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A model of wheat supply response in Australia's mainland states*

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The model of Australian cropping reported in this study is focused on estimating the effect of changes in output prices on the area planted to wheat and other crops in the mainland states. Direct price effects are modelled as are the interaction between activities that occurs with crop rotations, the effects of complementarity and substitution between activities and the constraints on farm adjustment. To reflect differences in the nature of agriculture in different parts of Australia, separate models were developed for each of the five main cropping states.

It is assumed that farmers adjust to changes in the expected farm returns available from alternative cropping and livestock activities. The allocation of land is also affected by the pattern of cropping in the previous winter and/or summer season. The results suggest there are sizable differences between states in the responsiveness of wheat cropping to changes in wheat prices, with farmers in New South Wales estimated to be the most responsive and those in Victoria and Queensland the least responsive. These differences accord well with what is known about cropping activities in each state.

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Introduction

The model described here has been developed to improve on that previously used within ABARE (Foster and Dewbre 1983; Dewbre, Shaw, Corra and Harris 1985) for policy analysis, and to project short and medium term outcomes for Australia's cropping industries. One consideration was a requirement to generate forecasts of crop production, with the emphasis on wheat, for individual states as well as for Australia. A second consideration was that there are significant structural differences between the agricultural sectors of various states. It is therefore expected that substitution and complementarity relationships, both among individual crops and with livestock activities, can be more reliably modelled when examined separately for each state. It was also hoped that improved forecasts for Australia as a whole could be achieved from an aggregation of individual state based models as opposed to those from a model which treats Australia as a single entity.

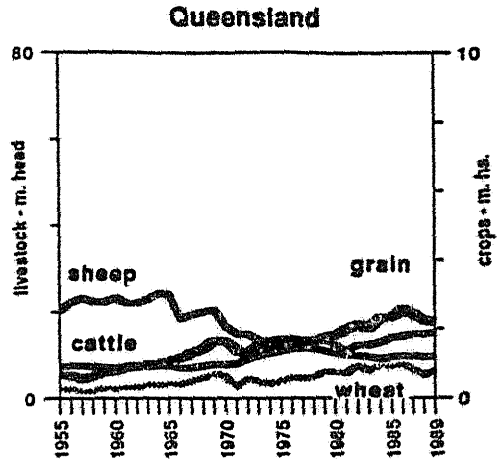
In this study the focus is on modelling the relationship between crop prices and areas cropped but there is recognition of the interaction with sheep and cattle grazing since this can affect cropping activities. For example, summer sorghum provides grain which may be fed to cattle (complements) while sheep may graze land on which a winter grain crop might otherwise be planted (substitutes).

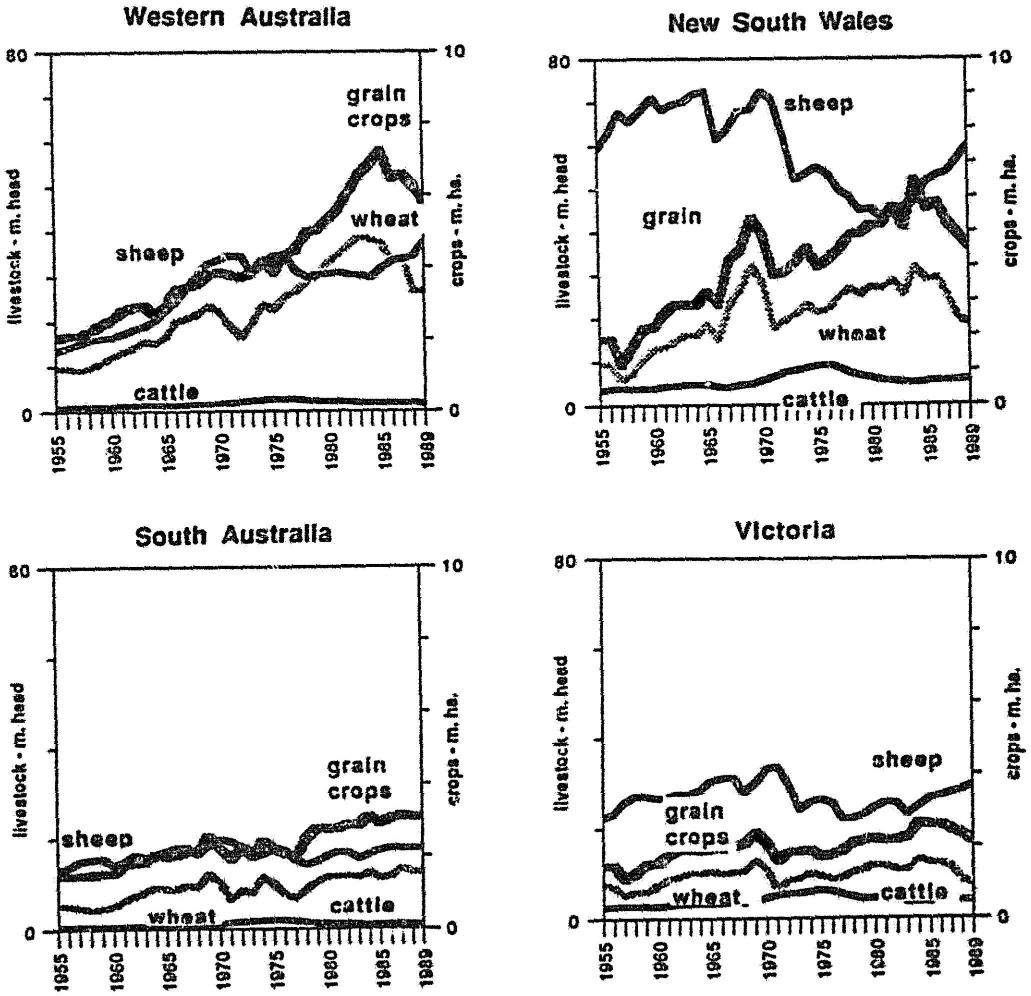
As is indicated in figure 1, there are considerable differences in agricultural activities between states. Wheat is the major crop in all states and dominates winter cropping activities. Among the other winter crops there are elements of both substitution and complementarity with wheat. These arise for instance through the use of crop rotations to improve soils and control disease.

