Retroanalysis of Farm Management Strategies in Southern New South Wales Using the PRISM Bioeconomic Model

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Abstract. While the profitability of farming in southeastern Australia is decreasing, the complexity is increasing. Many farms in southern New South Wales produce a mix of wheat, lupins, oats, barley, wool and lambs. The proportions of land allocated to these enterprises are variable between farms, and may be adjusted on individual farms according to fluctuations in prices, but what combination is optimal? Wide fluctuations in commodity prices occurred in the 1980s, and these presented opportunities and threats to many farmers. This study retrospectively assesses the impacts of the commodity prices of the 1980s on mixed farms in southern New South Wales. Models of farming systems are cost-effective tools for researching this and other farm management issues, and a linear and integer programming model is used in this study to identify optimal farm management for the historical commodity price data. Differences between years in the estimated operating profit and management systems of a 1,000 ha farm were informative. Although farm operating profit varied from $80,000 to $240,000 p.a. the optimum crop rotation system was almost constant. The optimum main rotation has a pasture phase (2 to 4 years) followed by a sequence of wheat, lupins and wheat crops. Large increases in the wool price in the late 1980s created a potentially profitable change in the livestock system from lamb production (from crossbred ewes) to wool and lamb production (from Merino ewes and wethers). It is concluded that the PRISM model has the potential to identify improved farm management strategies, though some modifications could make the analyses more realistic.

1. INTRODUCTION

Agriculture has progressed from a simple, labour intensive activity to a complex, profit-oriented business. Cropping systems have existed since 10,000 BC, and by 600 BC farming was sufficiently complex to warrant the establishment of agricultural schools in China. Peasants learned about rotations, machinery and economics [Trager 1992]. In Europe, new crop rotations were developed in the 7th and 8th centuries, and in the 19th century coal and diesel powered tractors began replacing animal and human power.

The green revolution of the post-war period (1946-) has seen substantial increases in the size of farms through the use of powerful machinery, chemicals and new crop varieties. Farmer numbers have consequently declined in developed countries; from 72% of the US workforce in 1820 to 2.5 % in 1991 [USDA 1993]. Farmers in developed countries now conduct large complex businesses, where appropriate farm management strategies separate the profitable from the bankrupt. Technological innovation and international competitiveness have made farm budgeting and business planning valuable and commonplace [Malcolm 1990]. The microcomputer and computer software such as spreadsheets are now important tools for researchers, farm advisors, and some farmers.

In Australia, mathematical programming models have been valuable for analysing farming systems. MIDAS (Model of an Integrated Dryland Agricultural System [Morrison *et al.* 1986]) has been successfully applied to bioeconomic problems in several areas of Western Australia, and the MIDAS concept has been adapted for use in southeastern Australia as the PRISM models (Profit-Resource Integration - Southern MIDAS, Robinson *et al.* [1995]). These models (PRISM-Wagga and PRISM-Wimmera) represent the different enterprises that operate on mixed farms and the interactions between them.

Other analyses of farm economics, such as gross margin comparisons, fail to take into account the interactions between enterprises, and typically show that cropping has higher margins than pasture-based activities. Less restrictive analyses than gross margins provide more useful information. What is needed is a system that accurately accounts for both the direct and indirect financial benefits of enterprises. For example, the benefits of leguminous pastures to following crops include weed and disease suppression and biological nitrogen fixation. Likewise, crops have benefits for livestock, including grazing value from stubbles. PRISM represents these interactions, and therefore may be used with confidence to identify the most profitable combinations of farm activities for a given set of biological and economic circumstances. PRISM-Wagga represents the agricultural production systems in southern New South Wales (Figure 1).

