coyle (1993) assumed weak separability between crops and livestock to simplify the model structure, stating that this restriction is necessary and sufficient for stage 2 of a two stage procedure where total land is budgeted between crops and livestock in stage 1.

Figure 3: **Schematic representation of the area allocation model**



agronomic factors such as crop rotations. In the context of a single crop area equation in a partial framework, researchers generally use the lagged endogenous variable to incorporate dynamics into the analysis. However, in a system of crop area equations, Coyle (1993, p. 60) indicated that individual crop area demands depend on lags in adjustment in overall crop rotations and suggested the use of the lag of the total land allocated to the group of enterprises. He pointed out that 'given that some crops may be substituted into rotations more easily than other crops, the rate of change in total crop acreage may have different impacts on different acreage allocations'.

In this paper we have included the dynamic considerations mainly through the use of lagged area allocated to the group of enterprises. However, in sorghum and maize area equations the lagged endogenous variable was used to account for the adjustment process as the lagged summer cereal area yielded poor results. This may not be surprising since these crops normally do not compete with other summer cereals such as rice grown on irrigated lands. Lag of summer crops area was included in the winter crops area equation with the view that an increase in summer plantings in one year could reduce winter plantings the following year, particularly in the regions where opportunities for double cropping are limited.

• *Producer price expectations*

Because of a significant time lag between the decision to sow a crop and the actual realisation of output, producers are likely to base their planting decisions on prices they expect to prevail at the harvest time. Expected prices are not usually observed and little is known of how producers form price expectations. As a result, proxy measures representing producer price expectations are used in area response analysis.

It is generally argued that failure to adequately represent price expectations in supply response models can lead to seriously biased response estimates (Sulewski, Spriggs and Schoney 1994). Typically, area response studies have used price expectation formulations based on past prices. Most commonly used formulations of producer price expectations include naïve expectations, moving averages, autoregressive expectation formulations, adaptive expectation models and futures prices (for details of these expectation formulations, see Sulewski et al. 1994). However, as Shideed and White (1989) note, there is no a priori method to identify a superior specification for price expectations. Furthermore there is little agreement among researchers on superiority of any specification in the empirical work.

This study employed naïve expectations, except for aggregate winter cereals and oilseeds categories where two year moving averages were used.[2]

• *Technological changes*

Advances in technology, such as development of new crop varieties or improvements in production practices and equipment, could influence changes in crop areas. The specific technological changes were not included in the model. However, a trend variable was included in estimating the equations to capture general changes in technology or any other systematic effects.

2 Various models of price expectations (including autoregressive models) were considered for comparison purposes. However, the results based on naïve expectations were generally better than those from other specifications. Perfect price expectation formulations were also specified in estimating equations (where producers were assumed to have perfect knowledge of prices prevailing at harvest time, i.e. $P^e_t = P_t$) but results obtained were not any better than the results with naïve expectations.

Equations

The system of behavioral equations corresponding to the assumed structure in figure 3 may be written in the general form as:

Top level – total crop and pasture area allocations

$$\ell^{Cr} = f\,(P^e_{Cr}, P^e_{bf}, P^e_{wl}, P^e_{i}, K_t, L_t, \ell^{Cr}_{t-1}, R_t, T)^{3}$$

$$\ell^{Pa} = L_t - \ell^{Cr}$$

Second level – winter and summer crop area allocations

$$\ell^{Wi} = f\,(P^e_{Wi}, P^e_{Su}, P^e_{i}, K_t, \ell^{Cr}, \ell^{Su}_{t-1}, R_t, T)$$

$$\ell^{Su} = \ell^{Cr} - \ell^{Wi}$$

Third level 1 – winter cereals, oilseeds and pulses area allocations

$$\ell^{Wcer} = f\,(P^e_{Wcer}, P^e_{Woil}, P^e_{Wpul}, P^e_{i}, K_t, \ell^{Wi}, \ell^{Wi}_{t-1}, R_t, T)$$

$$\ell^{Woil} = f\,(P^e_{Wcer}, P^e_{Woil}, P^e_{Wpul}, P^e_{i}, K_t, \ell^{Wi}, \ell^{Wi}_{t-1}, R_t, T)$$

$$\ell^{Wpul} = \ell^{Wi} - \ell^{Wcer} - \ell^{Woil}$$

Fourth level 1 – wheat, barley, oats and triticale area allocations

$$\ell^{Whe} = f\,(P^e_{Whe}, P^e_{Bar}, P^e_{Oats}, P^e_{Trit}, P^e_{i}, K_t, \ell^{Wcer}, \ell^{Wcer}_{t-1}, T)$$