The size of the sheep flock and cattle herd and trends in livestock numbers also vary significantly among the states. Sheep dominate livestock numbers in all states, with the possible exception of Queensland. Over the period 1955 to 1989, sheep numbers trended upwards in Western Australia, downwards in New South Wales and Queensland and remained relatively steady in Victoria and South Australia. Over the same period, cattle inventories varied little in each state except from 1969 to 1975 when they increased relatively quickly.

Although prices for crop and livestock commodities have followed similar historical trends in each of the states it is noteworthy that changes in the pattern of farming activity have not been uniform across states, as noted above, reflecting differences in substitution possibilities between crop and livestock production.

FIGURE 1: Crop Areas and Livestock Numbers - by State





To produce reliable production forecasts it is necessary to model the substitution between crops and livestock which occurs in Australia. The model presented here treats each state separately and also examines summer crops separately from winter crops while recognising interaction between the two groups and with livestock activities.

In the model it is assumed that when farmers respond to changes in price relativities they take into account the costs of production as well as the costs of making changes to the structure of farm activities. For example, in responding to an improved short term price outlook for wheat a farmer will be cognisant of costs which could be associated with expanding wheat area, such as disposal of livestock and ploughing up existing pasture. Rather than completing intended structural change within a year, farmers are considered to favour more gradu shifts between activities. This process may continue over several years if the price outlook remains favourable.

The model

From a theoretical perspective, perhaps the most important feature of Australia's main agricultural industries (cropping, beef grazing and wool growing) is the relatively extensive size of farm units, which facilitates the joint production of beef, sheep and crops, on individual farm enterprises. Modelling this phenomenon has been central to many previous studies of supply response in Australian broadacre agriculture, with researchers specifying multi-output production technologies and rejecting non-joint technology (see, for example, Vincent, Dixon and Powell 1980; McKay, Lawrence and Vlastuin 1982; Wall and Fisher 1987; Lawrence and Zeitsch 1989; Low and Hinchy 1990).

As farmers have no control over the vagaries of weather, it is decisions about the allocation of land that are critical to determining the supply of wheat and other crops. While weather effects are important determinants of crop production they are not considered in the current model.

Assuming a multi-output production technology, the usual properties of production functions and profit maximising behaviour, demand equations for allocatable inputs like land can be specified as a function of the price of each output that uses the input and the prices of variable inputs of production. That is,

$$D_k = f(p_1, \ldots, p_m, w_1, \ldots, w_k)$$

where D_k is demand for input k (land, chemicals, fertiliser, etc.); $p_1, \ldots, p_m$ are the prices of m alternative outputs which use input k; and $w_1, \ldots, w_k$ are the prices of the k inputs used in producing the m alternative outputs.

As there are so many livestock and crop outputs for which Australian land is used, an input demand function for land would involve estimating a prohibitively large number of parameters. To make this problem tractable, nine separate output categories were defined and cost of production indexes specific to the crop, sheep and beef enterprises were created. This approach reduces the number of parameters to manageable proportions while allowing for the important interrelationships between the numerous alternative cropping and livestock outputs to be identified.

