Modelling the impact of water policy reforms on dairy farm performance in the Southern Murray–Darling Basin

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Multiperiod linear programming models of dairy farming in the Murray Valley are presented in this paper. The models simulate the ability of dairy farms to adapt to changing rural water policies within the constraints defined by the farms' financial and resource characteristics. Technological, institutional and environmental aspects are incorporated in the model. A detailed description of the model is provided with an illustrative example of the effects of increasing water charges on farm performance. The derived demand for water for irrigated dairy farms in the Murray Valley is discussed.

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1. Introduction

Irrigated agriculture in Australia is currently facing a number of challenges. These include a program of rural water policy reforms, declining soil and water quality in many irrigated regions, and changing world supply and demand conditions for agricultural commodities. The challenge for irrigators is to adjust the mix of their production inputs, technological processes and resource use options in the light of these changes.

The ability of farmers to react to these changes depends on a number of factors including the financial and resource characteristics of the farm, farmers' business goals and their attitudes to risk. The range of production possibilities available, the optimal mix of production inputs and the profitability of alternative enterprises will change over time because of the dynamic nature of a farm's operating environment. The longer term viability of farm businesses will change, depending on the returns obtained from the adoption of new technology, the potential for expansion of farm operations and the capacity to identify and adjust to the optimal mix of enterprises.

Given differences in resource attributes and a wide variation in farm performance observed across industries, significant changes in the regional profiles of irrigated farming may result from the water policy reforms. For the objectives of government policy reform processes to be met, with least cost to the community, there is a need for improved information on the potential impacts. An understanding of the level and distribution of current financial performance of irrigators, and their ability to adapt to changing circumstances, will be an important aid to governments and the farming industry. Farmers require insights into the possibilities available to adapt to changing policies while governments require information on the likely extent and costs of adjustments. In this context, the Dairy Research and Development Corporation (DRDC) commissioned ABARE to conduct a policy analysis on the irrigated dairy industry in the Murray Valley.

This paper presents a detailed description of the modelling approach adopted for this analysis. The modelling system provides a framework to assess the medium term responses of irrigators from changes to their operating environment. An illustrative example of a model simulation is outlined and some results are discussed.

2. Modelling Objectives

The main objective of this research is to analyse the implications of institutional/policy changes in the water sector on the medium term performance of irrigated dairy farms. The study area is defined as the Murray Valley, an important region for dairying and a region with a number of emerging environmental concerns, such as salinity and rising watertables. The Murray Valley is centred around the Murray River and contains a number of irrigation areas and districts in both Victoria and New South Wales. Dairy farms are concentrated in the Berriquin irrigation area in New South Wales and in Victoria the Shepparton and, to a lesser extent, Kerang irrigation areas.

The Murray River forms the border between New South Wales and Victoria, and the development of irrigation industries has been influenced by differing State policies. The irrigation areas in northern Victoria were largely established by the early 1900s and were prompted by closer land settlement objectives of prevailing governments. In contrast, irrigation development on the New South Wales side of the Murray River occurred half a century later, and the water supply was initially established for stock watering and pastures rather than intensive cropping.

There are different dairy marketing arrangements between the two States that also influence the dairy industry. Two distinct, but interrelated, sectors exist in the dairy industry; the market milk sector that produces fresh milk for daily domestic consumption, and the manufacturing milk sector that produces processed dairy products for both domestic and international markets. Milk production in northern Victoria is predominantly used in the manufacturing sector, while over half of total milk production in New South Wales is geared to meet fresh market demand. Inclusion of the New South Wales and Victorian regions in the analysis permits a comparative assessment of the different production systems in the two States, and their implications on the impact of water policy reforms.

3. Methodology

A mathematical programming approach is employed in this analysis. Mathematical programming can accommodate several interacting variables, and offers flexibility to track dynamic interactions among variables. Model parameters such as prices of production inputs and demand for outputs can be exogenously adjusted to explore their implications on farm planning and performance.

