Effects of Tactical Responses and Risk Aversion on Farm Wheat Supply

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Abstract

A discrete stochastic programming model of the farming system of the eastern wheatbelt of Western Australia is used to examine the effect of tactical responses and risk aversion on wheat supply. Including within-season tactical changes to wheat areas decreases the own-price elasticity of supply. By contrast, introducing risk aversion has no consistent effect on the own-price elasticity of supply. The implications for supply models are discussed.

Introduction

Several authors, particularly from a theoretical perspective, have investigated the effect on product supply of a farm manager's attitude to risk (eg Sandmo 1971; Just 1974; Ishii 1977; Chavas and Pope; 1985; Fraser 1986; Pope and Just 1991). Receiving far less attention has been the effect of tactical responses or adjustments on product supply.

So far, research on tactical decision-making in agriculture has focused on input use within single enterprises. For example, Nordblom, Ahmed, Miller and Glenn (1985), Mjelde, Dixon and Sonka (1989) and Feinerman, Kwan Choi and Johnson (1990) have studied nitrogen input. Thorton and Dent (1984), Stefanou, Mangel and Wilen (1986) and Antle (1988) have examined pesticide use. Because of their focus on input use, these authors do not discuss the output ramifications of inclusion of tactical decision-making for inputs.

This paper departs from these previous studies in two important ways. Firstly, the effects of tactical decision-making and risk aversion on output response and levels are considered. Secondly, a whole-farm rather than a single enterprise framework forms the basis of this study. Specifically, this paper examines the effect of within-season tactical decision-making and risk aversion on farm level wheat supply.

Model Description

The investigation of farm wheat supply is based on a model of the farming system of the Merredin region in Western Australia (see Figure 1). The farming system is described by Kingwell and Pannell (1987) and the farm model of that system is described by Kingwell, Morrison and Bathgate (1992).

(Figure 1 about here)

In the Merredin region most farms possess a mix of soil types, each with different production parameters and management requirements. Most rain falls from May to October, followed usually by a summer drought from December to March. Depending on rainfall incidence, crops are sown as early as late April and as late as early July and are harvested in late November to early January.

Crops include cereals (mainly wheat) and the legume crops, lupins and peas. Livestock consist almost entirely of sheep for wool and meat production. Lambing is in late autumn or early winter and shearing is in spring and autumn. Sheep are run on annual pastures during winter and on a combination of crop residues and dry annual pastures in summer.

Farm operations are highly mechanised and most farms are family owned and operated. Contract, casual and occasionally permanent labour assist in many farm activities.

The farm model used here is a discrete stochastic programming (DSP) model called MUDAS (Model of an Uncertain Dryland Agricultural System). The salient features of MUDAS are its consideration of:

(i) climatic variation and its effects on production outcomes, prices and returns;
(ii) the farm manager's adjustments to decisions.
Although there is uncertainty, as a season unfolds farmers can make adjustments to some of their decisions and thereby favourably alter the impact of that season on production and profits. The degree of adjustment is normally limited by previous decisions.
(iii) product price variance and covariance and
(iv) the manager's aversion to risk.

As a DSP model, MUDAS can incorporate various objective functions associated with risk-neutral or risk-averse farm management. Optimization is through selection of an optimal set of farm activities. These activities draw upon the farm's limited resources of soil areas, finances, machinery and labour. Included in the set of optimal activities are decisions about rotation selection on each soil class, adjustments to crop and pasture areas in certain seasons, livestock numbers and flock composition, livestock feeding and husbandry in each type of season, machinery and labour use in each season, agistment and grain storage, fertiliser and stocking rate decisions and working capital requirements.

The tactical or adjustment options in MUDAS relate to a particular season or set of seasons. The adjustment options represent a second stage in the decision sequence. In this second stage, some information is known about the season and the farmer may choose to make adjustments to farm plans to increase profit or utility in the light of this information. In most cases at this stage the seasonal state is known and the farmer then faces probabilistic product price information, some of which is conditional on the season state.