The nine categories chosen include five multi-output groups — total winter crops, total summer crops, other winter crops, other summer crops and sheep —as well as four single output categories — wheat, sorghum, wool and beef. For each output category an estimated farm return variable was created, defined as the ratio of the gross value of production per hectare for crops and per head for livestock, to the relevant enterprise specific cost of production index:

$$FR_i = \Sigma_k(a_{k,i} p_{k,i}\, y_{k,i}) \,/\, \Sigma_j(b_{j,i}\, w_j) \qquad (i = 1, \ldots, 9),$$

where FR_i is the estimated (per hectare or per head) farm return for the output category i; $a_{k,i}$ is the weight given to output k of category i (for single output categories, of course, the solitary weight has a value of unity); $p_{k,i}$ is the unit gross value of output k of category i; $y_{k,i}$ is the yield of output k of category i; $b_{j,i}$ is the per hectare or per head level of use of input j for category i; and w_j is the prices paid index of purchased input j.

For the aggregate crop categories, the numerator of the farm return variable was defined as the area weighted average of the gross value of production per hectare of the individual crops. The weights used to construct the sheep enterprise farm return were the average shares of total sheep industry revenue accounted for by wool, lamb, mutton and live sheep over the period 1965–82.

The purchased factor inputs included in the construction of the enterprise specific cost of production indexes, the denominator of the net return variables, were chemicals, electricity, fertiliser, fuel, interest, marketing expenses, motor vehicles, machinery, seed and fodder and hired labour. Prices of these inputs were obtained from ABARE's index of prices paid by farmers while the weights for individual inputs used in each of the crop, sheep and beef enterprises were sourced from ABARE's Australian agricultural grazing industries survey (AAGIS). The weights were defined as the Australian average annual rate of input use per hectare or per head on specialist crop, sheep and beef farms over the period 1970–82. Harris, Corra, Shaw and Dewbre (1985) contains more detail of the construction of these indexes.

Producer price expectations

Farm decisions are made on the basis of the financial returns expected by farmers in future seasons (expected returns), these being based on expectations of both prices and yields. Thus an important aspect of agricultural supply modelling is the chosen assumption about the way producers form their expectations of future price and yield outcomes. Since price and yield outcomes are not normally known in advance, agricultural producers have to base supply decisions on their own expectation of future prices and yields. In the present model, it was assumed that only one year ahead expectations of prices and yields are relevant to cropping decisions by Australian farmers. Consequently, the models considered to represent the expectations process for prices and yields were tested only for one year ahead forecast accuracy. It should be noted that if farmers form expectations further ahead, the models considered may not generate the most accurate forecasts.

Numerous models of price and yield expectations were tested. The simplest model of the expectations process is to assume producers are naive and simply expect to receive last year's price again this year. Alternative price expectations models used in other studies include a geometric lagged function of past prices (Anderson 1974; Saylor 1974; Shumway 1983) and simple moving averages (Dewbre et al. 1985). In recent studies, autoregressive integrated moving average (ARIMA) models developed by Box and Jenkins (1976) have been used to extrapolate expected prices. This approach, as shown in Nerlove, Grether and Carvalho (1979), satisfies the hypothesis of rational expectations made by Muth (1961).

Preliminary analysis using ARIMA modelling indicated that in most cases expected prices for livestock and major crops (wheat, barley and oats as well as sorghum in Queensland) were best modelled as a random walk — that is, the price expected in period 't' is the price observed in period 't–1'. Following Foster and Dewbre (1983) and Dewbre et al. (1985), three and five year moving average models of price expectations were also tested but predictions from these models performed worse than simple naive forecasts.

Additional analysis was undertaken using a combined trend regression and time series model (SAS/ETS 1988). With this approach, first the price series is regressed against a function of time (either linear or quadratic) and then an autoregressive model is applied to the residual series of the trend regression. Combining the trend forecasts with those from the autoregressive model gives the completed price forecasting model. The final model chosen is selected on the principle of parameter parsimony and standard measures of forecast accuracy.

On the basis of standard measures of forecast accuracy such as mean absolute percentage error, mean square error and Theil's inequality coefficient (U_2), the combined trend regression–time series model produced the best predictions among the various price expectations models tested. For the majority of the livestock and major crops price series a quadratic trend regression combined with an autoregressive process of order one or two for the residual series of the trend regression, proved the best forecasting model. For illustrative purposes, the combined trend regression–autoregressive models for the saleyard price of beef (*PBEEF*) and the wheat price in Western Australia (*PWHW*) are presented below, with t-statistics in parentheses.