$$\ell^{Bar} = f\,(P^e_{Whe}, P^e_{Bar}, P^e_{Oats}, P^e_{Trit}, P^e_{i}, K_t, \ell^{Wcer}, \ell^{Wcer}_{t-1}, T)$$

$$\ell^{Oat} = f\,(P^e_{Whe}, P^e_{Bar}, P^e_{Oats}, P^e_{Trit}, P^e_{i}, K_t, \ell^{Wcer}, \ell^{Wcer}_{t-1}, T)$$

$$\ell^{Trit} = \ell^{Wcer} - \ell^{Wher} - \ell^{Bar} - \ell^{Oat}$$

Fourth level 2 – canola and other winter oilseeds area allocations

$$\ell^{Can} = f\,(P^e_{Can}, P^e_{Oth\ woil}, P^e_{i}, K_t, \ell^{Woil}, \ell^{Woil}_{t-1}, T)$$

$$\ell^{Oth\ woil} = \ell^{Woil} - \ell^{Can}$$

Fourth level 3 – lupins and other winter pulses area allocations

$$\ell^{Lup} = f\,(P^e_{Lup}, P^e_{Oth\ pul}, P^e_{i}, K_t, \ell^{Wcer}_{t-1}, \ell^{Lup}_{t-1}, T)$$

$$\ell^{Oth\ pul} = \ell^{Wpul} - \ell^{Lup}$$

3 L_t was not included in estimating equations due to the unavailability of a complete series for this variable.

Similarly, equations were formulated for summer crops:

Third level 2 – summer cereals, oilseeds and pulses area allocations

$$\ell^{Scer} = f(P^e_{Scer}, P^e_{Soil}, P^e_{Spul}, P^e_i, K_t, \ell^{Su}, \ell^{Su}_{t-1}, R_t, T)$$

$$\ell^{Soil} = f(P^e_{Scer}, P^e_{Soil}, P^e_{Spul}, P^e_i, K_t, \ell^{Su}, \ell^{Su}_{t-1}, R_t, T)$$

$$\ell^{Spul} = \ell^{Su} - \ell^{Scer} - \ell^{Soil}$$

Fourth level 4 – sorghum, maize and other summer cereal area allocations

$$\ell^{So} = f(P^e_{So}, P^e_{Ma}, P^e_{i,}, K_t, \ell^{Scer}, \ell^{Scer}_{t-1,}, T)$$

$$\ell^{Ma} = f(P^e_{So}, P^e_{Ma}, P^e_{i,,}, K_{t,}, \ell^{Scer}, \ell^{Scer}_{t-1,}, T)$$

$$\ell^{Oth\ scer} = \ell^{Scer} - \ell^{So} - \ell^{Ma}$$

Fourth level 5 – soybean, sunflower and cotton area allocations

$$\ell^{Sb} = f(P^e_{Sb}, P^e_{Sf,}, P^e_{Oth\ soil}, P^e_{i,}, K_{t,}, \ell^{Soil}, \ell^{Soil}_{t-1}, T)$$

$$\ell^{Sf} = f(P^e_{Sb}, P^e_{Sf,}, P^e_{Oth\ soil}, P^e_{i,}, K_t, \ell^{Soil}, \ell^{Soil}_{t-1}, T)$$

$$\ell^{Oth\ soil} = \ell^{Soil} - \ell^{Sb} - \ell^{Sf}$$

where

ℓ	=	area planted in thousand hectares
Cr	=	total crop
Pa	=	total pasture
Wi	=	winter
Su	=	summer
Wcer	=	winter cereals
Woil	=	winter oilseeds
Wpul	=	winter pulses
Scer	=	summer cereals
Soil	=	summer oilseeds
Spul	=	summer pulses
Whe	=	wheat
Bar	=	barley
Oats	=	oats
Trit	=	triticale
Can	=	canola
Oth woil	=	other winter oilseeds
Lup	=	lupins
Oth pul	=	other winter pulses

Oth scer	=	other summer cereals
So	=	sorghum area
Ma	=	maize area
Ri	=	rice
Sb	=	soybean
Sf	=	sunflower
Co	=	cotton
Oth soil	=	other summer oilseeds
L	=	total agricultural land
bf	=	beef/cattle
wl	=	wool/sheep
Pe	=	expected price/price index (in $A/tonne)
R	=	area weighted rainfall index
i	=	input
K	=	level of quasifixed inputs
T	=	time trend
t	=	current period
t-1	=	one period lag

Data and variables

The area response equations were estimated over the period 1974-75 to 1995-96 at the national level. Data on crop areas, and unit gross values of production for 22 crops were obtained from the Australian Bureau of Statistics (ABS). Weighted average annual wool, sheep, and beef prices were sourced from the ABARE publication, *Australian Commodity Statistics* (ACS). Bureau of Meteorology monthly rainfall data were taken from the ABARE corporate database.