In MUDAS there are over 52,000 coefficients and most of these are derived or specified in spreadsheets that describe the data and assumptions of the model. The data input file for MUDAS is over 2 MB and there are over 12 MB of squeezed spreadsheets. The model comprises 2265 activities and 1464 constraints. The solving algorithm used by MUDAS is AESOP, a linear version of MINOS (Murtagh and Saunders 1983) for microcomputers. Solution management and report writing are accomplished using MARG (Pannell 1990), a programme to facilitate the running of mathematical programming models such as MUDAS.

Expanding further on the main features of MUDAS[1]:

Season types

In MUDAS climatic variation is approximated by nine discrete seasons. The season types and their classification characteristics are given in Table 1. Descriptions of the data and methods used to categorise the seasons are given in Kingwell, Morrison and Bathgate (1991).

(Table 1 about here)

Product price variance and covariance

An examination of price variances of a range of inputs and farm products from 1981 to 1991 revealed that, in real terms, farmers had faced little price variance for their major inputs of repairs and maintenance, machinery, herbicides and fertilisers. Fuel was the exception. By contrast, farmers' main commodities such as wheat, live sheep, wool and lupins, displayed marked price variance. Hence, because the main source of price risk for farmers was the variable prices they received for their major commodities, only product price variance and covariance was included in MUDAS.

These variances and covariances are currently represented in MUDAS by cash flow rows that represent commodity prices in any group of five years between 1981-82 and 1990-91. Farm-gate prices expressed in 1989-90 dollar terms are recorded for wheat, lupins, over 20 sheep classes, barley, oats, peas and three wool classes. Some lupin prices and sale prices for some sheep classes were adjusted for the effects of some seasons. It is widely acknowledged that in seasons in which sheep feed is very scarce, farmer demand for lupins increases and farmers quit more sheep. These decisions by farmers cause, in these seasons, an increase in lupin prices and a lowering of sheep prices among cast-for-age categories in particular. These effects are included in MUDAS and represent a modification of historical prices only in the few seasons in which sheep feed would be very scarce.

Risk aversion

The representation of risk aversion in MUDAS is by a method developed by Patten, Hardaker and Pannell (1988) and derived from work by Lambert and McCarl (1985). Lambert and McCarl applied non-linear programming techniques to maximise directly expected utility. Patten, Hardaker and Pannell followed the same approach as Lambert and McCarl except that they applied linear rather than non-linear programming techniques. The treatment of risk by Patten, Hardaker and Pannell involved the linear segmentation of the utility function and, unlike the Lambert and McCarl method, required the utility function to be concave. This last restriction on the utility function was tolerable since it implied risk aversion, the risk attitude most commonly observed among Australian farmers (Bond and Wonder 1980; Bardsley and Harris 1987).

In MUDAS six linear segments are used to define a constant absolute risk aversion (CARA) utility function in each season, with the length of each segment being conditional on the type of season and associated activity returns. Previous mathematical programming models of agricultural regions of Australia have either assumed risk neutrality (eg Wicks and Dillon 1978, Hall et al. 1988) or made the CARA assumption (Easter and Paris 1983)[2]. The method used here to incorporate risk easily accommodates different degrees of risk aversion and approximates through linear segmentation the following objective function of maximizing expected utility:

$$\text{Max } E[U(x)] = \sum_{t=1}^{n} p_t (1 - e^{-\rho x_t})$$

where x_t is the return to management and capital at terminal node t,

p_t is the probability of occurrence of ending at terminal node t,

ρ is the Pratt-Arrow coefficient of absolute risk aversion and

n is the number of terminal nodes and equals 45 (that is, 9 weather states by 5 price states).

Strategic activities

Strategic activities in MUDAS include rotational land use and sheep management activities. In addition, there are strategic activities setting cropping machinery investment, grain storage capacity and the initial level of grain stored.

Activity coefficients are unique to each season. These coefficients include estimates of pasture growth in each type of season, soil class and rotation phase and crop yields for each season, soil class and rotation phase.

