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Influence of strategies and heuristics on farmers' response to change under uncertainty[†]

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Hierarchical Decision Models of woolproducers' decisions provide unique insights into the impact of major price changes. Producers' lagged response in some contexts appear to be due to the ambiguous decision environment they face, their strategic goals and responses to that environment apart from lags caused by factors such as attitude to risk, expectations adjustment, adjustment costs and learning costs. Much of the response to major price changes comes from strategic decisions to change enterprises rather than marginal changes to existing enterprises. In ambiguous environments, methods may need to be found that incorporate simplifying behavioural rules and strategies.

1. Introduction

A key problem for policy-makers, economists and extension workers is how quickly farmers will respond to policy changes that affect their enterprises. Economists, extension workers and policy-makers are also interested in the factors that are important influences on farmers' decisions in response to various policy instruments so that they can incorporate the appropriate elements into their programs. Factors influencing the decisions can range from the characteristics of the available options, the resources and constraints faced by the decision-makers, the characteristics of the decision-makers and the environment in which they operate. The system is complex. Economic models used to predict farmers' response patterns simplify the decision by specifying an objective function or decision problem and deal with complexity by making further assumptions and imposing constraints

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(e.g. Thilmany 1996; Blakeslee 1997; Marshall *et al.* 1997; Pannell and Nordblom 1998; Wang *et al.* 1998; Winter-Nelson and Amegbeto 1998; Coyle 1999). Responses to change are then modelled in a mathematical programming, mathematical simulation or econometric framework. Major difficulties for the model builders include the appropriate specifications for the objective function, what assumptions to make about how expectations are formed, and which constraints and variables to include. Incorrect specification is therefore a major problem (Just 1993).

This article outlines an attempt to shed some light on this model specification problem by taking a different theoretical approach that maps the decision context to reflect the contextual complexity of many farmers' decisions. It is based on a descriptive and qualitative approach rather than the more traditional predictive and quantitative approaches of economic modellers. It addresses the questions: What processes do farmers use to make decisions that have a major impact on their response to changes in price and policy variables?; and What factors have an important influence on their decision-making processes? Hence, its aim is to inform the debate about specification rather than challenge existing quantitative approaches. These aims are consistent with the call by Just (1993, p. 29) for 'a new generation of models and research . . . at the micro level to support aggregate model specification and related forecasting, market and policy analysis'. Similar concerns have been expressed by Leontief (1993, p. 4) who called for 'more realistic, more detailed' analysis, and by Rosenberg (1993, p. 21) who argued the need for economists to 'concern themselves with individual agents'.

We used hierarchical decision models (Gladwin 1976; Murray-Prior 1998) to explore the frameworks in which Australian wool producers made major production and marketing decisions (e.g. whether to change from prime lamb production to merino ewe breeding, whether to mate some merino ewes to prime-lamb rams, and when to sell their wool). Results from models of wool producers' decisions suggest that, in markets with a high degree of price uncertainty and, to a lesser extent, when the enterprises have an extended gestation period between investment and return, long-term strategic positions taken by producers reduce their responsiveness to fluctuations. Strategies (e.g. diversification, not responding to price changes) help producers cope with uncertainty but also decrease responsiveness because they feel unable to detect meaningful trends from random fluctuations.

2. Conceptual framework

Wool producers in Australia make a range of decisions, in a complex and turbulent environment, where prices for their output (e.g. wool) and some of their inputs (e.g. money) involve major ambiguities (in the sense of Heath

and Tversky 1990)[1] that are compounded by the ever-present uncertainties of the weather. Therefore, any attempt to describe and predict their decisions had to incorporate these elements. An equally important issue was that the information-processing capacities of the wool producers are limited (as are those of the rest of us). This implies they would use simplifying rules and models based on their experience to cope with this environment. Support for this view comes from a range of sources (e.g. Simon 1955; Schoemaker 1982; Heath and Tversky 1990; Grether 1992; Kunreuther *et al.* 1995).

If the results of this study were to make a meaningful contribution to understanding wool producers' decisions, then the analytical approach needed to be able to incorporate the main features of these rules. This was so even if the consequence was the successful prediction of behaviour that would not be considered 'economically rational', otherwise the underlying reasons for the behaviour would be masked by the assumptions of the model. This requirement dictated the need for a qualitative methodology (Leedy 1993; Denzin and Lincoln 1994). Selection and development of the theoretical model and the associated empirical techniques were guided by the following beliefs:

- To develop an understanding of the reasons for the choices made by wool producers, information would need to be collected on specific decisions they had made.
- As far as possible the method of collecting the information should introduce a minimum of theoretical bias about what factors should be included in the models.

In an attempt to accommodate these guidelines a methodological framework was chosen combining features of Ethnographic Decision Tree Modelling (Gladwin 1976, 1989) and Personal Construct Theory (Kelly 1955). A detailed discussion of this framework can be found in Murray-Prior (1998). It assumes decisions are decomposed so that the various alternatives are compared sequentially using several characteristics or aspects. These can be elicited and formulated as a series of questions or criteria that form a decision tree. Theoretical bias is reduced because no assumptions are made about which factors should be included in the models. People are assumed to behave as 'scientists' whose motivation and behaviour are directed by their expectations of the future and the interactions of their behaviour with the future. The combination of Personal

[1] Ambiguous situations are ones where information is scarce or conflicting or where decision-makers lack confidence in the estimates.

Construct Theory and the Hierarchical Decision Model provides a theory and empirical model of behaviour that explains the motivation and reasons for behaviour, allows for and explains learning, and can describe and predict individual decisions.

One advantage of Hierarchical Decision Models over most qualitative approaches is that the models can be tested directly using the decision trees and individual decisions. Where errors are apparent, further elicitation can occur and then the models can be retested until a satisfactory level of prediction is obtained.