The expected values for the *PBEEF* series is estimated as:

$$PBEEF_t^{**} = \hat{PBEEF}_t + 0.90(PBEEF_{t-1}\ \hat{PBEEF}_{t-1}) - 0.37(PBEEF_{t-2} - \hat{PBEEF}_{t-2})$$

For the beef price a quadratic trend regression was estimated. That is,

$$\hat{PBEEF}_t = \underset{(4.51)}{41.30} \underset{(-3.29)}{- 3.31T_t} + \underset{(7.80)}{0.18T_t^2}$$

$\bar{R}^2 = 0.90$ DW $= 0.64$

Estimation period: 1950–90

where T is time.

The residual, $RES_t = PBEEF_t - \hat{PBEEF}_t$, is modelled as an AR2 process:

$$RES_t = 0.90RES_{t-1} - 0.37RES_{t-2}$$

Using the same approach but modelling the trend residuals as an AR1 process, the expected wheat price series for Western Australia ($PWHW_t$) is estimated as:

$$PWHW_t^{**} = \hat{PWHW}_t + 0.57(PWHW_{t-1} - \hat{PWHW}_{t-1}),$$

where

$$\hat{PWHW}_t = \underset{(6.20)}{51.74} - \underset{(-1.77)}{1.89T_t} + \underset{(6.27)}{0.18T_{t-2}}$$

$\bar{R}^2 = 0.91$ DW = 0.84

Estimation period: 1955–89

and

$$RES_t = 0.57RES_{t-1} = 0.57(PWHW_{t-1} - \hat{PWHW}_{t-1})$$

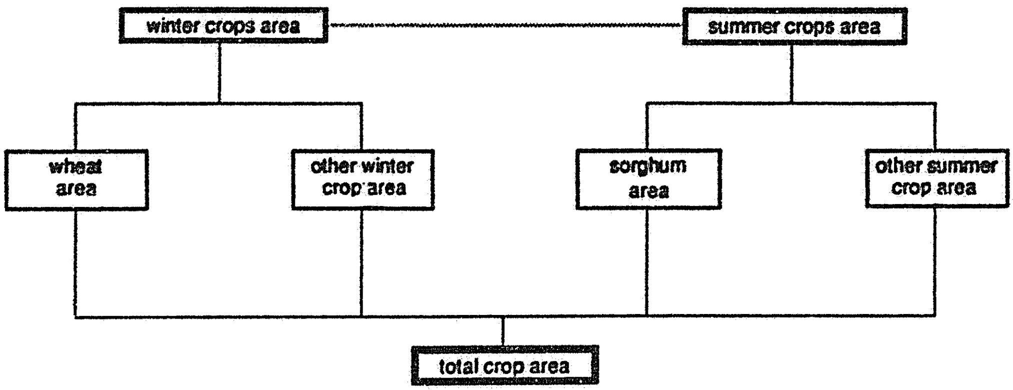
The combined trend regression–time series model was also used to model producers' expectations of the major crops' yields, the remaining component of the expected return variables. Analysis revealed a linear time trend sufficed for all the yield models while the autoregressive representation for the trend residuals was not required in most cases.

For crops other than wheat, barley and oats, and sorghum in Queensland, the combination of a small number of observations or incomplete data for the period under study and the relatively small area sown to these crops precluded the application of the combined trend regression–time series technique. Instead, a naive price expectations process was assumed for the minor crops since the ARIMA approach indicated this model was adequate for the major crops' price series. For the expected yields of the minor crops, a simple five year moving average was chosen to represent the expectations process as this model performed better than naive forecasts.

Specification of the state crop supply models

Crop area allocations in the five mainland states are modelled as a hierarchical sequence of decisions as presented in figure 2. At the most aggregate level, land is explicitly allocated to either total winter crops or total summer crops or implicitly to alternative activities. In the next stage, total winter crop area is allocated to either wheat or 'other winter' crops (that is, other winter cereals plus winter oilseeds and legumes), while the total summer crop area is assigned to either sorghum and other summer crops (that is, maize plus summer oilseeds). The decision to allocate land to cropping is influenced at both stages by the relative profitability of the various crop and livestock alternatives, represented by the expected return variables outlined earlier. In the current model, summer crops are ignored in Victoria,

FIGURE 2: BASIC STRUCTURE OF THE CROP MODEL



South Australia and Western Australia because the areas devoted to these crops are extremely small in comparison with winter crop areas in those states.