The crops included in this model are wheat, barley, oats, triticale, lupins, canola, sorghum, maize, soybean, sunflower, cotton, rice, linseed, safflower, field peas, chickpeas, faba beans, vetch, lentils, mung beans, navy beans and peanuts. Price was defined as the unit gross value of production. Crop price indexes for aggregate crop categories were defined as:

$$CRPI_c = \sum_i W_{ic} * P_{ic}$$

where $CRPI_c$ is the crop price index for crop category c, W_{ic} is the area share (weight) of crop i in category c and P_{ic} is the price of crop i in category c. For some crops, data on areas or prices were not available for the entire study period. These crops were included in the indexes only for the years for which consistent time series were available.

Area response functions were assumed to be homogeneous of degree zero. Prices (price indexes) of inputs, appearing in each equation, were used to deflate all output prices and price indexes, except those for wool and beef. Input price indexes were basically the indexes of prices paid by farmers published in various issues of ABARE's *Australian Commodities*. The inputs included in the construction of these indexes were fertilisers, chemicals, fuel and lubricants, electricity and maintenance. Wool and beef prices were deflated by a general input price index which, in addition to the above inputs, also included seed, fodder and livestock components.

Area weighted rainfall indexes (AWRI) for crop categories were constructed to account for weather variability influencing crop planting decisions. Since the rainfall regions as defined by the Bureau of Meteorology do not correspond to the ABS cropping districts, there was a need to identify Bureau of Meteorology regions that can be taken as representative of selected ABS cropping districts in Australia. Seventeen representative Bureau of Meteorology regions were identified with ABS cropping districts in New South Wales, Victoria, Queensland, South Australia and Western Australia. Monthly rainfall in each of these regions was taken as indicative for a number of ABS cropping districts. For example, rainfall in Bureau of Meteorology region 53 in New South Wales was taken as indicative for the ABS cropping districts 10, 25 and 35. The area proportion of each crop was obtained from the ABS electronic database for each district in Australia. The monthly area weighted rainfall indexes for crop categories at the national level were defined as:

$$AWRI = \sum_i \sum_j W_{ij} * R_j$$

where i represents a number of crops in a category (for example, winter cereals category comprises of wheat, barley, oats and triticale, so $i = 1,..., 4$ for this category); j represents Bureau of Meteorology region ($j = 1, \ldots, 17$); W_{ij} is the proportion of national area of crop i in region j, and R_j is rainfall in region j. Thus, AWRI is the area weighted rainfall index for a crop category. The indexes were calculated separately for winter and summer crop categories. Although planting times within a season vary across regions, most winter and summer crops are planted during April–June and October–December respectively. Average of AWRIs, calculated for each of these months, were used for respective crop categories.

Estimation and results

The model was specified as a linear system of area response equations. Of course, it is desirable to estimate the entire system using the full information techniques such as Full Information Maximum Likelihood (FIML) or Three Stage Least Square (3SLS). However, these techniques require larger sample size as the number of observations must exceed the sum of the number of exogenous and endogenous variables in the system. The limited sample used in this study did not allow full information approaches.

Given the size and the structure of the model in this paper and the available sample size, the model was partitioned into submodels (each representing area allocation at a particular level in figure 3). Each submodel was estimated separately using the Seemingly Unrelated Regressions (SUR) technique. This method takes account of cross-equation correlation, which may be due to variables omitted from the equations. The assumed structure of area allocation model requires that one crop/crop category in each group be determined residually. The crop/crop category in each group with a least share in total area allocated to that group was chosen to be determined residually.

The estimated coefficients of the specified submodels for aggregate crop categories as well as for individual crops are available from the authors. Overall, the specified equations explain a high proportion of historical variation in the dependent variable. Generally, no evidence of significant serial correlation was found, though the Durbin-Watson (DW) statistic was in the indecision zone at the 5 per cent level of significance for some equations (with most of them close to the upper limit). All own-price coefficients have positive signs and cross-price coefficients (except the winter pulses price coefficient in winter cereals and oilseeds area equations, the winter cereal price coefficient in winter oilseeds area equations and the triticale price coefficient in the barley area equation) are negative and are consistent with economic theory. The positive relationship between winter pulses price and winter cereals and oilseeds areas may reflect crop rotation requirements in land management. Generally, the coefficients of time trend are negative for cereals (except barley and maize) and positive for winter oilseeds. This may reflect that management practices and technology for winter oilseeds, especially canola, have improved over time relative to cereals.