3. Data collection and analysis

Two groups were selected for personal interview from a sampling frame of graziers in the Armidale Lands Protection Board area of the Australian New England Tableland. The first or 'development' group was used to develop and test interview techniques and formats, develop initial models, refine the models and to undertake limited testing. Tests were conducted on the refined models with the second or 'test' group. The sampling unit was the management team of a grazing unit with land that could run a commercial sheep operation with at least one person who spent most of their time working on the property. Seventy-five possible contacts were selected randomly for each group (8 per cent of the total). A sample size appropriate for achieving statistical significance was not required because the methodology involved in-depth qualitative analysis. However, the main factors limiting sample size were the cost and complexity of conducting the in-depth interviews. From the 'development' group, 45 were interviewed, two of them as part of the pilot for the second series of interviews. Forty-nine were interviewed from the 'test' group. The remainder were not interviewed because they were considered part-time operators, they refused, or a suitable time could not be arranged. Interviews were conducted for the 'development' group from July 1991 to January 1992 and for the 'test' series from May to July 1992.

Two conceptually different types of decisions, categorised as major strategic decisions and major annual decisions, were modelled in the study. They were treated as separate types of decisions because they tended to involve different sets of factors. Only the major strategic decisions are discussed here. Decisions affecting sheep numbers occurred at many levels from strategic through to tactical and decisions at one level often had implications for decisions at other levels. Decisions to change livestock numbers, however, are discussed in combination with the major strategic decisions because, in a sense, they are part of the same story. Major strategic decisions were decisions that had a major impact on property management, were generally expensive to

implement, could affect financial viability and had long lead times. The types of decisions modelled were:

- Begin merino sheep breeding.
- Stop merino sheep breeding.
- Change wool diameter of merino breeding flock.
- Keep young seconds to reduce diameter of wool clip.
- Run wethers from own flock following decision to begin merino breeding.
- Begin to keep own wethers past four teeth (2 years).
- Stop running own wethers.
- Mate ewes from merino breeding flock to prime lamb rams for first-cross lambs.
- Raise own first-cross ewes (merinox British breed) by mating ewes from merino-breeding flock.
- Buy merino ewes and breed first-cross ewes.
- Mate bought merinos to produce first-cross lambs.
- Begin to buy merino woolcutters.
- Wool-diameter type of woolcutters to buy.
- Buy another wool-diameter type of woolcutter.
- Stop buying a wool-diameter type of woolcutter.
- Delay sale of wool.
- Whether to sell main lines by auction or private sale.

An attempt was made to develop hierarchical decision models that could predict annual changes in livestock numbers. This was unsuccessful because the factors involved in decisions to increase or decrease stock numbers proved to be too situation-specific and the models too complex and difficult to generalise. Therefore, only the most important factors influencing a change in livestock numbers were elicited.

Interview techniques derived from Personal Construct Theory, including the repertory test (Kelly 1955), laddering (Hinkle 1965), pyramiding (Landfield 1971) and ABC (Tschudi 1977) techniques, were used to simplify the process of identifying decisions, the elicitation of decision criteria and to overcome difficulties in distinguishing decision criteria from beliefs. For a discussion of how to construct the decision trees for the decisions mentioned above, see Gladwin (1989) and Murray-Prior (1998).

Properties averaged 1429 ha and 1017 ha respectively for the 'initial' and 'test' groups, which are similar, for the shires surveyed, to the average of 1040 ha for the Australian Bureau of Statistics (1990). Sheep numbers for the 'test' group average 3,594 per property, which is comparable to the average of 3,555 for the Australian Bureau of Statistics (1990). These were split as follows: 24 per cent superfine merino, 47 per cent fine merino, 16 per cent medium merino and 13 per cent non-merino.

4. Findings of the study

Approximately two-thirds of the models gave the correct prediction in more than 90 per cent of cases, with all but two giving greater than 80 per cent accuracy. Inaccurate models were for rarer decisions, which meant there was little opportunity to develop accurate models in the 'development' phase of the study. These rates are similar to those reported by Gladwin (1975, 1976) and Zabawa (1984). Since the results of the modelling are contained in 17 decision trees spread over many pages, only a small sub-sample can be presented here. Complete details of all models can be found in Murray-Prior (1994).

An example of a major strategic decision, the decision to change the micron of the merino breeding flock, is given in figures 1 and 2. It contains a couple of sub-decisions and examples of factors contained in other decisions of this type. The factors involved in the major strategic decisions can be considered under five main headings: (a) the trigger aspects which initiated a decision to change; (b) price changes and relative profitability of the possible enterprises; (c) strategic orientations (e.g. not to 'chase the market', or to buy in sheep, rather than breed); (d) physical context (e.g. land, labour, management skill, other enterprises, seasonal); and (e) risk (sometimes allowed for in strategy and sometimes considered separately). The influence of the first three of these on decisions and their implications for models of supply are discussed in this article.

4.1 Trigger aspects

In the initial stages of the research it became obvious that producers unconsciously filtered, or often deliberately ignored, information about the short-term relative profitability of their major enterprises. The following comments were made:

> Not going to change in the short term — a long-term strategy is more important.
> Chasing market trends is like shutting the gate after the horse has bolted.
> Don't follow trends — believe in sticking with what I've always done and I won't get into any bother.
> We're here for the long term benefit — not going to go chasing the end of the rainbow.

These comments reflect the long-term orientation of many producers which mainly arose because of the difficulty of predicting prices and their experience of prices being like a 'pendulum' which swung back in their favour eventually. In such an environment producers tended to maintain their existing mix of enterprises unless something occurred that triggered them to consider a change.