The behavioural equations corresponding to this structure have the general form:

$$AREA_{n,t} = f(FR_{i,t}, \ldots, FR_{j,t}, AREA_{W,t-1}, AREA_{S,t-1}, T, Q)$$

where $AREA_n$ is the area of land devoted to crop n; FR_i is the expected return for crop i or crop category ($i = 1, \ldots, m$); FR_j is the expected return for alternative livestock output j ($j = n, \ldots, z$); $AREA_W$ is the area of land devoted to winter crops, and $AREA_S$ is the area devoted to summer crops (to represent crop rotation and the fallowing of crop land); T is the time trend; and Q is a dummy variable to account for the impact of the wheat delivery quotas in 1971 and 1972.

In addition to the expected return variables, one or more of four other variables were included as explanators in each equation. The dynamics of crop area response, the desirable practice of crop rotation and the necessity to fallow land were all captured through the inclusion of appropriate lagged crop areas. The area of land cropped last season represents farmers' previous investment in cropping and their previous application of fertiliser, ploughing and other land preparation to grow crops. Similarly, the decision to graze livestock requires long term investment in improved pasture, fencing and so on. Consequently, in the very short run farmers cannot reach the desired level of output in response to changes in expected profitability but instead partially adjust each season until achieving their desired long run crop area and level of production.

The practice of fallowing land is important where, as in Queensland, relatively large areas of both winter and summer crops can be grown and opportunities to double crop are limited. In these circumstances, an increase in the area sown to winter crops could result, in the short run at least, in a reduction in summer crop area. Similarly, a large summer plant last year can be expected to reduce the winter crop area sown this year. As a result, the relevant lagged crop areas have been included in the model in an attempt to capture this phenomenon.

It was also necessary to include a dummy variable in the model to capture the effects on farmers' crop land allocation decisions of the imposition of quotas on wheat deliveries in the early 1970s'. Subsequently, a simple intercept dummy performed best when applied to the 1970-71 and 1971-72 seasons. Time trend variables were also included to account for any systematic effects not captured by the other explanatory variables. There is little doubt for instance that technological change has enabled the expansion of cropping into areas traditionally devoted to grazing.

It should be noted that the structure chosen to model crop area allocations requires that two land area categories be determined residually. In the present model, both the area of other winter crops which include barley, oats, winter legumes and winter oilseeds and the area of other summer crops which include summer oilseeds are determined as the difference between the total winter or summer areas and the wheat and sorghum areas, respectively.

Data

Data on area, production and the gross value of production of fourteen crops for each state were obtained from both central office and state office publications of the Australian Bureau of Statistics (ABS) for the period 1954-55 to 1988-89. Livestock yields were obtained similarly, while average auction prices for each of the livestock outputs were obtained from the Australian Meat and Live-stock Corporation as well as the National Council of Wool Selling Brokers of Australia and compiled by ABARE.

The crops included in the study included wheat, barley, oats, triticale, sorghum, maize, lupins, fieldpeas, canola, safflower, linseed, sunflower, soybean and peanuts. For each crop in every state, the average yield was constructed as the ratio of production to area harvested. Price was defined as the average gross value per tonne of production. While the wheat, barley, oats and sorghum data are readily available from 1954-55 to 1988-89, the series for most of the remaining smaller crops are either not reported consistently over this period or the number of observations are only small for crops that are relatively new in Australia. Consequently, for each observation only those crops with positive values for both the gross return and area were used to construct the aggregated farm return variables for both the 'total' and 'other' categories of winter and summer crops. The weights used to aggregate these variables were the area planted to each crop. For example, as triticale data have been collected from 1980-81 only, the aggregate farm return variables exclude triticale before that year but include it, weighted by area, from 1980-81 onwards.

Results

All behavioural equations were specified as loglinear and estimated by the ordinary least squares (OLS) regression technique. The choice of a loglinear functional form has two advantages. First, the parameter estimates can be interpreted as elasticities and, second, logarithmic transformations ensure non-negative solutions for these variables in simulation, a feature considered desirable for crop areas and production.

Estimation results for the winter and summer crop area system of equations for the mainland states are reported in table 1 and table 2, respectively. Parameter estimates of the expected farm return variables are correctly signed and significantly different from zero at the 90 per cent level of probability, with the only exception being sorghum in the Queensland sorghum area equation. The wheat quota dummy variable and the time trend are included in several of the area equations, with plausible signs and reasonable levels of significance. In addition, the significance of the previous crop area variables supports the hypothesis that in response to changes in expected returns Australian crop farmers partially adjust each year toward the desired long run crop area. The result also suggests that fallowing is an important cropping practice in Queensland.

For the Victorian crop area equations, a dummy for the 1968-69 and 1983-84 seasons was included to account for the large increase in areas sown following severe droughts in the preceding seasons. This phenomenon appears to have been unique to Victoria.