Model simulation and evaluation

Using the estimated coefficients, each of the submodels was simulated separately to generate historical and 'out of sample' forecasts.[4] Results of some of these simulations are presented below. As can be seen from figure 4, most of these submodels appear to perform well, especially in terms of reproducing the turning points, not only in the historical period but also in the two year out of sample period, when simulated separately.

These submodels were then combined in a full model which consisted of 22 equations. The full system was simulated to generate dynamic historical and ex post forecasts. The performance of the model is depicted in figure 5. The results from the full model were evaluated using *root–mean–square (rms) per cent* simulation error, *Theil's inequality coefficient,* and comparisons of the actual and predicted average values. The results for the main variables from the simulation model are presented in tables 1 and 2. Overall the model performance seems satisfactory in dynamic simulations at forecasting the most important endogenous variables within and out of sample.

4 In the out of sample period — that is, 1996-97 and 1997-98 — model results were only compared with the preliminary ABS estimates of crop areas as final estimates were not yet available for these two years.

Figure 4: **Within sample and out of sample (1996-97 and 1997-98) simulations of submodels**

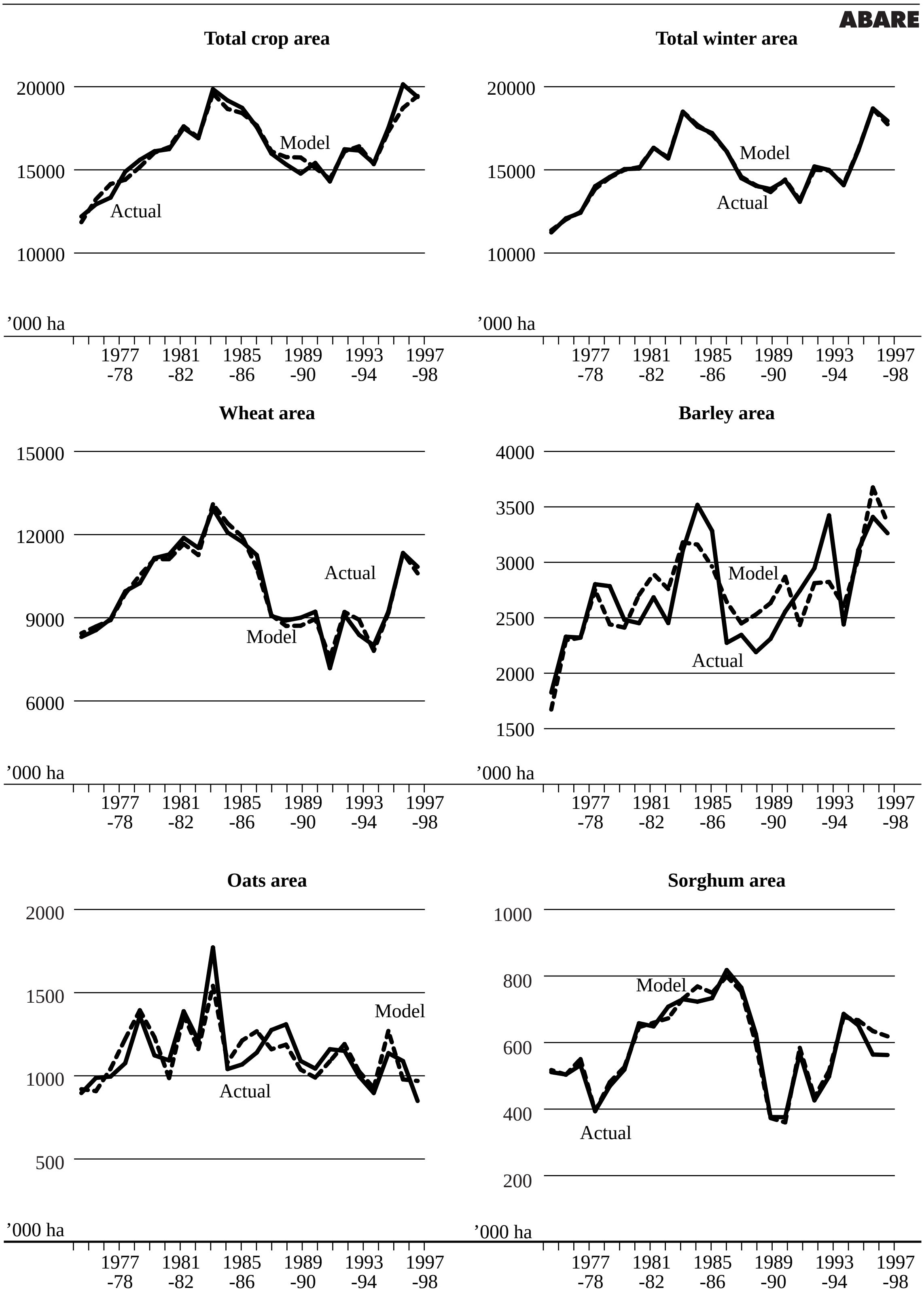
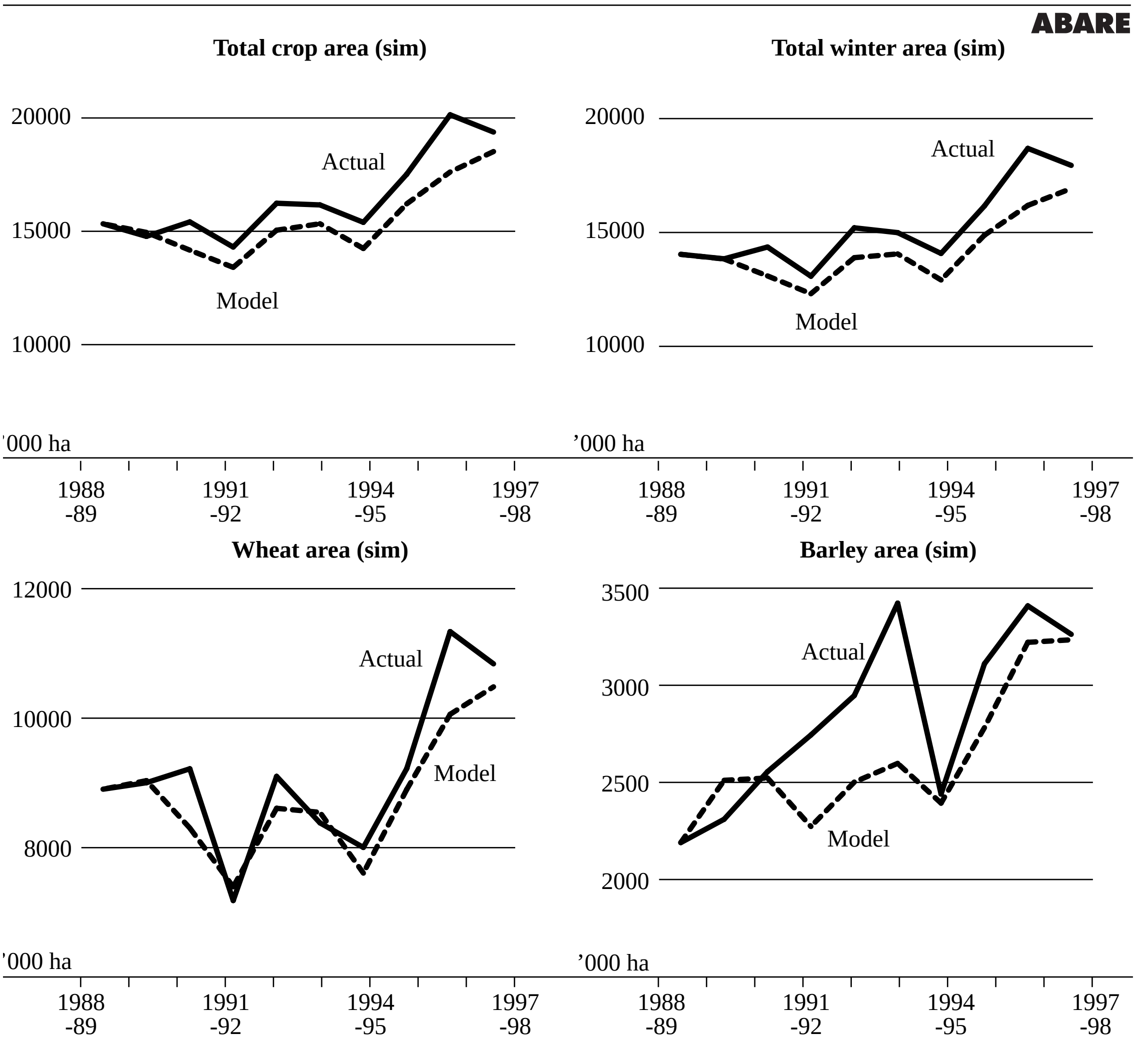