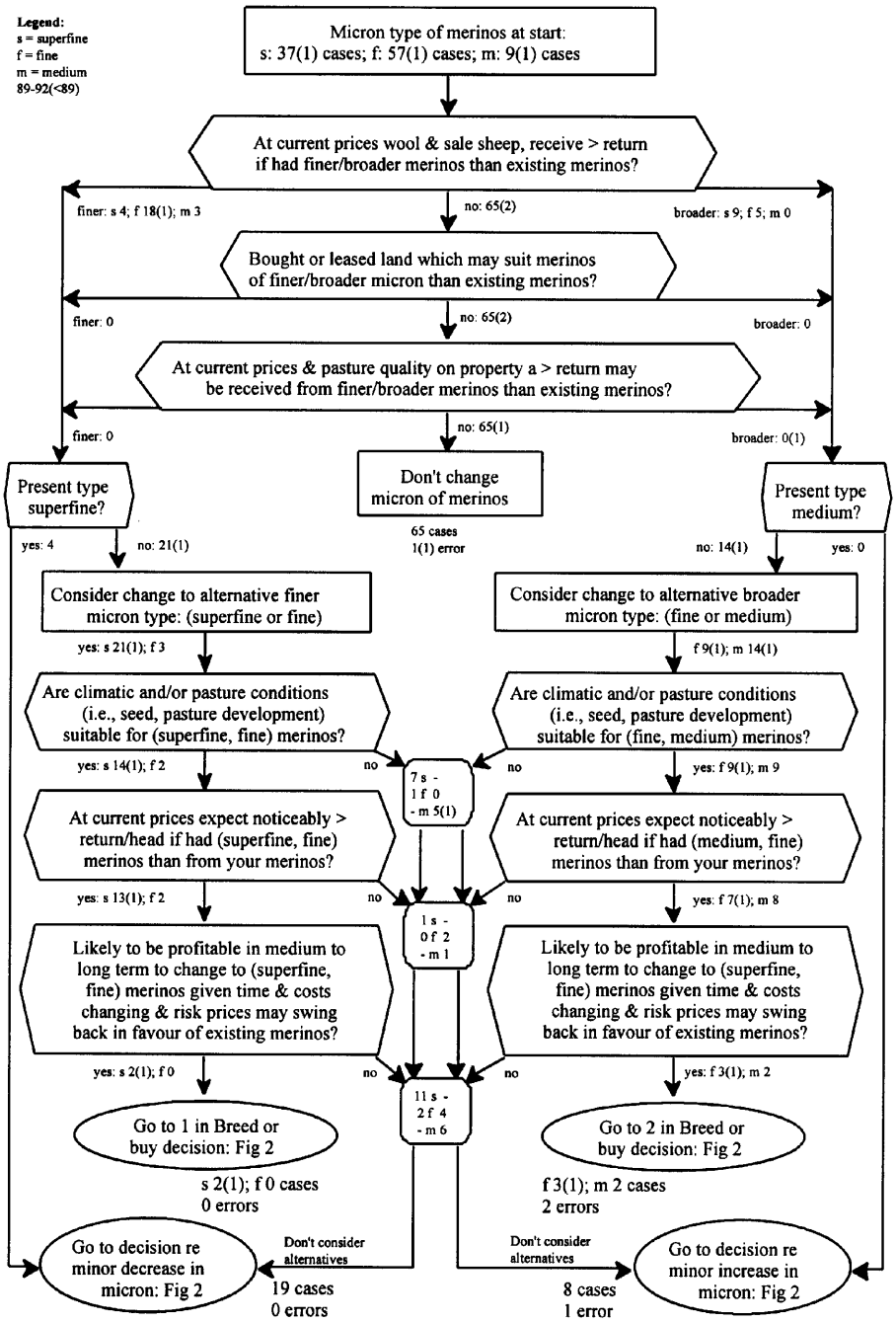

Figure 1 Change micron of merino breeding flock

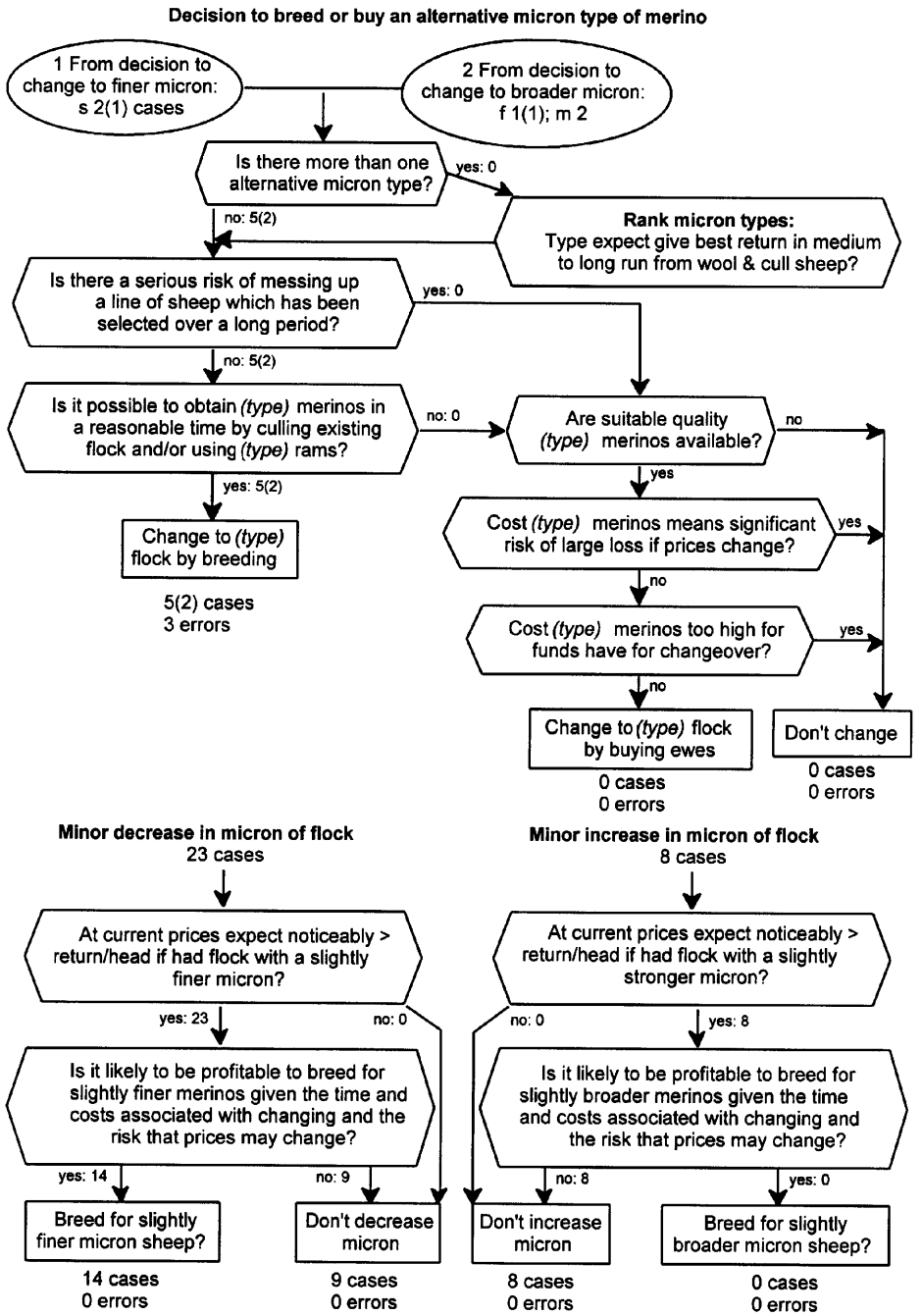

Figure 2 Change micron of merino breeding flock (continued)