Mathematical programming techniques are widely used for analysis involving agricultural production and resource planning decisions. Williamson, Topp and Lembit (1988) used a sub-regional dairy farm model to analyse the implications of regulating dairy marketing arrangements in New South Wales and similar analysis was undertaken for Victoria. However, the activity mix and the level of disaggregation in this model were not sufficient to meet the requirements of this project. Therefore DAIRYPLAN was built by ABARE in collaboration with Agriculture Victoria and the New South Wales Department of Agriculture.

Wall, Marshall, Jones, and Darvall (1994) used regional representative farm models to look at the implications of Land and Water Management Planning options on farm productivity and watertable recharge in New South Wales. This model and the KYDAIRY (Branson 1993) model, developed to consider the profitability of different feed systems in Victoria, provided a basis for building the production matrix of the DAIRYPLAN model. Importantly, the original models were specified only for a single year, while the focus of the current research is to consider adjustment options available over the medium term. Consequently, a time dimension, capital, investment and taxation activities adapted from earlier modelling work by Mallawaarachchi, Hall and Phillips (1992) were included in DAIRYPLAN.

3.1 Model description

DAIRYPLAN is a multiperiod optimisation model designed to closely reflect the irrigated dairy industry in the Murray Valley irrigation region. The model focuses on the development of alternative irrigation adjustment scenarios to face the challenges offered through water policy reforms, including the evaluation of possible on-farm investment options, and their implications for farm performance. The optimisation period (t) is twenty years and consists of twenty single year time periods (y) that are grouped into an eight-year farm development phase followed by a twelve-year stabilisation phase. Each year is further subdivided into seasons and single months in order to reflect intra-seasonal variation in pasture production, water availability, crop–water requirements and the livestock energy demands.

3.1.1 Objective function

The model objective function maximises the cumulative net cash surplus (S_t) over the planning horizon. It is subject to the previous year's post–tax surplus (sp_{y-1}), annual operator drawings (OP_y) and the residual loan liability ($LL_{y_{20}}$).

$$\text{Maximise } S_t = \sum_{y=1}^{t} sp_y(1+r)^{t-y} - LL_{y_t} \tag{1}$$

Where sp_y, the post-tax surplus in year y,

$$sp_y = \sum_{j=1}^{n} (c_{jy} - \sum_{i=1}^{m} a_{ijy} x_{jy} p_i)(1-\alpha)(1-\beta) - OP_y \tag{2}$$

and where c_{jy} denotes all the revenue from production and disposal activities j, in each year y,

n	is the number of activities j;
t	denotes the length of the planning horizon with time steps y,
r	denotes the real rate of interest at which annual surpluses are invested on or off-farm,
a_{ijy}	is the amount of resource i used per unit of activity j,
x_{jy}	is the magnitude of activity j,
p_i	is the price of resource i (land, labour, capital, irrigation inputs, etc),
α	is the marginal rate of taxation, where $0 \le \alpha \le 1$
β	is the marginal rate of discretionary consumption where $0 \le \beta \le 1$; and
A_{iy}	is the total availability of each resource i in each year y.

Subject to:

other resource constraints:

$$\sum_{j=1}^{n} a_{ijy} x_{jy} \le A_{iy} \quad (i = 1,\ldots,m;\ y = 1,\ldots,t)$$

The main revenue raising activity in the model is milk production, with additional revenues being obtained from sale of surplus cows, and interest obtained from off-farm investments. Productivity gains can be made through pasture improvements, changes to irrigation management, expansion of farm operations and investment in alternative sources of water or in water saving technology.

3.1.2 Planning horizon and terminal wealth

Investment decision processes involve the selection of activity streams, the timing of their introduction and the determination of the level of activity in each period. DAIRYPLAN is dynamic in the sense that input and outputs have dates attached to them. Hence the income which is the output from one year's production process becomes the input to the next year. Obviously the supply of labour, price expectations and the level of trade-off between consumption and investment can be expected to vary over time. However, the issue being addressed in this project is to consider the implications, with all other things unchanged, of water policy reforms on investment patterns and income streams. For simplification, DAIRYPLAN assumes that income is sufficient in each year to meet the optimal current consumption requirements in every year. DAIRYPLAN ignores future changes in consumption preferences.