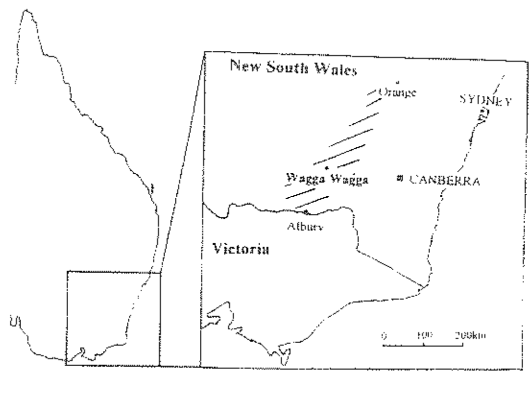

Figure 1. The geographical coverage of the PRISM-Wagga bioeconomic model.

This study is a retrospective assessment of some of the economic circumstances of the 1980s. It assesses the effects of farm commodity prices on farm management and profit, independent of climatic effects and technological advances. The aims of this study are to identify:

- the effects of price variability on farm profit,
- the management systems that maximise profit for various prices, and
- the key prices or price ratios that determine the optimum management system.

2. METHODS

2.1 The PRISM-Wagga model

PRISM-Wagga is a linear and integer programming model that calculates the long-term profitability of farming systems on the red earth soils near Wagga Wagga in New South Wales [Robinson *et al.* 1995]. Economic and biological data, such as costs, prices and yields, and the relationships between farm activities are used to select management strategies that maximise farm operating profit. Operating profit includes operating income and expenditure, depreciation of assets and the opportunity cost of capital, but not farm business costs (such as consultant's fees), debt servicing, taxation or personal expenditure.

Farming systems in southern New South Wales are relatively complex and flexible, and the model represents a wide range of farming activities, including the production and sale of wheat, oats, barley, canola and lupins. Continuous cropping is not represented, as few farmers have been able to overcome the hazards of plant disease epidemics and herbicide resistance in weeds that are inherent in crop-intensive systems. Various sheep enterprises chiefly produce lambs and wool, utilising subterranean clover and annual ryegrass pastures and crop stubbles. Grain and pasture hay are also utilised by livestock at times of limited paddock feed availability, though the use of these is restricted by their relative expense. Two of the four sheep enterprises earn income mainly from wool sales; Merino wethers and self-replacing Merinos. The first cross Merino-British breed and second cross Merino-British breed enterprises earn more income from lamb sales. Pasture is usually 100% utilised by livestock in PRISM, resulting in stocking rates that are higher than typical commercial rates by up to 50%, but are similar to rates sustainable in research trials.

2.2 Biological and economic farm data

The pasture growth data in the model are based on field experiments [Wolfe and Southwood 1980, Reeve and Sharkey 1980] and farm paddocks [Robinson *et al.* 1993]. Potential crop yields are estimated from rainfall data via transpiration estimates and efficiencies [de Wit 1958, Doyle and Fischer 1979]. The transpiration efficiencies, in turn, were calculated from grain production and growing-season rainfall data collected on local farms [Butler and Laycock 1994]. The actual yield of crops depends on the paddock history, as set by the rotation. In general, if a cereal crop such as wheat or barley is preceded in the rotation by a legume such as lupins or pasture, it has a higher yield due to weed and disease control benefits and nitrogen fixation.

All farming technology represented in the model, including machinery use, crop varieties and pesticides, is based on 1995 standards. Canola (rapeseed) is excluded from the simulations due to a lack of price data for the period of interest.

The 1980s were notable for climatic and economic volatility. The wool price in particular varied from low levels to record highs. The model uses gross price data collated for the relevant commodities (Table 1). The net (farm-gate) prices for each commodity is calculated using constant (1995) transport costs and levies. A 1,000 ha farm is simulated, on which the management system was allowed to vary completely to maximise profit in each year. In practice, however, there are many constrains limiting year-to-year management flexibility, and these results may therefore overestimate the magnitude of changes and the financial returns from making changes. Separate investment or development analysis is required to examine in greater detail the implications of management changes indicated by PRISM.