In the terminology of Personal Construct Theory, producers were construing the changes in prices and climate as random events that were beyond their power to predict; thus, their best option was to ignore them. This 'view of the world' seemed the dominant view among producers, and information about other enterprise options tended to be ignored — that is, they were eliminated pre-attentively by this construct or aspect. Before they would reconstrue this view a change had to occur which was not eliminated; one which forced them to change their construction of events. These changes we called trigger reasons.

It is apparent from the response to the trigger reasons that, in some circumstances, producers were insensitive to fluctuations in prices. For instance, in 1989–90, for the decision to begin merino breeding, only four out of the fifteen producers who weren't merino breeding said that, at the prices for wool and cull sheep at the time, the return from merino breeding was noticeably better than from their existing sheep enterprises. At this time wool prices were still very high (see figure 3), and on most properties in the New England, merino breeding would have been more profitable than other sheep enterprises. One explanation is that it was common for producers to express the view that they did not know if one enterprise was more profitable than another. This appeared to result from two main factors: they had not

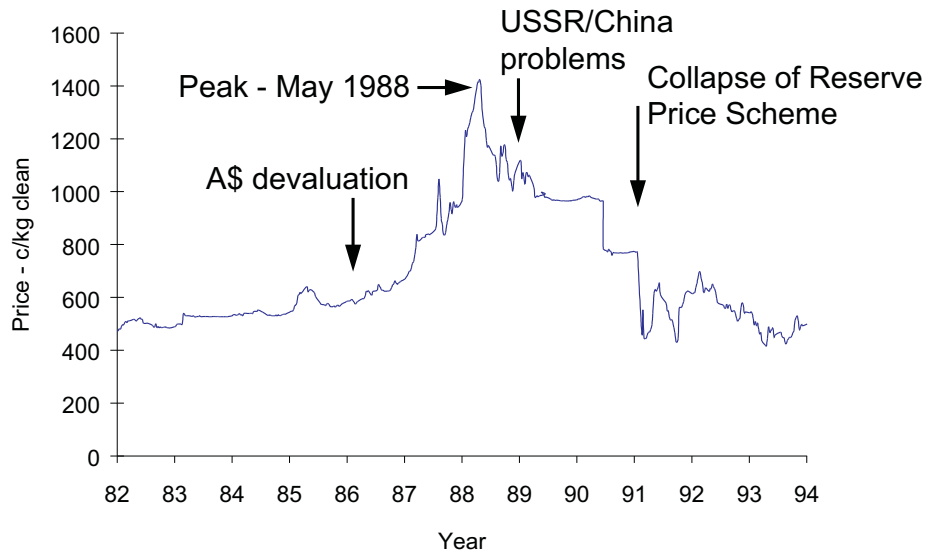

Figure 3 Variation of 22 micron clean wool prices — 1982–94
Source: Derived from Australian Wool Corporation (various issues 1980–94), *Wool Market News Annual Price Summary*, Australian Wool Corporation, Melbourne.

bothered working it out ('it's no good continually optimising . . . can't calculate profit margins all the time'); and, many producers were not sure of the production details required to calculate the profitability for enterprises with which they had little experience.

Conversely, for the decision to stop merino breeding, in 1991–92 only eight out of 36 said they had considered (no matter how briefly) that, at prices prevailing at the time, other enterprises would produce a better return than merino breeding. This was at a time when wool prices had fallen dramatically after the Reserve Price Scheme (the national floor price scheme) collapsed (figure 3).

In other words, the overwhelming majority of merino breeders were completely unresponsive, in terms of questioning their continued involvement in merino breeding, to one of the most dramatic collapses in wool prices recorded. They did not even think about it. Although they were aware of the drop in wool prices, it had not triggered a reconsideration of their involvement in merino breeding. Most of them were in it for the long haul, and while they might (and only might) consider changes to their enterprises at the margin, it would take a fairly dramatic long-term decline in fine-wool prices to make many of them seriously consider changing to something else.

In addition, it appears producers may have been aware of changes in prices, but these may not have triggered a consideration of the relative profitability of enterprises. Support for this notion is provided by the responses to the model of the decision to stop running their own wethers. Most producers who were breeding and running their own wethers saw little difference in their profitability. Typical responses were:

I'm in wool production and wethers cut you the most wool.
I haven't thought about breeding being more profitable than wethers.

Yet most comparisons of merino breeding and wethers favoured breeding (e.g. Agricultural Business Research Institute, various issues 1977–88). In the 1980s factors such as the live-sheep trade brought higher prices for cull and stock culled on age (cfa). Whereas before this period almost all the income in a traditional wool enterprise came from wool, during the 1980s a significant proportion came from the sale of stock. This shifted the relative profitability towards breeding over straight wool production suggesting a profit-maximising (or utility-maximising) producer should increase the proportion of ewes to wethers.

It appears many producers had not responded mentally, let alone managerially, to a change in the relative prices for the products produced by the two competing enterprises. The first comment above is in the nature of a 'rule of thumb' derived from experience. Together they suggest these graziers had taken a long-term strategic decision to be wool producers.

Experience from the past had been that in New England a self-replacing merino flock with a significant proportion of wethers was the best way to achieve this. The main purpose of the merino breeding operation was to provide a reliable source of wethers. Information that might lead to a change in this decision was being filtered out, or ignored, so the question of change did not arise.

Factors other than price also triggered decisions to change enterprises. For some decisions, these factors were more important as trigger reasons for a change than fluctuations in price (e.g. purchase of land was an important reason for decisions to begin running bought merino wethers).