Tactical activities

The tactical or adjustment options that the farm manager may consider within a season are a major component of MUDAS. The focus of tactical options included in MUDAS is within-season managerial response to weather rather than managerial response to within-season price changes.

Given some information about the start of a season and probabilities of associated finishes to seasons, a farm manager can deviate from his overall farm strategy by pursuing some within-season tactical options. For example, part of a farm strategy may be to maintain continuous pasture on a particular soil class. However, in seasons highly favourable for cropping, a farm manager may choose to crop all or part of that soil class which would ordinarily be in pasture.

Some adjustment options have an impact in the following year. Representation of these adjustment options requires accounting for both their initial year and subsequent year effects. Initial year effects are the changes in inputs, costs and production that occur in the year of adjustment. Thus replacing pasture by wheat would mean accounting for the net change in inputs, costs and production of having one extra hectare of wheat and one less hectare of pasture than specified in the rotation.

Subsequent effects of adjustments reflect the fact that one year's deviation from a rotation may have effects in subsequent years on the soil fertility, weed burden in crops and pasture availability. For example, in a wheat/pasture rotation, replacing one hectare of pasture with wheat may mean in subsequent years less pasture production, yet lower crop herbicide costs than assumed in the steady state wheat/pasture rotation.

The tactical or adjustment options represented in MUDAS are land use area adjustment, machinery and labour adjustments, sheep liveweight deviations, sheep agistment, pasture and stubble management, crop fertilizer application and lupin feeding. All these adjustment activities relate to either one season type or a combination of season types which cannot be distinguished at the time a decision is made.

For the sake of brevity and because of its importance to wheat supply, only the tactical option to alter crop and pasture areas within seasons is described. Readers are referred to Kingwell, Morrison and Bathgate (1991 & 1992) for description of the other tactical features of MUDAS.

Crop and pasture areas

A major adjustment option for many farmers is to alter the area of crop or pasture, particularly on sandy loam and clay soils, depending on seasonal conditions. In the MUDAS model the adjustment options for changing crop and pasture areas are mainly restricted to three classes of sandy loam or clay soil and involve all seasons except seasons 5 and 7 (see Table 1).

The difficulty of representing the initial and subsequent year effects of adjusting rotations is compounded by the fact that adjustment activities are specific to the phase of rotation as well as the rotation. That is, it is not only different to replace pasture with wheat in a pasture/pasture/ pasture/wheat rotation from a wheat/wheat/wheat/pasture rotation, but there is also a difference in replacing the first rather than the second, or the second rather than the third consecutive year of pasture.

Each area adjustment option, together with their production and cost ramifications within a season and across seasons, are described in spreadsheet files. Data from these files are subsequently incorporated in MUDAS. Because the sequence of season types in subsequent years is unknown, effects in subsequent years are spread across all seasons and weighted according to the probability of occurrence of the season in which the adjustment occurs. Effectively MUDAS assumes the nine states of nature are preceded and followed by expected seasons. Readers are referred to Kingwell, Morrison and Bathgate (1991) for elaboration of this method of representing inter-year effects within MUDAS.

In this paper the crops considered in MUDAS are wheat and lupins. In some seasons on one soil class, substitution between lupins and wheat is an option. The exclusion of other cereals ensures selection of wheat even at very low expected prices for wheat.

It is hypothesized that at any expected wheat price, a farmer's ability to alter crop areas in response to seasonal conditions would, relative to the case where such area adjustment was not possible, raise expected wheat yields per planted hectare and allow greater profit to be derived from wheat production. This ability to alter crop areas within seasons would, it is hypothesized, raise the importance of seasonal conditions upon production decisions and lessen the importance of expected prices. The net result would be to reduce the farmer's wheat supply responsiveness to the expected price.