Figure 5: **Within sample and out of sample (1996-97 and 1997-98) simulations of full model**



Elasticities and comparisons

Estimates of the short run elasticities of crop areas with respect to prices are presented in table 3. These estimates were obtained using a simulation experiment with the area allocation model. All own-price elasticities are positive and less than one, with the most price responsive crop being canola. The estimates of short run cross-price effects between livestock (wool and beef) and winter crops (except canola and lupins) suggest substitution relationships among these enterprises. However, livestock prices seem to have a very weak or no impact on summer crop areas planted. Canola and other winter crops appear to have a substitution relationship. Prices of all major winter crops are found to have no impact on lupins area in the short run. Also, the own-price elasticity of lupins area is the smallest among all winter crop areas own-price elasticity estimates. This may be expected because lupins are grown mainly for crop rotations. For winter cereals, estimates of cross-price effects suggest substitution relationships among these crops. Similarly, sorghum and maize are found to have competing relationships with summer oilseeds.

Table 1: **Historical simulations results – sample period 1989-90 to 1995-96**

	Criteria			
Equation	**RMS error**	**U (Theil)**	**Actual average**	**Predicted average**
	%		’000 ha	’000 ha
Total crop area	5	0.01	15 687	15 985
Total winter area	5	0.01	14 532	14 234
Winter cereal area	7	0.01	12 577	12 255
Winter pulses area	7	0.01	1 729	1 764
Wheat area	6	0.01	8 587	8 387
Barley area	11	0.03	2 790	2 642
Oats area	11	0.02	1 067	1 107
Canola	63	0.05	184	202

Table 2: **Out of sample simulations results – sample period 1996-97 to 1997-98**

	Criteria			
Equation	**RMS error**	**U (Theil)**	**Actual average**	**Predicted average**
	%		’000 ha	’000 ha
Total crop area	1	0.01	19 759	19 530
Total winter area	3	0.02	18 319	17 542
Winter cereal area	2	0.01	15 698	15 253
Winter pulses area	4	0.03	2 024	1 909
Wheat area	3	0.03	11 088	10 668
Barley area	0	0.00	3 336	3 321
Oats area	11	0.06	969	1 083
Canola	21	0.19	553	380

Table 3: **Estimates of the short run elasticities of crop areas with respect to price – this study a**

	1 per cent change in price										
Area	**Wheat**	**Barley**	**Oats**	**Canola**	**Lupins**	**Sorghum**	**Maize**	**Soy-bean**	**Sun-flower**	**Beef**	**Wool**
	%	%	%	%	%	%	%	%	%	%	%
Wheat	**0.34**	–0.07	–0.01	–0.01	0.03	0.02	0.00	0.00	0.01	–0.07	–0.09
Barley	–0.01	**0.20**	–0.14	–0.01	0.02	0.01	0.00	0.00	0.01	–0.06	–0.07
Oats	–0.02	–0.38	**0.42**	–0.01	0.03	0.01	0.00	0.00	0.01	–0.06	–0.08
Canola	–0.30	–0.07	–0.03	**0.78**	–0.01	–0.01	0.00	0.00	–0.01	0.04	0.06
Lupins	0.00	0.00	0.00	0.00	**0.13**	0.00	0.00	0.00	0.00	0.00	0.00
Sorghum	–0.07	–0.02	0.00	0.00	–0.01	**0.36**	–0.01	–0.02	–0.07	0.00	–0.01
Maize	–0.03	–0.01	0.00	0.00	0.00	–0.08	**0.11**	–0.01	–0.03	0.00	0.00
Soybean	–0.04	–0.01	0.00	0.00	–0.01	–0.22	–0.02	**0.57**	0.31	0.00	0.00
Sunflower	–0.09	–0.03	0.00	0.00	–0.01	–0.44	–0.04	–0.04	**0.25**	–0.01	–0.01

a This table reports short run elasticities only for individual crops. However, a complete set of both short run and long run elasticities estimated in this study, including those for aggregate crop categories, may be obtained from the authors.