4.2 Price factors

Not surprisingly, prices for the various products were a major influence in most of the decisions to change enterprises. Within the models themselves, wool producers' expectations of prices for the products eliminated alternatives unconsciously, distinguished between alternatives in Stage 2, and formed part of the criteria with which they assessed the risks of making strategic changes.

An example of this range of aspects is in the model of the decision to change the micron of the merino breeding flock (figures 1 and 2). The price of wool and sale sheep acted as a trigger to encourage change. At this stage current prices were the main ingredient. If fine wool prices were higher, broader wools were eliminated automatically. They assessed the likely returns from a major change to a finer micron type of merino with current prices. If this criterion was passed, then a longer-term view of prices was undertaken using a criterion that assessed the benefits to be gained from changing a strategy of 'not chasing prices'. Other points to be noted with these criteria are that the prices of more than one product were considered and that it is the return that was compared rather than the price.

4.3 Return

Return, or return per head, was used in the criteria because return was the term used most commonly by producers when comparing enterprises. It was not necessarily the same as gross margin, although a few producers compared enterprises on this basis. Nor does it imply producers always made detailed comparisons of the likely return from enterprises.

Typically what appeared to happen was that producers focused on wool prices, calculated a return per head for estimated wool weights, and adjusted it for other factors such as sale price of sheep. A comparison made on this basis had to have an obvious benefit before the criterion was passed. This

occurred because of the inaccuracy and uncertainties involved in the comparison. Although the current price of wool might have been known relatively accurately, producers were unsure of the wool weights likely to be achieved by sheep of different micron types, and of sale prices for their cull and cast for age sheep. In addition, the process of adjustment for these factors was necessarily inaccurate. Other factors such as changes in lambing percentages, and differences in wool prices between hoggets and adult sheep, created additional difficulties.

4.4 Long-term price expectations

Most models included a criterion in which price of products was part of a long-term view (five or more years) of what was likely to happen in the alternative enterprises. Many producers had little confidence in their ability to predict price in the long term (or anyone else's ability for that matter). Wright (1986) also found many sheep and wheat producers were not confident in their ability to predict the wool and wheat markets. The observations of Munro and Fisher (1982) that wool producers were unwilling to form long-term price expectations and that they tended to rely on their own experience for long-term decisions, are consistent with this finding. To cope with their inability to predict wool prices, most producers adopted the strategy of not changing their enterprises in response to price fluctuations unless a long-term trend was apparent. For the major strategic decisions long-term price trends and historical performance of an enterprise seemed more important than current fluctuations in prices.

4.5 Strategic factors

Perhaps the most important group of aspects in terms of their influence on decisions were strategic factors. The influence of such factors first became apparent in situations where producers said their only reason for not changing to another enterprise was that they did not believe in 'chasing their tail', or that they 'didn't think it actually pays to change . . . if you stick with what you've got it all takes its turn'.

The consequence of this type of thinking is best illustrated by a case where the owners of one property considered selling their medium wool flock and replacing it with a fine wool flock. With the help of a consultant, budgets for the change were worked out based on various expected prices scenarios (this was before there was any hint of collapse of the Reserve Price Scheme). The change appeared (on paper) to be extremely profitable. Yet they did not change. Their reason was that they did not believe in making dramatic changes. They were not prepared to take the risk of departing from this

strategic orientation by making such a radical change in their operation; their inherent caution won the day. As it turned out, in retrospect of course, this may have been the best decision, and did not threaten the continued viability of their operation. Risk in this sense is being used in its broadest connotation of uncertainty and ambiguity, of threat to survival of the farm business.

This attitude was typical of many producers who took a similar approach when considering a major change in direction. Long experience had shown many that they were incapable of determining, with any reliability, the direction in which the wool market was heading. It was not surprising, therefore, that Munro and Fisher (1982) found wool producers did not like to make long-term predictions about prices. About the only thing many producers felt any confidence in predicting was that, over time, the market would favour each of the grazing industries and each of the different micron types of merinos. This does not imply that producers did not change enterprises or micron types of merinos. It was found that some producers who expressed a belief in not chasing market trends still went ahead. Belief in such a policy was therefore not a decision criterion. A change in those circumstances involved a reconsideration of strategy.

To account for this problem a decision criterion was sought which distinguished between those who believed in not following trends yet changed, and those who didn't change. While slightly different wordings were used for each of the major strategic models, they followed the pattern of the criterion used for the model in figure 1. This was:

> Is it likely to be profitable in the medium to long term to change to (superfine,[2] fine[3]) merinos given the time and costs of changing and the risk that prices may swing back in favour of your existing merinos?

This type of criterion was generally effective in distinguishing between those who were willing to change their strategy and those who did not.

The apparent lack of response to changes in prices, and the reluctance of producers to change although their budgets showed otherwise, may be empirical examples of the experimental evidence of the competence (Heath and Tversky 1990) and omission (Ritov and Baron 1992) biases.

Strategy was an important aspect of wool producers' decision processes in New England to handle Knightian uncertainty. This is not to suggest they necessarily used formalised strategies, although some did (e.g. one producer,

[2] Superfine sheep were adult sheep with an average wool fibre diameter across the flock of 18.5 micron or less.

[3] Fine sheep had an average fibre diameter from 18.6 micron to 20 micron.

who worked out changes based on budgets and various expected price scenarios, said that even when they made a decision to change, they had a policy of not changing by more than 10 per cent per year). It was their approach to handling the problem that 'Under constantly changing economic conditions . . . neither the decision-maker nor the observing economist can "know" the most profitable course of action' (Pasour 1993, p. 63).

4.6 Strategy and livestock numbers

Another area in which the influence of strategic decisions is apparent is in the numbers of merino ewes mated to merino rams from 1989–92. Wool prices peaked in May 1988 and although initially the decline was slow, by mating time in 1992, prices for 19 micron wools were around one-third of the peak in 1988. Yet between 1990 and 1992, matings of merino ewes to merino rams decreased by only 4 per cent (table 1). From 1991 to 1992 (i.e. the second mating after the collapse of the Reserve Price Scheme), 44 per cent of flocks still increased matings to merino rams, while the number that decreased matings was 50 per cent. Reasons for the increases were dominated by decisions to start merino breeding and the build-up following these decisions (see table 2). Reasons for decreases in matings were dominated by the drought of 1991–92, with very few indications that ewe matings had decreased because of the decrease in wool prices.