Methodology

Wheat supply responses were generated using versions of MUDAS that represented two different commodity price periods: 1981/2 to 1985/6 and 1986/7 to 1990/1. Each of these versions of MUDAS contained on-farm prices and costs that typified each period, with these prices and costs re-expressed in constant 1989/90 dollar terms. The first period was characterized by relatively high grain prices and low stable wool prices whereas the second period displayed variable wool prices that were mostly historically high relative to grain prices. These two price scenarios provided the price observations for all farm products apart from wheat. In effect the price of each commodity was described by 5 price observations of equal probability of occurrence.

Against the backdrop of each price scenario wheat supply functions[3] were generated assuming 12 hypothetical expected on-farm wheat prices arranged in $10 per tonne increments (e.g. 90, 100, 110 ...190, 200). Each hypothetical expected price was based on 5 price observations of equal probability of occurrence. The price variance formed by each set of 5 price observations was the same at each expected price and matched the observed actual wheat price variance of the period.[4]

Optimal MUDAS farm plans were generated at each expected price and accounted for particular model characteristics. These characteristics included risk neutral or risk averse management plus the presence or absence of options to adjust crop and pasture areas within a season. The factorial combination of price period (2), risk attitude (2) and area adjustment (2) meant that altogether 8=(2x2x2) supply functions were estimated. Quadratic equations were fitted to the wheat price and quantity data using OLS. Quadratic equations were also fitted to the price and wheat area data. Own-price elasticity of supply estimates were calculated at sample means.

The case of risk aversion was based on a Pratt-Arrow measure of absolute risk aversion of 0.000003. This measure re-expressed as a coefficient of relative risk aversion was, for example, 0.78 in the case of risk averse management for the period 1985/6 to 1990/1, assuming area adjustment within seasons. This measure compares favourably with the 0.70 estimate of Bardsley and Harris (1987) for the wheat-sheep zone and is less than the rule of thumb unity value used by Newbery and Stiglitz (1981).

Results

The estimated wheat supply functions for the price periods 1981/2 to 1985/6 and 1986/7 to 1990/1 are shown in Figures 2a and 2b and associated own-price elasticity of supply and OLS estimates are listed in Table 2. The adjusted R^2 values are greater than 0.94. Most of the beta coefficients are significant and most of the fitted equations are weakly curvilinear. The unexpectedly high R^2 values arise from the model's ability to represent incremental changes in wheat production. Often mathematical programming (MP) models of farming systems produce very disjointed step functions of supply response. However, MUDAS includes 7 soil classes, each commonly with 10 rotation options, plus there are progressive yield penalties determined by the length and month of crop sowing. Representing such complexity of the farming system generates smoother supply functions than those typically derived from MP models.

Over the period 1986/7 to 1990/1 sheep and wool prices were generally higher compared to the earlier period 1981/2 to 1985/6. These sheep and wool price relativities influence the position of the wheat supply curves in figures 2a and 2b, effectively generating a leftwards shift of the wheat supply curve in the latter period.

(Figures 2a and 2b about here)

In both price periods the supply curves for risk neutral management including area adjustments bring forth the greatest level of wheat production. Removing area adjustments or introducing risk aversion shifts supply curves leftwards. The strongest leftwards shift occurs when risk aversion is introduced in combination with loss of area adjustment.

The reduction in output associated with inclusion of risk aversion is a common finding in the literature. Investigating wheat supply response in the Mallee region of Victoria, Brennan (1981) identified farmers to be averse both to price and yield risk. Accordingly, these farmers reduced their wheat plantings and production in response to perceived yield and price risks. Other studies (eg Ishii 1977; Wilson, Arthur and Whittaker 1980; Schiff 1983) also show output under uncertainty tending to be smaller than output given certainty. Introducing risk aversion, although affecting the position of the production response, has no consistent effect on the own-price elasticities of supply. By contrast, including area adjustment consistently decreases the own-price elasticity of supply.