DAIRYPLAN has the flexibility to run over a variety of planning horizons, with or without terminal values. For this analysis, a planning horizon of twenty years has been chosen as being sufficient to provide an indication of the magnitude of returns from investments undertaken. This time period was chosen to allow long enough to enable a return on large investments, particularly land purchases. This planning period is separated into two phases, an eight year development phase and a twelve year stabilisation phase. In the first eight years the model farms are able to undertake capital developments on-farm as well as to invest off-farm. The next twelve years allows the model to evaluate return streams from on-farm investments.

No terminal values have been included in this run of DAIRYPLAN. Such activities are replaced by the past twelve years of the planning horizon in which stabilisation takes place without any on-farm investments. Inclusion of terminal values in the objective function did not change the investment profiles in this particular case, due to the length of the stabilisation period. However, there are likely to be cases when excluding terminal values will distort investment decisions in long term assets. By maximising terminal cash surplus, rather than net present value, problems involved in choosing an appropriate discount rate, have been minimised (Candler 1960).

3.1.3 Taxation treatment

Analysis of the feasibility of alternative investment options requires an assessment of the after tax returns. Ignoring the effects of income taxation and the tax treatment of depreciation allowances on capital investments will misrepresent the returns on investments. Comparison between farms with different marginal rates of taxation is also invalid in this instance.

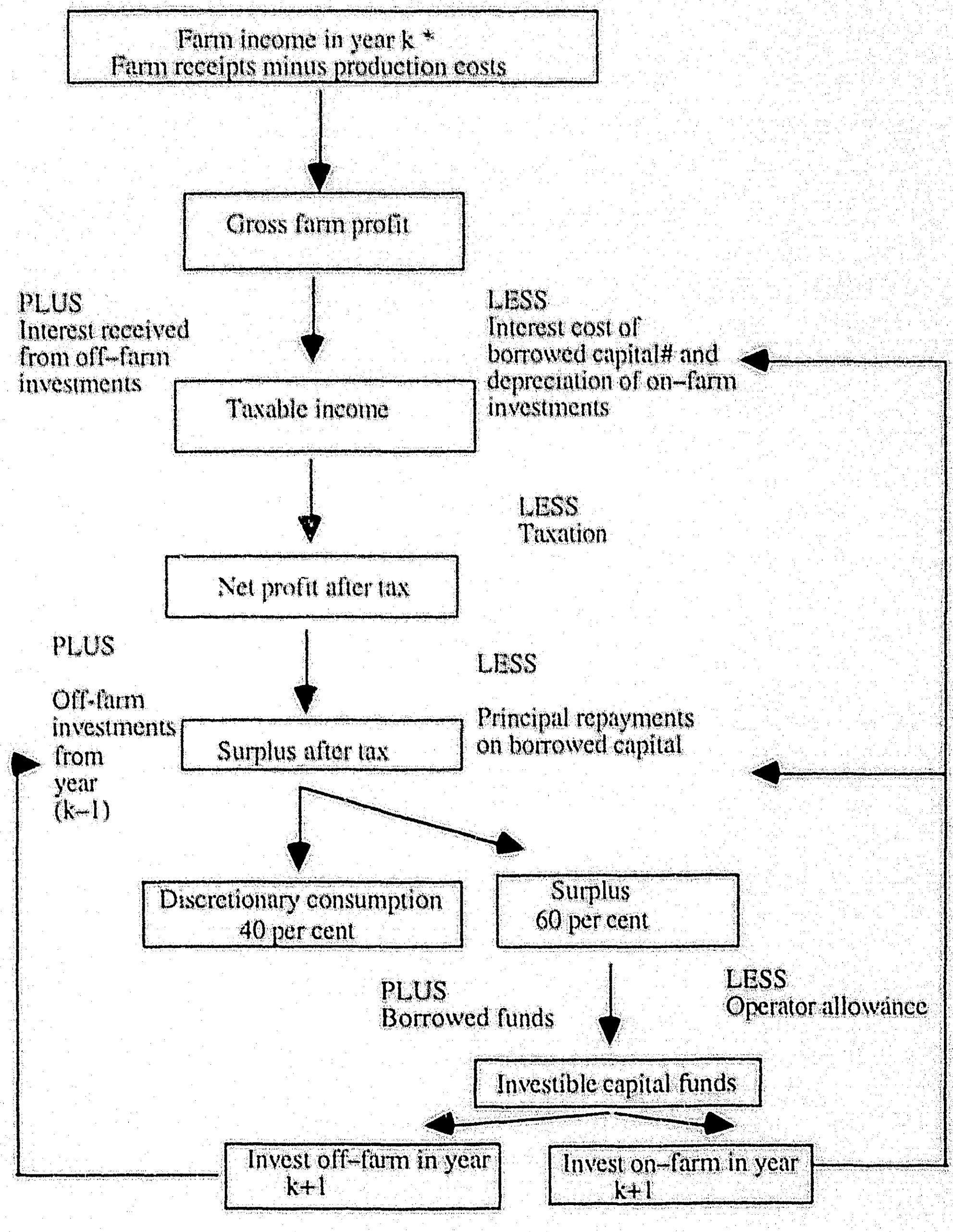
DAIRYPLAN incorporates a sub-matrix which represents the current taxation system. Since a large proportion of dairy farmers operate under a two-party partnership arrangement this is the farm financial structure adopted. The tax treatment in DAIRYPLAN is robust enough to capture the implications of taxation on relative profitability of alternative investment streams. Given the long length of the planning horizon there is some uncertainly over output prices such as milk. Further, as the focus of the research is on the implications of water policy reforms, real prices are assumed in DAIRYPLAN. Depending on the level of inflation the differential between after-tax lending and borrowing rates will vary. This has an implication for the profitability of different investment scenarios. However, given the complimentary nature of on–farm investments given the two model farms used in this simulation earn taxable incomes which place them in the same tax bracket, the assumption of real prices is unlikely to affect the modelled outcomes in this particular case. The implications for farms with different marginal tax rates of the differential between after tax rates for onfarm and off–farm investments is currently being investigated.