In other words, despite a near catastrophic decline in wool prices, almost half the flocks were still increasing the number of ewes being mated to

Table 1 Matings of merino ewes to merino rams in 'test' series flocks
n = 45

Merino ewe type	1989	1990	1991	1992
Superfine				
No. ewes mated	14245	14842	17529	15930
No. properties	11	11	11	11
% of properties	24%	24%	24%	24%
Fine				
No. ewes mated	19778	21651	18010	19367
No. properties	16	18	18	18
% of properties	36%	40%	40%	40%
Medium				
No. ewes mated	3260	3194	3293	2854
No. properties	3	3	4	3
% of properties	7%	7%	9%	7%
Total matings	37283	39687	38832	38151

Table 2 Reasons for change in matings of merino breeding flocks to merino rams 'test' series 1989–92

Reasons	Times mentioned[a]			Total
	89–90	90–91	91–92	
Reasons for increase				
Strategic change reasons				
Decided to start merino breeding.	2	2	0	4
Build-up following decision to begin merino breeding.	4	6	6	16
Decided to change to this micron type of merino.	0	1	0	1
Tactical change reasons				
At prices of wool and stock, expect better return from increasing merino breeding compared to other enterprises e.g. cattle, 2x lambs, bought wethers.	2	1	2	5
Expect better return from merino breeding compared with first-cross lambs this year.	1	1	0	2
Capacity reasons				
Increased carrying capacity due to fertilising, pasture improvement and/or improved grazing control.	4	1	2	7
Increased numbers because leased, bought or planning to buy another property.	3	4	0	7
Other reasons	3	2	4	9
Reasons for decrease				
Strategic change reasons				
Decided to stop merino breeding.	0	2	0	2
Phasing out following decision to change to another micron type of merino.	0	1	0	1
Higher culling rate because trying to improve quality of flock.	2	1	1	4
Tactical change reasons				
At prices of wool and stock, expect less return from merino breeding than other enterprises e.g. cattle, 2x lambs, bought wethers.	1	1	2	4
Expect better return from increasing first-cross lambs compared with merino breeding this year.	2	0	1	3
Capacity reasons				
Dry/drought conditions, shortage of feed	0	5	11	16
Other reasons	0	2	3	5

Note: [a] More than one reason was allowed and a producer may have commented on more than one merino flock e.g. if changing from one micron type to another.

merino rams in 1992, some four years after the decline in prices began. A large proportion of these increases were the result of long-term strategic decisions to begin merino breeding, generally made several years before when prices were still rising or were near their peak. Even for the remaining half who decreased the number of ewes mated, the major factor contributing to

the decline was the poor seasonal conditions. A similar pattern was apparent in the reasons given for changes in numbers of bred merino wethers. Traditional economic and econometric models would be expected to predict a much quicker and larger decline in sheep numbers and matings than is apparent from these findings. It implies much greater lags of production response to price than is normally implied in these models.

5. Implications of results for modelling farmer responses

Modellers of supply response in agriculture (e.g. French and Bressler 1962; French and Matthews 1971; Chavas and Johnson 1982; Kalaitzandonakes and Shonkwiler 1992; Marsh 1994) have used a variety of methods to cope with the complexities of specification, including decomposing into stages and decisions, partial adjustment frameworks, expectations adjustment assumptions, and procedures to overcome specification error. The results of this study suggest that the importance given to high level goals (e.g. survival) and the strategies developed to achieve these goals in an ambiguous environment defined the context in which all decisions were made. In some instances this resulted in a lack of responsiveness to extremely large changes in price. In this section the insights from this study for specification of supply models are discussed as are the benefits that might be gained by combining qualitative and quantitative methods to provide more accurate and comprehensive understandings of supply response in agriculture.

5.1 Ambiguity aversion

An important finding of this study was that producers ignored, or did not react to, quite major fluctuations in prices unless they perceived a long-term trend (e.g. reduced consumption of lamb). When making their decisions they also used simplified decision rules that were in the nature of on/off switches rather than a continuous adjustment process. Such behaviour is consistent with an hypothesis of aversion to ambiguity (Frisch and Baron 1988; Heath and Tversky 1990; Camerer and Weber 1992; Sarin and Weber 1993; Kunreuther *et al.* 1995; Ghosh and Ray 1997; Mukerji 1998).

In both experimental and empirical studies evidence is emerging that ambiguity aversion as well as risk aversion influence decision-making (Ghosh and Ray 1997); Sarin and Webber (1993) found that bid prices for ambiguous assets were lower than for nonambiguous assets. In the insurance industry Kunreuther *et al.* (1995) found that for ambiguous risks, insurers were reluctant to offer protection. They also found that for ambiguous risks premiums were increased above those implied by standard economic theory and that it led to excess profits in the long run. When making decisions about

ambiguous risks, underwriters were also found to use simplifying rules and heuristics that focused on the potential for losses, not probability-weighted functions of return or utility. Similarly, Mukerji (1998) suggested that ambiguity aversion was a more plausible explanation than transaction costs for incomplete contracts, with incomplete contracts tending to be most prevalent where uncertainty was rife. This literature suggests that, in general, lack of information or other forms of ambiguity may lead decision-makers to be more conservative and to use simplifying rules and strategies to cope with the uncertainty.

It is also possible, as suggested by one reviewer, that asset fixity and interactions between risk and transaction costs could be alternative explanations for some of the findings outlined in this article. With respect to asset fixity (see Edwards 1959; Johnson and Quance 1972; Johnson and Pasour 1981; Chavas 1995), it is probably the case that in some instances the asset-use value of sheep may have been between the acquisition price and the salvage value. However, the market price of sheep, while it is likely to overshoot like most markets, is generally liquid and provides a good estimate of the opportunity cost and hence the use-value of sheep so this is unlikely to be even a medium-term issue. In any case, it does not provide the only possible explanation for much of the evidence — for example, the trigger aspects discussed earlier in relation to the decision to stop breeding wethers, or the case of the producer considering a change from medium to fine wool. Asset fixity was not what they appeared to be concerned about.