Overall, the equations explain a high proportion of the historical variation in the transformed dependent variable (the logarithm of the area). In general, the Durbin–Watson statistics (DW) and the Durbin-h statistics indicate the absence of autocorrelation although some DW statistics are in the indeterminate range. However, for each equation, examination of the

Table 1: Regression results: winter crops areas, by state

	Constant	Expected farm returns for: Winter crop	Wheat	Wool	Sheep	Previous area of: Total crop	Summer crop	Winter crop	Wheat quota dummy a	Season dummy b	Time trend	*Data period*	*Adj R^2*	DW
Queensland														
Total winter	–90.53	0.48		–0.50			–0.25	0.25			0.05	*1956 to*	*0.86*	–1.25*
	(–5.890)	(3.10)		(–1.86)			(–2.16)	(2.16)			(6.86)	*1989*		
Wheat	–101.73		0.56	–0.56			–0.26	0.26			0.06	*1956 to*	*0.86*	2.19
	(–5.91)		(3.12)	(–1.89)			(–2.05)	(–2.05)			(6.79)	*1989*		
New South Wales														
Total winter	–27.55	0.77			–0.70	0.46			–0.21		0.02	*1957 to*	*0.87*	1.57
	(–1.64)	(4.57)			(–2.57)	(3.32)			(–1.87)		(2.03)	*1989*		
Wheat	–10.74		0.76	–0.79				0.63	–0.29		0.01	*1957 to*	*0.87*	2.13
	(–0.80)		(5.20)	(–3.13)				(4.94)	(–2.58)		(1.22)	*1989*		
Victoria														
Total winter	–4.15	0.14		–0.22				0.59	–0.23	0.22	0.004	*1956 to*	*0.86*	–1.62*
	(–0.67)	(1.87)		(–1.97)				(4.99)	(–2.90)	(3.91)	(1.27)	*1989*		
Wheat	2.09		0.40	–0.37				0.85	–0.58	0.26		*1956 to*	*0.81*	2.21
	(1.50)		(4.68)	(–2.65)				(6.85)	(–5.39)	(3.39)		*1989*		
South Australia														
Total winter	4.87	0.25			–0.58			0.72				*1957 to*	*0.92*	–1.26*
	(4.78)	(3.33)			(–4.94)			(8.73				*1989*		
Wheat	0.98		0.44	–0.57				1.12	–0.17			*1957 to*	*0.82*	2.06
	(0.51)		(4.05)	(–2.87)				(–6.85)	(–1.62)			*1989*		
Western Australia														
Total winter	–9.4	0.14		–0.26				0.75			0.01	*1959 to*	*0.97*	–0.33*
	(–0.85)	(1.77)		(–2.17)				(5.12)			(1.02)	*1989*		
Wheat	0.75		0.41	–0.37				1.07	–0.31			*1959 to*	*0.94*	2.21
	(0.62)		(3.83)	(–2.14)				(13.51)	(–4.39)			*1989*		

a A dummy which takes the value 1 in 1970-71 and 1971-72 and 0 elsewhere, except for Victoria where it is 1 in 1970-71 only. b In Victoria a dummy was used in the seasons 1968-69 and 1983-84 in which large post drought plantings occurred. * Durbin's h statistic.

Table 2: Regression results: summer crop areas, by state

	Constant	Expected farm returns for: Summer crop	Sorghum	Other summer crop	Sheep	Beef	Previous area of: Summer crop	Winter crop	Wheat quota dummy a	Time trend	Data period	*Adj R^2*	DW*
Queensland													
Total summer	–81.07	0.24			–0.36	0.24	0.50	–0.19	0.23	0.04	*1956 to*	0.98	0.57*
	(–3.33)	(2.06)			(–2.38)	(3.51)	(4.15)	(–1.91)	(3.23)	(3.39)	*1989*		
Sorghum	–68.16		0.21				0.63		0.52	0.04	*1956 to*	0.96	1.76
	(–2.20)		(1.36)				(2.98)		(4.12)	(2.18)	*1989*		
New South Wales													
Total summer	–295.24	1.63							1.52	0.15	*1957 to*	0.88	1.45
	(–11.31)	(4.23)							(5.07)	(11.55)	*1989*		
Sorghum	–31.33		0.31	–0.31			0.43		0.45	0.02	*1957 to*	0.94	2.38
	(–1.64)		(2.53)	(2.53)			(4.40)		(2.27)	(1.75)	*1989*		

a A dummy which takes the value 1 in 1970-71 and 1971-72 and 0 elsewhere. * Durbin's h statistic.

correlogram in conjunction with the Ljung and Box (1978) 'Q' statistic indicated the residuals were random (that is, no serial correlation or heteroscedasticity).