Table 4: **Estimates of the short run elasticities of crops area with respect to price – Foster and Dewbre (1983)** Data period 1957 to 1980

	1 per cent change in price					
Area	Wheat	Barley	Oats	Winter oilseeds	Sorghum	Summer oilseeds
	%	%	%	%	%	%
Wheat	**0.34**	–0.14	–0.07	–0.01	–0.01	–0.01
Barley	–0.54	**0.69**	–0.01	–0.01	–0.01	–0.01
Oats	–0.52	–0.11	**0.69**	–0.01	–0.01	–0.01
Winter oilseeds	–1.92	–0.40	–0.03	**2.69**	–0.01	–0.01
Sorghum	–0.26	–0.05	–0.01	–	**0.28**	0.10
Summer oilseeds	–0.26	–0.05	–0.01	–	0.17	**0.20**

Table 5: **Estimates of the short run elasticities of crops are with respect to price – Dewbre et al. (1985)** Data period 1959 to 1982

	1 per cent change in price					
Area	Wheat	Barley	Oats	Sorghum	Beef	Wool
	%	%	%	%	%	%
Wheat	**0.39**	–0.12	–0.03	–0.02	–0.04	–0.10
Barley	–0.32	**0.74**	–0.17	–0.02	–0.04	–0.10
Oats	–0.43	–0.07	**0.76**	–0.02	–0.04	–0.10
Sorghum	–1.70	–0.26	–0.11	**1.45**	–0.04	–0.10

Table 6: **Estimates of the short run elasticities of crops area with respect to price – Gunaskera et al. (1992)** Data period 1956 to 1989

	1 per cent change in price				
Area	Wheat	Other winter crops	All summer crops	Wool	Cattle
	%	%	%	%	%
Wheat	**0.31**	0.00	0.00	–0.21	0.00
Sorghum	–0.02	0.00	0.07	0.00	0.00

Table 7: **Estimates of the short run elasticities of supply with respect to price – selected studies**

			1 per cent change in price of		
Study	Data period	Elasticity of supply	Wheat	Wool	Cattle/ beef
			%	%	%
Kokic et al. (1993)	1980–91	Wheat	**0.23**	–0.07	–0.03
Low and Hinchy (1990)	1978–87	Wheat	**0.26**	0.20	0.07

Sources: Kokic et al. (1993); Low and Hinchy (1990).

The estimates of area responses reported in this study may not be directly comparable with those from previous studies because of differences in the study period, model specification and estimation methods. However, it is interesting and informative to make some general comparisons. To do this, elasticity estimates from the selected previous studies are presented in tables 2–5. The notable feature from these tables is that Australian broadacre agriculture is generally unresponsive to price changes. The results of the present study, that are found to be broadly in line with those from earlier studies, confirm this finding. Overall, it appears that elasticities for most enterprises remain stable, despite the developments that have been taking place in broadacre agriculture during the past two and a half decades.

Of particular interest are the own-price elasticities of area planted of major crops such as wheat with respect to own-price and prices of livestock. All the previous studies cited in tables 2–5 have found relatively unresponsive short run area elasticities for wheat, with estimates ranging from 0.23 to 0.39. This finding is supported by the present model where corresponding elasticity is found to be 0.34. Similarly, short run estimates of cross-elasticities of wheat area with respect to prices of wool and beef reported for this model are in line with estimates of previous studies reported in the tables, with the exception of Low and Hinchy (1990) (table 5). For instance, the analyses of Dewbre et al. (1985), Gunasekera et al. (1992) and Kokic et al. (1993) indicate a substitution relationship between wheat and livestock enterprises, with elasticity estimates falling in a fairly narrow range. In contrast to these, Low and Hinchy (1990) reported positive elasticities for wheat supply with respect to prices of wool and cattle, suggesting a complementary relationship between these enterprises, although the estimates were found to be statistically insignificant.

Conclusions

This study analyses crop area responses in Australian broadacre agriculture at the national level, using time series data from 1974-75 to 1995-96. The model presented here is broader in scope than previous models of area response in terms of crop coverage and the overall framework. The preliminary results suggest that the model is capable of generating plausible estimates. Generally, the results of this study suggest that short run area responses for broadacre enterprises are highly inelastic, confirming the conclusions of most earlier studies. The area responses for major broadacre enterprises estimated in this study are fairly close to those reported in earlier studies, despite differences in data periods and method. The parameter estimates for most enterprises appear to be stable over time, despite the developments that have been taking place in broadacre agriculture over the past two and a half decades.

While this study supports the findings of previous analyses, the results should be viewed as preliminary. The small sample size used in this study for estimating a large number of parameters means that further investigation is needed. For example, pooling cross-sectional and time series data, to increase the number of observations, may allow the estimation of entire set of equations in a system framework using full information techniques. Similarly, comparing alternative specifications of the model based on prices, revenues and various expectation formulations using rigourous econometric tests would be useful in arriving at the best specification. Since the model is intended to be used for forecasting purposes, its performance remains to be evaluated against other forecasting approaches/models.