Table 1. Gross commodity prices (AUD$) in Australia from 1980/1 to 1989/90. Source: ABARE [1983-92]. Prices are free-on-board at port for grain, the clean wool auction price, and the mean dressed price for lamb at the saleyard.

Harvest	Wheat ($/tonne)	Barley	Oats	Lupins	Wool (c/kg)	Lamb (c/kg)	Wheat:wool ($/t:c/kg)
1980/81	155	142	124	179	411	128	0.377
1981	159	134	96	150	432	124	0.368
1982	179	150	137	152	443	103	0.404
1983	164	150	89	169	485	105	0.338
1984	172	137	95	127	526	105	0.327
1985	168	121	104	156	533	92	0.315
1986	151	121	100	167	626	129	0.241
1987	163	133	108	176	1050	129	0.155
1988	212	172	126	199	1026	134	0.207
1989	195	174	108	174	911	139	0.214
mean 80/81-89/90	172	143	109	165	644	119	0.295

3. RESULTS

The annual optima are shown in Table 2. The volatile commodity prices of the 1980s had a relatively large effect on farm profitability, but a modest effect on the rotation and sheep enterprise strategies that maximise profit. In 9 out of 10 years, the optimum rotation strategy was oriented to maximising the output of wheat, as the PPWLW rotation has a high crop:pasture ratio and higher wheat yields (3.14 t/ha) than alternative rotations, such as PPWW and PPWWW. The pasture ley and grain legume (lupin) crop support the high wheat yields by suppressing weeds and diseases and fixing nitrogen. In addition they derive direct profits from lamb and wool and grain sales.

The modelled profit varied by a factor of 3 ($80-239,000) between 1981 and 1988; proportionally a greater range than the price ranges for wheat or wool. This is because the high fixed costs of cropping make the break-even price of grain relatively high. Products from pastures have low break-even prices, but have low relative profitability. These effects combine to severely limit profit when grain prices are low, and magnify the effects of price increases. Half (49%) of the total profit came from the 3 best years (1987-89), indicating the strongly skewed distribution of profit between years. If this type of distribution also exists over longer periods it is likely to have important management consequences. Studies of climatic variation using the MIDAS-related MUDAS model [Kingwell *et al.* 1992] have also indicated a skewed distribution of income between years, and emphasised the importance of a small proportion of climatically benign years on long-term farm profit.

In spite of the widely varying annual profit, the main rotation is nearly constant. PPWLW was used on approximately 95% of the farm area in 9 of the 10 years. The 1988 rotation strategy that produced $239,000 profit is very similar to the 1981 strategy that only produced $80,000.

The departure from the PPWLW rotation occurred when the wheat:wool price ratio fell to an exceptionally low value in 1987 (Tables 1 and 2). The returns from wool increased the length of the pasture phase in the main rotation from 2 to 4 years, and increased the total stock numbers carried on the farm. In dry sheep equivalents (DSE, ≈ 1 wether/ha), the stocking rate rose from approximately 6,020 in 1986 to 8,690 in 1987.

There were more significant changes in the sheep enterprises than in the rotations. Self-replacing Merinos were selected in 1986 when the wool price increased to 630 c/kg and the lamb price to 129 c/kg (a one third increase over their prices in the early 1980s). They were included from 1986 to 1989, and contributed significantly to the high farm income and profit in 1987 (Table 2). The wool:lamb price ratio was a poor indicator of the optimum sheep enterprise - high wool:lamb price ratios occurred in 1984 and 1985 when a 1st cross lamb enterprise was optimal.

Table 3 shows the hay and grain feeding strategies in greater detail. Hay is cut in spring and fed to livestock over the late summer - autumn period. In 1984 lupins were fed to the sheep rather than barley or oats. The PPWLW rotation was optimum in this year due to the high wheat yields in the rotation and the moderately high price of wheat. Although the barley price was higher than lupins, it was optimum to grow lupins not barley. The beneficial effects of lupins on subsequent wheat yields in the rotations accounts for this. In the rotations, barley crops are either substitutes for wheat crops or used to extend the cropping phase of rotations, providing stored grain for sheep. In 1984 barley was an uneconomic substitute for wheat due to the high wheat price, and lupins were an economical source of stored feed.