Predictions of wheat, other winter crops and sorghum areas for each state, generated from a dynamic simulation within sample, are presented in table 3. On the basis of the diagnostic statistics reported, the model performs adequately in dynamic simulation at forecasting the

Table 3: Model predictions from a dynamic historic simulation

	Actual mean a	Predicted mean a	Mean absolute % error	Root mean squared % error	Theil's U_2 statistics
Queensland					
Wheat area	733	739	10.91	12.61	0.12
	(176)	(118)			
Other winter area	255	247	16.86	20.34	0.21
	(64)	(29)			
Sorghum area	450	454	9.87	14.24	0.14
	(115)	(123)			
New South Wales					
Wheat area	3 166	3 268	10.66	13.96	0.13
	(459)	(496)			
Other winter area	979	996	13.76	18.55	0.16
	(227)	(120)			
Sorghum area	165	164	13.52	18.91	0.16
	(27)	(21)			
Victoria					
Wheat area	1 296	1 279	8.40	10.33	0.10
	(192)	(155)			
Other winter area	688	701	8.15	10.02	0.09
	(138)	(113)			
South Australia					
Wheat area	1 356	1 285	10.11	12.87	0.12
	(227)	(171)			
Other winter area	1 165	1 114	9.72	11.06	0.11
	(174)	(192)			
Western Australia					
Wheat area	3 871	3 577	9.54	11.19	0.12
	(675)	(438)			
Other winter area	1 240	1 266	8.96	11.08	0.11
	(359)	(309)			
Australia					
Wheat area	10 424	10 148	7.41	8.75	0.08
	(1478)	(1072)			
Other winter area	4 348	4 323	5.93	7.11	0.08
	(863)	(723)			
Sorghum area	618	618	8.19	11.56	0.11
	(124)	(130)			

a Standard deviation in parentheses.

most important endogenous variables within sample, particularly wheat areas. Theil's U_2 statistic also indicates that within sample predictions are considerably better than a naive no-change forecast.

Table 4 contains the associated crop area elasticity estimates, which were obtained from a simulation experiment with the crop land area allocation model. If it is reasonable to argue that crop yields are independent of crop prices, then the elasticities presented in table 4 could be regarded as crop supply elasticities. The elasticities reported are essentially the time path of observed percentage changes in crop areas in response to a change in expected returns following a permanent 1 per cent increase in 1988-89 farm prices. The supply elasticities reported for Australia are the sum of the production responses in each state and thus account for the differences in crop yields among the states. The statistical significance of the elasticity estimates has not been tested because calculating standard errors for these estimates is not a simple task.

For every state the own-price crop supply elasticities are unequivocally positive and inelastic, with New South Wales being the most responsive crop producer and Victoria and Queensland the least responsive. For wheat, the long run supply response is always larger than the initial impact with 50 per cent or more of the final long run response occurring after 1 year in the eastern states. In South Australia and Western Australia, however, the results suggest the adjustment process for wheat is relatively slower.

In each state the own-price supply elasticities estimated for the other winter crops area are considerably smaller than the corresponding estimates for wheat except in the two states with more significant areas of summer crops, New South Wales and Queensland. In both states, particularly New South Wales, wheat and other winter crops appear to be complements in the longer run as crop areas expand, reflecting the requirement for crop rotation in land management. In addition, summer crops in New South Wales also seem to be complements with winter crops in the longer run. In Queensland, on the other hand, winter and summer crops are substitutes.

In nearly all states, estimates of the cross-price effects between livestock and crops suggest considerable substitution relationships, particularly between wool growing and cropping. Beef prices seem to have no impact on cropping except in Queensland, where the results suggest it is a slight substitute for winter crops and a complement with summer crops (not reported).