When transaction costs are defined as the 'costs of planning, adapting, and monitoring task completion' (Williamson 1987, p. 2), or the 'economic equivalent of friction in physical systems' (ibid., p. 19) and include some of the costs discussed in Chavas *et al.* (2000) or Key *et al.* (2000), the issue is so broad that it is certain they will provide an explanation for some of the evidence presented in this article. In fact, the comment by one producer that you 'can't calculate profit margins all the time' supports this.

Transaction costs are also likely to contribute to the need for farmers to rely on strategy in order to cope. However, 'friction' does not appear to be the problem when dealing with ambiguity. '[I'm] not going to go chasing the end of the rainbow.' Lack or cost of processing time, or power, or whatever else is needed to overcome 'friction' in the system, does not appear to be the issue. Many farmers interviewed in this study appear to have adopted strategic positions in response to the ambiguity of the environment that resulted in them being indifferent to, in some cases, rational opportunities, as indicated by the examples referred to in the previous paragraph. Transaction costs were not the main concern although they may intersect to some extent with concerns about ambiguity. Ambiguity, patterns of thinking and strategic responses adopted in response to ambiguity, consistent with the

literature above, appear to subsume transaction cost concerns and may therefore be alternative and plausible explanations that require further investigation.

5.2 Expectations and adjustment mechanisms

A fundamental problem for models of supply is the appropriate method for incorporating price. Most incorporate a mechanism for modelling price expectations. Lags in response of production to prices are sometimes attributed to lags in the adjustment of price expectations. A variety of procedures are used: naïve expectations, adaptive expectations, polynomial representations of previous prices; linear and non-linear rational expectations and futures markets. Just (1993) provides a concise discussion of the advantages and disadvantages of these procedures. While adaptive expectations are the most commonly used approach, tests have not found any of the models to be the most appropriate (Just 1993; Garcia and Leuthold 1997).

As indicated earlier, in this study quite major fluctuations in prices were ignored or not responded to by producers for considerable periods due to strategic responses, apparently in response to ambiguity. When responding they tended to use simplified decision rules and on/off response patterns rather than continuous adjustment processes. Response to price fluctuations was also found to be context-dependent. By this it is meant that some changes in prices in one context led to a change in behaviour while the same, or even greater, changes in another context had no effect. Just (1993) suggests perceived permanence of price changes as an explanation for this type of behaviour; however, ambiguity of the decision-making environment is probably a more comprehensive explanation. Many models of the formation of expectations (e.g. distributed lag models) use past observations of prices that are assumed to have consistent weighting, implying a fixed sensitivity to the value of the variable. Such an assumption may not be appropriate. It is certainly not appropriate at the individual level, and the collective response of wool producers in this study to the collapse of wool prices suggests it may not be appropriate at the aggregate level, either. It also provides an explanation and support for the suggestion by Just (1993) that the different estimates of short-run elasticities over time in supply models may be due to factors not included in the problem — perhaps the contexts in which the decisions are made. Over time these vary and hence the responses will vary, implying a need for models to allow for varying lag weights. How these weights might vary and how this could be incorporated in supply models is an area for further research. The recent paper by Key *et al.* (2000) is an example that takes account of the context of decisions, but not in the sense of changes in the environment that is the focus of this article.

Even if information about producers' expectations was collected by means of a survey, the level of confidence in these expectations, or the context of their application, could influence decisions based on these expectations. This might occur in the same way that level of confidence has been shown to affect the use of elicited or implied probabilities (e.g. in the Ellsberg paradox). In this study evidence was found of reluctance to bet (or gamble) on expectations about wool prices. However, as is expected from economic theory, in this research and that of Munro and Fisher (1982) the long-term history of prices is an important factor in producers' decisions. Yet, they do not like to make long-term predictions about price, even though some decisions are based on a view of what is likely to occur in the long term.

A further debate relates to whether the significance of lagged variables is due to price uncertainty or the costs of adjustment. Based on data collected from producers in the three wool-producing regions of the state, Munro and Fisher (1982, p. 222) argue the distributed lags 'are attributable more to the costs of adjustment than to the effects of price uncertainty'. Their argument is not necessarily valid and, in any event, the evidence from the decision models suggests it may be an unresolvable 'chicken or the egg' problem. The lack of significance in their models attributed to prices lagged more than one period may be due to the assumption of fixed sensitivity, not lack of influence in the formation of expectations. If the effect of past prices depends on the context in which the change takes place, then the further removed the period, the more variable the influence is likely to be. Sometimes it may be relevant; in other cases, possibly not at all. In addition, the Munro and Fisher (1982) study was conducted during a period of relative price stability with the Reserve Price Scheme in operation, while the present study was conducted during a period of turbulence.

More recently models of expectations based on the rational expectations approach of Muth (1961) have been used. These models assume that producers have an underlying model of the economy which is continually updated rationally through a process of learning and that this model is used to generate price expectations. Just (1993) raised a number of problems with these mechanisms, including the requirements to formulate such a model, problems of forecasting exogenous variables and empirical problems with generating rational expectations mechanisms. However, the evidence from this study suggests a key problem for the rational expectations model arises from its underlying assumption that the information is unambiguous. If decision-makers face an environment where information is ambiguous, then the Bayesian type learning implied in the rational expectations model has some serious problems (Hodgson 1997). In fact, many farmers in this study did not believe they or anyone else had a clear idea of what would happen to prices in the future. To put in perspective the magnitude of the problem for

wool producers, one only has to remember that in the couple of years before the collapse of the Reserve Price Scheme (and even after) no one was making any predictions that remotely resembled the decade of low prices that followed.

Another approach has been to use futures market prices. However, while these may be useful for modelling annual planting, or tactical adjustment decisions, the prices they represent are unlikely to offer a valid representation of expectations farmers are likely to use when making long-term strategic decisions.

An area for further research could be to look for insights into how some of these issues might be handled from decision models that attempt to incorporate ambiguity (see Camerer and Weber 1992; Sarin and Wakker 1998).