3.1.4 Intertemporal cash flows and accounting

The cash flows, treatment of taxation and the way in which capital is incorporated in the model are illustrated in Figure 1 (adapted from Mallawaarachchi *et al* 1992). All farm income-generating activities in each year contribute to a single revenue pool from which all farm operating expenditure is deducted. Taxable income for each period is obtained by adding any interest received from off–farm investments and subtracting the interest costs of borrowed capital and an allowance for capital depreciation. Taxable income is channelled through a sub–matrix that simulates the progressive tax system[1] to calculate the tax liability and post–tax surplus of the farm. Principal repayments of existing loan liabilities are deducted from this surplus. This post–tax income plus any additional funds from off–farm investments is then available for discretionary consumption (40 per cent) and investments (60 per cent). Compulsory operator drawings (of around $15 000 after tax) are made each year before undertaking any investments. Investment funds can be supplemented by additional borrowings (at a real interest rate of 10 per cent) in each year. Investments may be made off-farm in the form of single year bank deposits with a real rate of return of 6 percent. On and off–farm investments can be made during the first eight years (excluding the first year) of the planning horizon, but are limited to off–farm investments only during the last twelve years.

[1] Farmers are eligible to use the income averaging provision to reduce the adverse impacts of fluctuating income on tax liability. This model is deterministic and income fluctuations are only a consequence of changing investment patterns. Incorporation of income averaging was not attempted but it is unlikely to change the investment activities (although it may change the timing) because of the upward trending of incomes seen for the dairy farms modelled.

Figure 1 – Schematic representation of intertemporal cash flows and accounting



* In the first year, an endowment of funds for working capital is exogenously defined to ensure that the farm business is sufficiently liquid to meet the fixed costs and operator allowance requirements.
# The farm must meet debt repayments on existing capital debt, which is defined by the ABARE's Australian Dairy Industry Survey (ADIS).

3.1.5 Farm structure

While much of the milk and pasture production data was provided by the State departments of agriculture, an understanding of different farm structures was obtained through an ABARE regional survey of dairy farming. This provided a better understanding of the variation in the physical structure and financial performance in each of the three regions in the Murray Valley (Tran and Scoccimarro 1995). A cluster analysis procedure was used to group the sample dairy farms into statistically different groups based on the size of the farm's herd. Average values of key physical and financial characteristics (Table 1) of each of the clusters are used as input to DAIRYPLAN.