Table 4: Elasticity estimates

Percentage change in production of:		1 per cent change in the farm price of: Wheat	Other winter crops	All summer crops	Wool	Cattle
Queensland						
Wheat	after 1 yr	0.33	0.00	0.00	–0.23	0.00
	after 2 yrs	0.41	0.02	–0.04	–0.27	–0.06
	long run	0.48	0.02	–0.12	–0.25	–0.11
Other winter	after 1 yr	–0.06	0.35	0.00	–0.14	0.00
	after 2 yrs	0.01	0.21	–0.03	–0.16	–0.05
	long run	0.06	0.21	–0.10	–0.15	–0.09
New South Wales						
Wheat	after 1 yr	0.45	0.00	0.00	–0.33	
	after 2 yrs	0.69	0.09	0.00	–0.48	
	long run	0.89	0.12	0.13	–0.60	
Other winter	after 1 yr	0.23	0.41	0.00	–0.12	
	after 2 yrs	0.25	0.32	0.39	–0.14	
	long run	0.27	0.32	0.35	–0.15	
Victoria						
Wheat	after 1 yr	0.24	0.00		–0.33	
	after 2 yrs	0.29	0.02		–0.48	
	long run	0.37	0.04		–0.60	
Other winter	after 1 yr	–0.18	0.06		–0.02	
	after 2 yrs	–0.16	0.07		–0.05	
	long run	–0.14	0.06		–0.09	
South Australia						
Wheat	after 1 yr	0.26	0.00		0.00	
	after 2 yrs	0.36	0.11		–0.24	
	long run	0.63	0.26		–1.02	
Other winter	after 1 yr	–0.08	0.19		0.00	
	after 2 yrs	–0.05	0.17		–0.16	
	long run	0.03	0.21		–0.44	
Western Australia						
Wheat	after 1 yr	0.23	0.00		–0.15	
	after 2 yrs	0.31	0.04		–0.27	
	long run	0.53	0.13		–0.62	
Other winter	after 1 yr	–0.28	0.10		–0.02	
	after 2 yrs	–0.27	0.10		–0.03	
	long run	–0.25	0.11		–0.09	
Australia						
Wheat	after 1 yr	0.31	0.00	0.00	–0.21	0.00
	after 2 yrs	0.44	0.06	0.00	–0.33	–0.01
	long run	0.62	0.12	0.03	–0.56	–0.01
Sorghum	after 1 yr	–0.02	0.00	0.07	0.00	0.00
	after 2 yrs	–0.04	–0.01	0.41	–0.04	0.10
	long run	–0.07	–0.01	0.47	–0.07	0.14

The elasticity estimates reported in this model are not directly comparable with similar estimates from other studies since, with the exception of Dewbre et al. (1985), other studies have not incorporated price expectations in their models. Rather it has been more common to assume that any change in price is equivalent to an immediate and equal change in expected price. Notwithstanding this, it is still informative to compare the present elasticity estimates with those from other analyses.

Nearly all the studies reviewed contain Australian crop supply elasticity estimates rather than estimates for individual states of Australia. Without exception these studies report relatively unresponsive Australian wheat supply elasticities, a finding supported by the present analysis. For instance, Vincent et al. (1980) reports an Australian own-price wheat supply elasticity of 0.77 compared with 0.62 for the corresponding elasticity in the present model. Similar estimates in McKay et al. (1982) and Dewbre et al. (1985) are 0.50 and 0.40 respectively, while Lawrence and Zeitsch (1989) reported a short run wheat supply elasticity of 0.20. Low and Hinchy (1990), the only study reviewed which contains estimates of wheat supply elasticities for each state, reports estimates ranging from 0.14 for South Australia to 0.44 for New South Wales, and 0.26 for Australia.

These previous studies also contain estimates of elasticities of wheat supply with respect to livestock prices. The three earliest published analyses of Vincent et al. (1980), Mckay et al. (1982) and Dewbre et al. (1985) all indicate that wheat and wool/sheep growing are substitutes, with estimates of –0.25, –0.42 and –0.09 respectively. In contrast to these estimates, both Lawrence and Zeitsch (1989) and Low and Hinchy (1990) report small but positive elasticities for Australian wheat supply with respect to livestock and wool prices, a finding which suggests a complementary relationship between wheat and livestock. The estimate of this elasticity in the present study is –0.56.

Conclusions

The model of Australian cropping reported in this study is focused on estimating the effect which changes in output prices for a range of agricultural activities have on the area planted to wheat and other crops in the mainland states. Direct price effects are modelled in addition to the interaction between activities which occurs from crop rotations, complementarity and substitution between activities and constraints on farm structural adjustment. To reflect differences in the nature of agriculture in Australia, separate models were developed for each of the five main cropping states.

The estimation results suggest there are important differences among the states in the price responsiveness of wheat cropping. Among the states, New South Wales wheat farmers seem to be the most responsive to price changes, while Victorian and Western Australian wheat farmers are relatively less responsive. These differences accord with what is known of the technical aspects of cropping and the livestock options available in each state.

Prior to estimating this model there had been concern that our inability to model the effects of weather in individual seasons might be a more serious issue in a state based model than in a model for the total of Australia. While this omission appeared not to be a serious problem, inclusion of 'weather' variables does represent an avenue for further research. Model predictions may improve by accounting for events such as favourable planting rains prompting a larger sowing of favoured crops at the expense of crops normally sown later in the season. Conversely, barley area could rise and wheat area could be reduced when autumn rains are too late for wheat but adequate for the normal later planting of barley.

Nevertheless, the model developed in the current study should be useful for examining the effects of changing wheat prices on Australian wheat areas and production. The model also represents a platform to which more detailed descriptions of other cropping decisions might be incorporated at a later date.

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