The explanation for this finding that inclusion of within-season area adjustment reduces the price elasticity of supply response is aided by considering two facets of price elasticity. Commonly, price elasticity of supply (ε) is expressed as:

$$\varepsilon = \frac{dP \cdot Q}{dQ \cdot P}$$

where the (*dP/dQ*) portion refers to the slope or responsiveness of supply to price change at sample means while the (*Q/P*) portion describes the shift position of the supply response. A decline in the price elasticity of supply can be caused by either a decrease in slope (*dP/dQ*) or a rightwards supply shift (*Q/P*) or some combination of both. Figures 2a and 2b show that inclusion of within-season area adjustment does generate a rightwards shift in the supply response, thereby reducing the price elasticities of supply.

(Figures 3a and 3b about here)

The rightwards shift of some supply curves arises from shifts in the area sown to wheat as shown in Figures 3a and 3b. However, some rightwards shifts in supply are not associated with shifts in the area sown to wheat but rather from production increases caused by tactical changes to crop areas. For example, tactical increases in wheat area in seasons likely to produce high yields (seasons 1,2,4 and 6) and decreases in wheat area in other seasons likely to produce low yields (seasons 8 and 9) boost expected wheat production per planted hectare on the soil classes subject to tactical adjustment. Thus for any expected wheat price in the ranges considered, these tactical changes in wheat area generate higher expected yields per planted hectare on these soils than those achieved when tactical adjustments on these soils are not possible. On a farm basis this yield advantage enables wheat production and its profits to be higher in the case where tactical adjustment is permitted, thereby generating a rightwards shift in the wheat supply function and a consequential lessening of the supply elasticity.

Besides the rightwards shift of the wheat supply curves there is also, particularly for the price period 1981/2 to 1985/6, a decrease in the slope or responsiveness of supply to price change at sample means (i.e. the *dP/dQ* component). To outline the reasons for the lower price responsiveness requires a brief discussion of the anatomy of the supply response.

At very high wheat prices most of the arable land (e.g. 80 per cent) is committed to wheat production, so the main benefit of tactical adjustment of the wheat area is to avoid losses in poor seasons (seasons 8 and 9) by reducing wheat areas on the heavy clay soil classes likely to yield very poorly in such seasons. However, because yields are low in these seasons on these soil classes and because these soils only comprise 25 per cent of an average farm's arable area, the effect of these tactical adjustments on expected wheat production is small. By contrast, at low wheat prices less land (e.g. 30 per cent) is committed to wheat production and there are significant benefits of tactical adjustment of wheat areas. For ex... in seasons likely to produce high yields (seasons 1,2,4 and 6) large opportunistic increases in wheat area are possible, particularly on the sandy loam and heavy clay soils. In these seasons increases in wheat area are supported by higher pasture yields that allow higher stocking rates. Sheep are moved into higher stocking rate situations releasing their former grazing land for cropping. These opportunistic increases in wheat area in the better seasons at low expected wheat prices result in large increases in wheat production. The different benefits derived from tactical adjustment of wheat area at high versus low wheat prices cause some convergence of the supply responses in the *with* and *without* area adjustment cases. For example, results for the 1981/2 to 1985/6 price series show some convergence of the supply responses in the *with* and *without* area adjustment cases as the expected wheat price increases. Associated with this convergence is the lesser slope (the *dP/dQ* component) of the supply curves that include area adjustment. The anatomy of these supply curves with their inherent changes in benefits from tactical adjustment of wheat area mean that the farm manager is less responsive to changes in expected wheat prices.

Overall, at any given level of wheat price, the facility to adjust wheat area within a season tends to increase expected farm wheat area (relative to the case where the facility is lacking) and it more definitely increases expected production. It particularly affects production across seasons and soil classes making the farm manager slightly less responsive to changes in expected prices.

The finding that inclusion of within-season area adjustment reduces the price elasticity of supply response has important ramifications for other supply response studies be they based on econometrics or mathematical programming (MP). In many cases, the representation of supply response in econometric models might be improved by inclusion of variables that capture the likelihood of within-season adjustments to crop area. For example, cross-sectional and time-series data on the commencement date for sowing wheat and/or measures of soil moisture in early autumn could be variables worthy of inclusion. Even proxies for these variables derived from rainfall and evaporation data could be usefully introduced. For MP supply models, one implication of these results is that these models should also capture some of the important production ramifications associated with including within-season adjustments to farm plans, otherwise these models risk over-estimating the price elasticity of supply. In practice this would mean designing models to describe climatic variation and production responses to such variation.