References

Askari, H. and Cummings, J.T. 1977, 'Estimating agricultural supply response with the Nerlove model: a survey', *International Economic Review*, vol. 18, no. 2, pp. 257–292.

Bewley, R., Young, T. and Colman, D. 1987, 'A system approach to modelling supply equations in agriculture', *Journal of Agricultural Economics*, vol. 35, no. 2, pp. 151–166.

Binkley, J.K. and McKinzie, L. 1984, 'Improving acreage response analysis with multiple equations', *North Central Journal of Agricultural Economics*, vol. 6, no. 2, pp. 91–98.

Chambers, R.G. and Just, R.E. 1989, 'Estimating multioutput technology', *American Journal of Agricultural Economics*, vol. 71, no. 4, pp. 980–995.

Coelli, T.J. 1992, *Forecasting wheat production using shire level data*, Working Paper, January 1992 draft, Econometrics Department, University of New England, Armidale, Australia.

Coyle, B.T. 1993, 'On modelling systems of crop acreage demands', *Journal of Agricultural Economics*, vol. 18, no. 1, pp. 57–59.

Dewbre, J., Shaw, I., Corra, G. and Harris, D. 1985, *EMABA — Econometric Model of Australian Broadacre Agriculture*, Bureau of Agricultural Economics, Canberra.

Fisher, B.S. and Wall, C.A. 1990, 'Supply response in the Australian sheep industry: a profit function approach', *Australian Journal of Agricultural Economics*, vol. 34, no. 2, pp. 147–166.

Foster, M. and Dewbre, J. 1983, The crops module of the EMABA model: an overview, BAE Working Paper 83.13, Canberra.

Gunasekera, D., Shaw, I., Brewer, K., Rodriguez, G., Linacre, A. and Martin, W. 1992, *Effects of Domestic Chinese Policies on World Grain Markets: Implications for Australia*, ABARE Research Report 92.10, Canberra.

Hall, N., Fraser, L. and Purtill, A. 1988, 'Supply response in broadacre agriculture', *Review of Marketing and Agricultural Economics*, vol. 56, no. 3, pp. 361–374

Kokic, P., Beare, S., Topp, V. and Tulpulé, V. 1993, *Australian Broadacre Agriculture: Forecasting Supply at the Farm Level*, ABARE Research Report 93.7, Canberra.

Krakar, E. and Paddock, B. 1985, *A Systems Approach to Estimating Prairie Crop Acreage*, Working Paper 15/85, Marketing and Economics Branch, Agriculture Canada, Canada.

Lawrence, D. and Zeitsch, J. 1989, *A Disaggregated Model of Agricultural Production Response*, Economic Studies Branch, Research Memorandum, Industries Assistance Commission, Canberra.

Low, J. and Hinchy, M. 1990, Estimation of supply response in Australian broadacre agriculture: the multi–product approach, ABARE paper presented at the 34th Annual Conference of the Australian Agricultural Economics Society, University of Queensland, Brisbane, 13-15 February.

Martin, P., Riley, D., Ashton, D., Delforce, J. and Loggia, D., 1998, *Australian Grains Industry 1998*, Report of the Australian Agricultural and Grazing Industries Survey of Grain Producing Farms, ABARE, Canberra.

McKay, L., Lawrence, D. and Vlastuin, C. 1983, 'Profit, output supply and input demand functions for multiproduct firms: the case of Australian agriculture', *International Economic Review*, vol. 24, no. 1, pp.311–327.

Nerlove, M. 1956, 'Estimates of the elasticities of supply of selected agricultural commodities', *Journal of Farm Economics*, vol. 38, no. 2, pp. 496–509.

Paris, Q. 1989, 'A sure bet on symmetry', *American Journal of Agricultural Economics*, vol. 71, no.2, pp. 344–351.

Shideed, K.H. and White, F.C. 1989, 'Alternative forms of price expectations in supply analysis for US corn and soybean acreages', *Western Journal of Agricultural Economics*, vol. 14, no. 2, pp. 281–292.

Sulewski, T., Spriggs J. and Schoney, R.A. 1994, 'Agricultural producer price expectations', *Canadian Journal of Agricultural Economics*, vol. 42, no. 1, pp. 301-310

Wall, C. A. and Fisher, B.S. 1987, *Modelling a Multiple Output Production System: Supply Response in the Australian Sheep Industry*, Research Report No.11, Department of Agricultural Economics, University of Sydney.