Table 1 Key parameters of the dairy farm clusters[1]

1993–94 estimates

	Units	New South Wales Cluster 1	New South Wales Cluster 2	Victoria Cluster 3	Victoria Cluster 4
Milking herd	no.	146	225	113	197
Water use[2]	Ml	560	740	220	406
TWE value[3]	$/Ml	33	33	20	20
PTWE value[4]	$/Ml	280	280	300	300
Farm income	$	77 000	151 000	46 000	85 000
Farm debt	$	127 000	223 000	64 000	131 000

1 Cluster 2 and 4 are used in this simulation
2 Total water use is net of any temporary water trading
3 This price for temporary tradeable water entitlements (TWE) does not include transaction costs.
4 The price of permanent tradeable water entitlement (PTWE) does not include transaction costs.

The grouping by cluster allows a weighted analysis of farms with different resource and financial characteristics. The main financial and physical parameters of each of the four clusters were used to calibrate the DAIRYPLAN model. The first year's output of DAIRYPLAN thus is intended to correspond to the survey average for the representative cluster. In order to illustrate the ability of the model to trace alternate production possibilities, investment patterns and income strategies, a simulation for cluster 2 (New South Wales) and cluster 4 (Victoria) is presented in this paper.

3.1.6 Farm income

The central element of the model is a dairy herd whose size is determined endogenously. Milk production is the main income generating activity. Selling yearlings and culls, any surplus on-farm production of hay, and the leasing or sale of surplus water entitlements are additional sources of income.

3.1.7 Herd structure

Victorian dairy farms operate on a single calving in spring, while in New South Wales, the necessity to sustain a constant level of milk production throughout the year results in both spring and autumn calving. In the model an average birth rate of eighty-seven per cent is assumed, with annual mortality of three per cent. It is assumed that each year twenty-five per cent of the dairy cows are replaced by heifers raised on the farm.

3.1.8 Feed supplies and demands

The main source of feed is a mix of perennial and annual pastures under irrigation. Dryland pastures provide additional flexibility in feed supply. Pasture quality and utilisation are assumed to vary on a monthly basis for different types of pasture. Perennial pastures can be converted to hay and silage (with some reductions in quality) to supplement the seasonal nature of pasture production. These stocks can be transferred to following years to allow flexibility in supplies. Supplements of barley grain and hay can be sourced off-farm. Feed supplies from all these sources are accounted for in monthly feed pools that are available to match monthly energy demands of the herd.

Yearly milk yields per cow are determined exogenously and are related to a monthly lactation curve for the farm. Since calving generally occurs over three months, the lactation curve was derived assuming calving percentages of 70, 20 and 10 over successive months. Feed demands are met by matching monthly energy requirements of lactating cows with energy supplies from feed pools. Base energy requirements are also set for yearlings, heifers and dry cows. There are maximum monthly intakes for each source of feed. As well, cows have a total gut fill reflecting physiological limits.

3.1.9 Land, labour and water resources

Dairy farms in the Murray Valley are generally located on sandy loam or loam soils both of which are included in the model. The farm area is divided into a number of layouts such as land formed border check layouts, non land formed and border check layouts and dryland areas. These layouts and soil types limit the types of pastures that can be grown.

Each farm has a number of sources of water available. These include water entitlements (and sales water in Victoria), access to dam spills in some irrigation months (off–

allocation water), groundwater and reuse water, and the purchase of temporary or permanent water entitlements available through trading in the water market.

Labour is sourced initially from the farm operator but can also be purchased at an hourly rate.

3.1.10 Investment opportunities

There are opportunities for both on and off-farm investments in DAIRYPLAN. The model includes a mechanism to screen out all farm developments that do not earn a market opportunity rate obtainable from off-farm investments. A real rate of six per cent (before tax) was used in the analysis (p.11 ABARE 1995) for off-farm investment. Comparisons of investment activities are made on a post-tax basis, both among farm activities and between farm activities and the market opportunity rate. On-farm investments will only be undertaken if the after-tax net return of the investment (after allowing for all costs, including the cost of any borrowed capital funds) exceeds the after-tax return which can be obtained off-farm.