The inference from this study that researchers who ignore effects of within-season tactical management may over-estimate the elasticity of the wheat supply response also has relevance to research or innovation assessment studies (e.g. Marsden et al. 1980; Edwards and Freebairn 1984). Many of these studies draw upon estimates of own-price elasticities of supply, some of which may need revision to include the influence of within-season tactical adjustment of wheat area.

(Table 2 about here)

The estimates of own-price elasticities of supply (production) given in Table 2 are mostly in the inelastic range (i.e. $\epsilon < 1$) and are consistent with those generated in other studies listed in Table 3; perhaps only because there is a wide range of reported elasticities! Adams (1988), for example, reviews five supply studies (Adams 1987; Dewbre et al. 1985; Fisher and Munro 1983; McKay, Lawrence and Vlastuin 1983; Wicks and Dillon 1978) and comments that the differences in their elasticity estimates are "indicative of the current lack of consensus concerning short-run supply elasticities for agricultural commodities in Australia."(p. 354) He concludes that the differences are due to the variety of approaches and data used in the studies.

(Table 3 about here)

Pandey et al. (1982) also show how the period of data can affect elasticity estimates. They found short-run and long-run elasticities of aggregate agricultural supply in Australia increased over the period 1950-1 to 1975-6. Results in Table 2 are consistent with their findings insofar as elasticity estimates for the price period 1986/7 to 1990/1 are greater than those for the period 1981/2 to 1985/6.

Conclusion

For both price periods either removing the facility to tactically alter wheat areas or introducing risk aversion shifts supply curves leftwards. The strongest leftwards shift occurs when risk aversion is introduced in combination with loss of area adjustment. Introducing risk aversion has no consistent effect on the own-price elasticity of supply. By contrast, including area adjustment decreases the own-price elasticity of supply for the cases of risk neutrality and risk aversior ... each price period. The explanation for the decrease in price elasticity lies in the shift and pr... responsiveness changes arising from inclusion of tactical adjustments of wheat area. One im...ication of this finding is that supply models that ignore within-season tactical adjustment of crop and pasture areas may over-estimate the own-price elasticity of the supply response.

The own-price elasticity of supply estimates generated in this study are mostly in the inelastic range and are consistent with those generated in several other studies. Results in this study help explain the commonly observed price inelastic wheat supply response insofar as seasonal opportunism or tactical responses to seasonal conditions lessen farmers' responsiveness to price changes. The results also have identified yet another explanatory variable (namely within-season wheat area adjustment) to include in the description of wheat supply response.

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1 A detailed desciption of MUDAS is available on request from the author.

2 Chavas and Holt (1990) have tested commonly applied risk specifications and found all wanting whereas Pope and Just (1991) conclude in favour of a constant relative risk aversion specification.

3 In estimating some of the supply functions an extra one or two price observations were added.

4 The assumption here is additive rather than multiplicative demand which may explain why the effects of inclusion of risk aversion are not as pronounced as some readers may anticipate.

Table I: Season types in MUDAS

Season	Opening rains	Summer rain index	Earlier sowing of lupins	Spring rainfall	Season proba-bility	Typical wheat yield (t/ha)[a]
1	early	high	n.a.	either	0.17	1.96
2	early	low	n.a.	high	0.12	1.27
3	early	low	n.a.	low	0.08	0.64
4	mid	high	yes	either	0.05	1.60
5	mid	low	yes	either	0.12	0.81
6	mid	high	no	either	0.13	1.28
7	mid	low	no	either	0.09	0.77
8	late	either[b]	yes	either	0.14	0.61
9	late	either[b]	no	either	0.10	0.57
				expected yield:		1.09

[a] Based on Perry (1990) yield simulations for Merredin heavy soil.