Table 2 . Optimum rotations and sheep enterprises for a 1,000 ha mixed farm for historical commodity prices 1980/1 to 1989/90. P=Pasture, W=Wheat, L=Lupins, O=Oats, B=Barley; MW=Merino Wethers, SRM=Self-Replacing Merino, 1st X=1st cross lamb.

Year	Profit	Rotation				Grain sales		Sheep enterprise/s	
		main		other		wheat	lupins	type	number[1]
	($000)	type	(ha)	type	(ha)	(tonnes)	(tonnes)		
1980	86	PPWLW[2]	946	PPPOLWB	54	1211	418	1st X	2798
1981	80	"	"	"	"	"	"	"	"
1982	99	"	"	"	"	"	"	"	"
1983	91	"	"	"	"	"	"	"	"
1984	87	PPWLW	1000	-	-	1254	385	"	2784
1985	92	PPWLW	946	PPPOLWB	54	1211	418	"	2798
1986	95	"	"	"	"	1212	"	SRM	2865
1987	181	PPPPWLW	882	PPPPOLWB	118	838	299	MW SRM	3672 2214
1988	239	PPWLW	934	PPPOLWB	66	1202	417	MW SRM	2673 1472
1989	192	PPWLW	909	PPWO	91	1228	386	SRM	2916

[1] sheep numbers are based on a wether or breeding unit (i.e. 1 Merino ewe + followers ≈ 2 wethers).

[2] PPWLW is a five year sequence of pasture, pasture, wheat, lupins and wheat (undersown with pasture)

Table 3. Optimum strategies for the supplementary feeding of livestock.

Year	Pasture area (ha)	Hay making (bales)	(bale size)	(cut)	Grain feeding Cereals (tonnes)	Lupins (tonnes)
1980-3	402	380	large(430 kg)	Sept.	14 barley + 27 oats	nil
1984	400	"	"	"	nil	39
1985-6	402	"	"	"	14 barley + 27 oats	nil
1986	"	370	"	"	"	"
1987	563	9500	small (23 kg)	Oct.	26 barley + 51 oats	"
1988	402	6300	"	"	17 barley + 33 oats	"
1989	409	380	large (430 kg)	Sept.	42 oats	"

4. CONCLUSIONS

The 1980s were very challenging for farmers. The early years were marked by drought and low commodity prices. Even under average yield conditions, PRISM-Wagga indicates that the most profitable farming systems achieved less than $100/ha operating profit. Servicing a farm debt and personal expenditure from this return would be difficult in many circumstances. The coincidence of drought with low prices was a further difficulty.

A major economic feature of the late 1980s was the effect of the wool price rise on farm profit, as shown in Table 2. The profit results of the model for 1987/8, 1988/9 and 1989/90 indicate the potential for farmers with Merino flocks to capitalise on the opportunities of volatile prices.

While the PRISM model's results are interesting and informative, there are some limitations. These include: (I) management was completely flexible between years, and (ii) yields were set to the long-term average.

If these limitations of PRISM and some other farm management models are overcome (and there is no technical reason why this is difficult), scenarios could be examined in the more realistic ways shown in Table 4. Dynamic annual crop and pasture yields could be derived from historical climatic information. Wheat yields have been simulated from rainfall and evaporation data [Cornish and Murray 1989], but a system has yet to be developed for relating pasture yields to rainfall.

Table 4. A range of price, yield and management conditions applicable in farm model studies.

Simulation	Prices adjusted	Yields adjusted	Management adjusted (to optimise)
This study (perfect foresight)	annually	fixed	annually (current year)
I. Fully dynamic	annually	annually	annually (current year)
II. Realistic	annually	annually	limited annual change (whole period)
II. Hindsight	annually	annually	annually (previous year)

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