There are a number of both short and longer term on-farm investments incorporated in the model. Agronomic improvements include conversion of annual to perennial pasture to obtain higher yields and a more uniform production; and the application of higher volumes of water to annual pasture to increase production. Expansion of production and potential economies of scale can be gained by increasing the existing dairy herd up to the capacity of the current dairy shed, as well as by investing in a larger dairy shed and herd. Increased flexibility in pasture production and opportunities to increase the size of the existing herd are also obtainable by purchasing additional land (although this has not been included in the simulation in this paper).

Given the focus on water policy reforms in this project, it is important to investigate the implications of management of existing water resources, the availability of alternative sources of water, and investment in water-saving technologies. The model incorporates all of these aspects. These investments increase the flexibility in the management of water for pasture production. For example, on-farm storage of various sources of water allows greater flexibility in meeting variable crop demands throughout the irrigation season. Investment in a dam enables re-use of irrigation run-off and the opportunity to install a spearpoint pump for groundwater pumping where the quality of water is suitable. Since these developments involve investment in discrete activities, they have been incorporated as binary variables. This ensures that only one of each type of investment occurs over the planning horizon.

4. Simulation approach

The model was built using GAMS (Brooke, Kendrick and Meeraus 1992) software. Simulations were conducted in an interactive manner by altering both resource constraints and parameter values as necessary. Models were designed for each State and cluster groups and were derived from a single parent matrix. Different activities and model parameters were adjusted for each simulation.

5. Water charges and water trading

Prices for temporary and permanent water entitlements vary between regions according to inter–seasonal water supplies, the timing of transactions, and the security of deliveries in any region. For these reasons it is difficult to determine an appropriate price to be used in DAIRYPLAN.

Indicative prices for temporary trading have been based on observed prices for the 1993/94 irrigation season in both States. The higher price in New South Wales (Table 1), reflects the lower security of supply in comparison to Victoria. The market for permanent water entitlements is not very active, so it is more difficult to determine emerging trends. Given that pricing information was not available through ABARE surveys, anecdotal evidence has been used to provide indicative prices in both States.

There are two components to the cost of water faced by irrigators when they purchase water on the transferable water entitlement (TWE) market. Irrigators will be willing to buy water at a price up to its opportunity cost (that is, its value in agricultural use) less the cost of water delivery charges to access the water. If, for example, the value of a megalitre (Ml) to an irrigator is $30, and the delivery charge $10 per Ml, then the premium the irrigator would be willing to pay for the temporary TWE is $20 per Ml. Thus, increases in water charges will influence the premiums at which temporary and permanent water entitlements can be obtained. The opportunity cost of water to the farmer remains unchanged unless the production possibilities and the returns associated with irrigation change.

DAIRYPLAN assumes no changes in production over the planning horizon and that as water delivery charges are increased, the premium of TWEs is reduced by a similar amount. This implies that the full unit cost of using the water from TWEs does not change as delivery charges are increased. However, as water charges increase (that is, water charges equal $30 Ml in our example), the premium payable on the TWE falls to zero. At this level of charges, the TWE market will cease to exist, unless there are sufficient changes in the irrigation farming environment that could lead to higher opportunity costs for water.

A consequence of the opportunity cost of water of an additional Ml of water remaining unchanged until charges reach the TWE value is that the investment strategy should remain unchanged over this price range. However, increases in water charges have a financial impact on farm surpluses and hence reduce equity funds. Since the cost of debt finance is higher than equity funds, the investment strategies are likely to change, particularly the timing.

By the nature of farm level models, this analysis only focuses on the water demands of dairy farmers in the Murray Valley. The extent of, and responses to, water policy reforms will vary throughout regions of the Murray-Darling Basin. Consequently, the market price of TWEs may not move directly with water charge increases in any one region. To examine this, the Irrigated Murray-Murrumbidgee Systems (IMMS) model will be used in subsequent analysis to determine the likely movement of TWE prices as water charges are increased across the whole southern Murray-Darling Basin water economy.

6. Model simulations

One of the reforms currently being implemented under the COAG agenda (COAG 1994) is increasing water charges to recover the cost of delivery. The introduction of 'full cost recovery' charges is likely to affect the amount of water demanded, farm income streams and the profitability of investment in on-farm sources of water. To provide an indication of the implications of increasing water charges on the investment profile, incomes and resource use patterns, a simulation was conducted by incrementally increasing the charge for water entitlements.