[b] Most of the years in this season type had low summer rain indices

n.a. Not applicable in seasons with early opening rains

Table 2: OLS estimates of quadratic supply curves and associated own-price elasticities for production and area responses

Price period	Risk attitude	Wheat area adjustment	Own-price elasticity of supply [b]	OLS estimates [a] a	b	c	R^2
Production							
1981/2 to 1985/6	Neutral	Yes	0.53	565	6.71 (2.58)	-0.0052 (0.008)	0.96
1981/2 to 1985/6	Neutral	No	0.61	-86	14.09 (3.03)	-0.0261 (0.006)	0.99
1981/2 to 1985/6	Averse	Yes	0.52	194	11.39 (2.96)	0.0205 (0.009)	0.97
1981/2 to 1985/6	Averse	No	0.69	-315	15.20 (3.12)	-0.0291 (0.010)	0.97
1986/7 to 1990/1	Neutral	Yes	0.83	-18	11.27 (2.63)	-0.0142 (0.010)	0.98
1986/7 to 1990/1	Neutral	No	1.03	84	6.81 (2.54)	0.0074 (0.010)	0.99
1986/7 to 1990/1	Averse	Yes	0.83	82	9.08 (2.01)	-0.0070 (0.008)	0.99
1986/7 to 1990/1	Averse	No	1.02	26	7.18 (1.71)	0.0031 (0.007)	0.99

Area							
1981/2 to 1985/6	Neutral	Yes	0.69	259	7.35 (2.90)	-0.0054 (0.009)	0.95
1981/2 to 1985/6	Neutral	No	0.70	-349	16.04 (2.12)	-0.0305 (0.007)	0.98
1981/2 to 1985/6	Averse	Yes	0.65	-172	13.00 (3.37)	-0.0242 (0.010)	0.95
1981/2 to 1985/6	Averse	No	0.78	-443	15.22 (3.27)	-0.0280 (0.010)	0.97
1986/7 to 1990/1	Neutral	Yes	1.01	-73	8.45 (2.42)	-0.0043 (0.010)	0.98
1986/7 to 1990/1	Neutral	No	1.16	103	4.60 (2.57)	0.0164 (0.010)	0.98
1986/7 to 1990/1	Averse	Yes	1.04	-39	7.39 (2.26)	-0.00005 (0.009)	0.98
1986/7 to 1990/1	Averse	No	1.12	79	4.66 (1.86)	0.0117 (0.007)	0.99

[a] Estimates for a,b and c from the fitted quadratic $Q = a + bP + cP^2$ or $A = A + bP + cP^2$; where Q is wheat production (tonnes), P is the on-farm wheat price ($ per tonne) in constant 1989/90 dollars and A is the area sown to wheat (hectares).

Standard errors are in parentheses and adjusted R^2 are given.

[b] Elasticity estimates are calculated at sample means.

Table 3: Various estimates of own-price elasticities of supply for wheat

Source	Estimate		
	SR	MR	LR
Wicks and Dillon (1978)	1.01[a], 1.31[b]		
Wicks and Dillon (1978)			1.40[a], 1.55[b]
Longmire et al. (1979)		0.35[c]	
Vincent et al. (1980)	0.77		
McKay et al. (1983)	0.46[d]		
Fisher and Munro (1983)		2.05	
Easter and Paris (1983)		1.73	
Dewbre et al. (1985)		0.92	
Hall and Menz (1985)		0.59[c]	
Adams (1987)	0.74		
Hall et al. (1986)			1.2[e]
Fisher and Wall (1990)	0.62[f]		

SR is short run; MR is medium run: LR is long run

[a] estimates are for Western Australia

[b] estimates are for ABARE wheat-sheep zone

[c] for all cereals

[d] for all crops

[e] for ABARE Western wheat-sheep zone for all crops

[f] for ABARE wheat-sheep zone