5.3 Use of simplifying behavioural rules

Just *et al.* (1990) provide evidence that simple behavioural rules may explain farmer behaviour more successfully than a model assuming profit maximisation. This is interpreted by Just (1993) to be due, in that case, to habit formation and that practices will be modified in response to profit if the opportunity costs become sufficiently large. Presumably this partly explains the lack of response of wool producers in this study, but their deliberate strategy of not following trends provides an equally compelling explanation. It provides a better explanation of the cases where producers did not respond despite ostensibly quite compelling profit advantages. The evidence from studies of insurance markets (Kunreuther *et al.* 1995) and artificial intelligence (Hodgson 1997) supports the findings of this study in suggesting that, in complex, ambiguous environments, decision-makers are likely to make their decisions on the basis of habit or rules. The problem is to identify when and how these habits and rules are applied.

Take the suggestion by some producers that they run wethers because they 'cut the most wool'. This sounds suspiciously like a habit. It is also possible that behaviour that might be interpreted as habit derives initially from a deliberate strategy that has been in operation for a long period of time. To complicate matters further, if strategic approach rather than habit is the explanation for lack of response, then producers may be more (or less) responsive to change because the former is part of conscious process while the latter is an unconscious process.

Another possible explanation for some lack of response, which is consistent with the strategic explanation, is that limited cognitive capacities mean that producers can only pay attention periodically to the profitability of their enterprises (Earl 1990). Thus, consideration of change will occur if

something happens to attract the person's attention, or the person has a policy of undertaking reviews at regular intervals. This view is consistent with the role of triggers in initiating change found in this study. Such triggers can lead to sudden kinks in response, a major example of which is that caused in the United States by the 1973 USDA call for farmers to plant 'fence row to fence row' (Just 1993). Qualitative studies such as this can provide an insight into such effects.

If, in addition to the presence of triggers, decisions at the micro-level are made with hierarchical decision processes, then models that assume smooth functional forms with continuous first- and second-order derivatives may have problems at the aggregate level. The defence against this argument has been a form of the 'as if' argument based on the assumption that the aggregation of the data will negate the non-additive effects at the micro level. However, because livestock numbers in this study were extremely slow to respond to the decline in prices and this occurred across the whole of the sample, the 'law of large numbers' is unlikely to render the behaviour identified in this research insignificant in aggregated data. The behaviours were noticeably biased in one direction and were apparently not cancelled by other producers' reactions for other sets of circumstances and other types of land.

This is not to say that models incorporating simplifying behavioural rules or other non-standard techniques need to be applied in all, or even most, situations. However, it does suggest that further research is required into the issue of when they are appropriate and how they might best be modelled. There is some suggestion from this research that non-standard techniques are less relevant to tactical adjustments and more applicable to larger shifts caused by strategic responses.

5.4 Decomposing production

There has been a long history of decomposing models of production into various stages related to the overall technology, production or marketing processes (French and Bressler 1962; French and Matthews 1971; Chavas and Johnson 1982; Kalaitzandonakes and Shonkwiler 1992; Marsh 1994). The conclusion to be drawn from this study is that these relationships can be complex. Individual decisions may often be taken in semi-isolation, perhaps using different decision processes and using different types of expectations or decision rules about prices. Decisions to change the micron of a merino wool flock may interact with other decisions about, for example, whether to keep cull ewes for an extra year. Both will have an impact on the number of sheep and the supply of wool in the current and subsequent years. The continuing influence of the strategic decisions, to begin merino breeding on subsequent

matings of merino ewes, shows that decisions about changing enterprise are long-term decisions that continue to have effects even when the original reasons for the change have disappeared. This implies a need to treat decisions to change enterprises differently from decisions to change the size of an existing enterprise. This does not relate to decomposition on the basis of technology, production processes or marketing processes but to a distinction between tactical and strategic adjustments. Hence, supply models of complex livestock systems would benefit from studies such as the present one that looked at the various important decisions that influence the overall supply.

5.5 Variable specification

Correct specification of the variables to be included in models is a key issue because omission bias can lead to biased estimates of the parameters. However, modellers also have to determine the appropriate structure, functional form, and coefficients of important variables if they are to be successful (Just 1993). It is extremely difficult to address all these issues at once with the limited data that is normally available. While imposing constraints from economic theory is one approach that can help with this problem, as has been indicated above, this should be treated with caution if economic theory is not relevant for particular aspects or a series of decisions in the production process. Preliminary qualitative studies may help with both issues of variable specification and relevance of economic theory. Marketing research is one discipline that makes extensive use of qualitative studies as a complement to quantitative studies, particularly for identifying important variables.

6. Conclusion

This study provides support for an hypothesis that, on farms which face ambiguity in their decision-making environment, high-level strategies developed in response to ambiguity contribute to lags in production response to price changes. This is in addition to lags caused by attitude to risk, adjustment of price expectations, transaction costs, adjustment costs, learning costs and information costs. Most of the commonly used methods for incorporating price expectations such as adaptive expectations, rational expectations and futures markets may be inappropriate for situations where decision-makers are dealing with long-term decisions in a situation of Knightian uncertainty or ambiguity. One possibility for overcoming this problem might be to incorporate simplifying behavioural rules in models of supply. Another might be to look closely at theoretical models that take account of ambiguity aversion.

Given the complexities and problems associated with modelling supply from a purely economic perspective, whether using a mathematical programming, mathematical simulation or econometric framework, agricultural economists may benefit from looking 'beyond the pale' and taking a pluralistic approach to addressing the issue. Taking a pluralistic approach would involve addressing the question of modelling supply by using more than one paradigm, each with its own set of methodologies, methods and techniques in the manner suggested by Jackson (1999). The paradigms could be used in a competing or complementary way, with investigations within each paradigm using the methods in a manner consistent with the theory of the paradigm. For example, a quantitative econometric study could be combined with a qualitative study such as this one. Jackson points out that the outcome of such a study may involve results and explanations that are inconsistent or in direct conflict, but that these would have to be examined objectively, taking into account the assumptions on which the findings were based. A less radical alternative would be to incorporate a qualitative study as the first stage of a quantitative study of supply to help identify the relevant variables as well as the technological, production, marketing and decision-making processes involved.

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