In both the New South Wales and Victorian farm models, the main impact of increasing water charges was a financial one, due to the increased cost of water delivered to the farm. Water use declined only marginally, due to the inelastic demand determined endogenously over the range of charges considered. Consequently, water costs became an increasing share of total farm costs (Table 2 and 3).

Investments in on-farm activities such as pasture improvements assisted in moderating falls in farm income, while also improving the gross margins per Ml of water. The pattern of the on-farm investments differed between the modelled farms in the New South Wales and Victorian Murray.

6.1 New South Wales Murray model farm

The model simulations suggest that, at existing charges for water ($11/Ml), it was profitable for irrigators to invest in on–farm water storage to capture and utilise irrigation drainage flows, and to augment water entitlements with groundwater pumping (assuming the quality of groundwater is suitable). This is consistent with the results of the Australian Dairy Industry Survey (ADIS) which suggests that about 75 per cent of surveyed dairy farms in the Murray Valley have installed a irrigation drainage reticulation system and about 8 per cent are using groundwater supplies.

As charges increase, total water use declines only marginally. At water delivery charges of $16 per Ml and beyond it became profitable for the farm to reduce the area to perennial pastures and to increase the area of annual pastures. This reduced the total demand for water, resulting in less off–allocation water being utilised. The loss in pasture production was somewhat compensated by an increase in on–farm hay making.

Table 2 Implications of increasing water charges on New South Wales Murray model farm, Cluster 2

Model output in year 20

Water charge[1]	Total water use	Gross margin[2]	Water costs as a proportion of TVC[3]	NPAT[4]
$	Ml	$/Ml	%	$ '000
11	1336	184	19	119
13	1336	184	21	118
16	1338	183	24	117
19	1317	186	29	115
23	1307	187	32	112
29	1287	191	37	110
37	1266	191	42	106
46	1266	194	46	101
59	1266	191	52	95
75	1266	193	58	87
97	1266	194	63	77

1 The water charge comprises two of components: a fixed and a variable charge.
2 Gross margins are defined as the receipts from milk production less the variable costs, excluding water costs.
3 Total variable costs of production.
4 Net profit after tax as defined in Figure 1.

Over the range of water charges investigated, the dam and groundwater pump remained profitable investments. Both these investments represented about one third of the water demanded by the modelled farm throughout the planning horizon. The level of increase in water charges had an impact on the timing of investments. At current water charges investment in dam storage was profitable and the auxiliary investment of groundwater pumping was delayed for a year. At higher water charges, the investment in the groundwater pump was bought forward a year, due to the larger gains from sourcing cheaper water.

6.2 Victorian Murray model farm

The model simulations indicate that, at current water charges of around $20 per Ml, it was profitable for dairy farms to become more intensive, by expanding their existing herd to the shed capacity. Anecdotal evidence suggests that this trend to larger herd sizes has been occurring in northern Victoria over the last few years. By gaining economies of scale, the model farm had access to additional investible funds. Demand for water increased to meet the increased feed requirements of the dairy herd. On-farm investments in the dam and groundwater pump provided additional sources of water to meet this higher water demand and for partial substitution of off-farm sources. Increased pasture production was possible by applying the additional water to perennial pasture. To fully utilise pasture production, both hay and silage were produced on the farm.

The use of on-farm water sources appears consistent with trends from ADIS which suggests that about 70 per cent of surveyed irrigators used re-use systems and about 13 per cent sourced groundwater supplies. Over the range of water charges considered, both the dam and groundwater pump were introduced in the second year of the planning horizon.

The patterns of income streams differ between New South Wales and Victorian model farms. Due to the lower returns per litre of milk and higher water charges in the Victorian Murray, it was profitable for the farms to maintain higher stocking rates per hectare than in New South Wales. To meet feed requirements at lowest cost, the Victorian Murray model farm had higher areas to perennial pastures and makes both hay and silage on farm. The increased pasture production obtained meant the gross margins per Ml were comparable to the NSW Murray model farm. However, while some economies of scale are obtained by higher stocking rates, incomes were lower in the Victorian model farm than in the New South Wales Murray farm.

Table 3 Implications of increasing water charges on Victorian Murray model farm, Cluster 4

Model output in year 20

Water charge[1]	Water use	Gross margin[2]	Water costs as a proportion of TVC[3]	NPAT[4]
$	Ml	$/Ml	%	$ '000
20	1105	182	16	100
26	1105	182	19	98
34	1105	182	23	95
42	1105	182	26	91
54	1105	182	31	87
69	1105	182	37	81
89	1102	182	42	73
115	1082	182	47	62

1 The water charge comprises two components: a fixed and variable charge.
2 Gross margins are defined as the receipts from milk production less the variable costs, excluding water costs.
3 Total variable costs of production.
4 Net profit after tax as defined in Figure 1

7. Interpretation of model results with respect to model assumptions

The analysis reported above is based on several simplifying assumptions, whereas farmers' actual production and investment decisions are governed by a complex interaction of factors related to their farming objectives. The implications of these assumptions on investment patterns can be investigated in the model through sensitivity analysis.

7.1 Variable water deliveries

The amount of water available for use on farm will vary between years as well as between States and regions. The simulations presented above assumed constant irrigation water deliveries throughout the planning horizon. Variability in water deliveries would be expected to influence income streams and could also influence the timing and type of investments undertaken. In particular, consecutive years of low supplies of water could potentially damage perennial pastures, or, for New South Wales farmers, result in quota penalties if milk production cannot be maintained. Results from DAIRYPLAN suggest that dairy farmers have significant financial capacity for supplementary feeding of concentrates and to invest in alternative supplies of water. To assess the consequences of water supply fluctuations, variable water availability is currently being investigated in DAIRYPLAN.

7.2 Availability of groundwater and dam storage

There are likely to be significant differences in the quality and quantity of groundwater available within the study area. High and saline groundwater levels often mean that it is not feasible to build a dam or extract groundwater. The consequences of not being able to extract groundwater or invest in dam storage were investigated for the model dairy farm within the Victorian Murray. Over the range of water charges considered, income streams declined progressively compared to the base level scenario, as the opportunity to obtain cheaper on–farm groundwater sources was constrained. Water demand was reduced by about 230 Ml compared to the base scenario resulting in less area to perennial pasture and an increase in annual pastures. Additional supplementary feeds were bought to meet feed requirements. While additional supplies of water could be obtained from the transferable water market to increase pasture production, it was cheaper for the model farm to purchase supplements.

8 Conclusions

Farm–level multiperiod models of representative dairy farms of the Murray Valley irrigation region were developed with DAIRYPLAN. They were designed to provide information on the likely responses of irrigators with different resource and technology endowments to a changing operating environment. The modelling framework offers control over several important parameters that collectively determine the nature and level of responses of farm businesses facing adjustment pressure. In particular, DAIRYPLAN includes a time dimension whole farm accounting, and a range of production and investment options. Constraints impose a realistic family consumption and business taxation regime and bring the model framework closely in line with the real farm situation.

The simulations presented in this paper show that the model dairy farms in Victoria and New South Wales Murray are able to invest in on–farm water investments as water charges increase. These investments provide alternative sources of water as well as water saving. The ability to substitute cheaper sources of water results in only a small reduction in the total demand for water over the range of water charges investigated.

Full cost recovery charges are currently estimated to be about $19 per Ml in New South Wales Murray and about $23 per Ml in the Victorian Murray (New South Wales Department of Water Resources, John De Groot, personal communication and Laurie

Conheady, Office of Water Policy Reform, personal communication, November 1994). DAIRYPLAN results indicate that water charges around these levels do not have a significant impact on the longer term viability of the model farms. Investigations of the implications of the water policy reforms on model farms covering the range of resource and financial characteristics is being assessed as part of a wider project.

While DAIRYPLAN has been developed to assess implications of water policy reform it provides a suitable framework for addressing a wide range of other policy issues. These could include the assessment of the impacts on dairy farm performance of changing milk prices, marketing polices, adoption rates of new technology and policy options for addressing on–farm effluent disposal.

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