DISCUSSION PAPER 91.10

Impacts of regulatory changes on sugar cane growers

ABARE

DISCUSSION PAPER 91.10

Impacts of regulatory changes on sugar cane growers

Scott W. Bartley and Peter J. Connell
Project 8221.101

ABARE

Australian Bureau of Agricultural and Resource Economics

ISSN 1030-9527
ISBN 0 644 22137 2

Australian Bureau of Agricultural and Resource Economics
GPO Box 1563 Canberra 2601

Telephone (06) 246 9111 Facsimile (06) 246 9699 Telex AGEC AA61667

ABARE is a professionally independent research organisation attached to the Department of Primary Industries and Energy.

Published for ABARE by the Australian Government Publishing Service, Canberra.

Printed in Australia by P. J. Grills, Commonwealth Government Printer, Canberra

Foreword

The Australian sugar industry is by world standards a low cost and technically efficient industry. But in comparison with other rural industries in Australia, it is highly regulated. These regulations control the price paid for cane, the quantity of cane grown and the sugar produced from it. Unlike most other Australian rural industries, individual producers are not able to make decisions on the level of their output and how they market their product.

The world sugar market is one of the most volatile of the agricultural commodity markets. With the removal of the sugar import embargo and accompanying domestic pricing arrangements in July 1989 the Australian sugar industry is now even more exposed to world market. It is therefore vital that individual growers and millers are in a position to act with greater flexibility to take advantage of changing opportunities in the world market.

This paper is the third in a series of ABARE studies into the costs of regulation and controls in the Australian sugar industry and is focused on the cane growing sector. The two earlier studies, published in 1986 and 1987, highlighted the gains to the sugar industry from changing the regulations and controls affecting the harvesting, transport and milling of cane. Many of the gains identified in those reports have since been achieved through industry rationalisation.

The technical results reported in this paper along with other ABARE research provided the basis of ABARE's submission to the Industry Commission's 1991 inquiry into the Australian sugar industry in August 1991.

BRIAN FISHER
Executive Director

Australian Bureau of Agricultural and Resource Economics

September 1991

Acknowledgments

The authors wish to acknowledge the efforts of Don Rudd, who developed the cane farm model, Brent Borrell, for his guidance in the earlier stages of the project, and the assistance of the many industry personnel who provided information used in this report. Acknowledgment is also given to Thilak Mallawaarchchi and Ali Abdalla for their assistance in developing and operating the model and to Gordon MacAulay for his comments on the paper.

Contents

List of boxes, figures and tables

Boxes

Figures

Tables

Summary

Regulations impose costs on the cane growing sector

Two earlier studies by the Bureau of Agricultural Economics highlighted significant potential economic gains available to the Australian sugar industry. Many of the gains identified in those studies have since been realised through industry rationalisation. In this paper, the focus of the research is on the industry regulations and controls that impose significant costs on the cane growing sector of the industry.

Origins and impacts of industry controls

. . . and prevent growers from adjusting production

The history of the industry's regulations can be traced back to 1901, with many of the subsequent regulations being introduced to solve the problems created by earlier controls. As the number of controls has increased, the efficiency of the cane growing industry has declined. The operation and effects of the various controls are strongly interrelated. Together, the controls restrict the production and activities of growers and millers so that they are not free to adjust readily either the level or the means of production in a way that ensures profits are maximised.

Land assignments create artificial scarcity of land

Land assignments, which limit the area that can be used for cane production, create an artificial scarcity of land for sugar cane production. To increase production, growers are forced to use other more expensive inputs, such as fertilisers, which increase the unit cost of production. As long as the opportunity cost of land is low and while individual producers who could profitably grow cane are prevented from doing so, controls impose a cost.

Farm peaks restrict adoption of flexible production practices

Farm peak entitlements — that is, delivery quotas for cane going to the higher priced no.1

pool, with the other cane going to the no. 2 pool — may further restrict the adoption of flexible production practices to suit particular agronomic or market conditions. The incentives incorporated into the farm peaks system encourage growers to deliver a minimum amount of cane for crushing each year. Because these amounts are generally high relative to the production potential of existing farms, they may limit the ability of growers to exploit periods of high prices and to reduce production costs when prices are low.

Modelling the impacts of industry regulations

Models developed to represent farm performance

To estimate the impacts of regulations on the cane growing sector, linear programming models of representative cane farms were developed. Although the actual performance of cane farms varies from region to region and from grower to grower, the results obtained from the model are likely to be indicative of the broad impact of regulations on cane farm practices in the Queensland cane growing sector.

Farm types modelled
– those able to expand
– those unable to expand

Two models were set up to represent two groups of farms: one for those growers who have no constraints on the availability of land suitable for cane growing and so can increase cane production and one for those growers who are landlocked and cannot grow more cane. The resources — for example, land, machinery, labour, fertiliser — of the representative cane farms reflect estimated industry averages.

Three scenarios examined

To estimate the impacts of various controls the model was run under three scenarios:

– baseline

- a base scenario, representing the industry in the 1989 season, with average assigned areas, farm peaks and farm resources for the two farm types and with prices for the no. 1 and no. 2 price pools set according to the 12 per cent pool price differential formula introduced in the 1990 season;

– 30 per cent industry expansion

- a second scenario, representing the industry after a proposed 30 per cent expansion in the cane area, with the existing system of farm peaks and price pooling arrangements in place; and

- a third scenario, representing the industry after a 30 per cent expansion in cane area, but without the existing system of farm peaks and with a single price pooling arrangement only.

– 30 per cent industry expansion and single pool price

Results and implications

Gains of $71 million a year possible

The results obtained from this work suggest that a 30 per cent expansion in the assigned cane area, relative to the 1989 season, could increase net farm revenue in the cane growing sector of the industry by around $56 million a year. The replacement of the farm peak and current price pooling arrangements with a single price pool was estimated to provide potential gains of a further $15 million a year — making total gains of around $71 million a year — as a result of increased production flexibility and improved pricing of marginal cane. The gains achieved by landlocked farms under this increased flexibility were found to partially offset the slight fall in the world sugar price resulting from the expansion in Australian cane production.

Results sensitive to price assumption

The results were found to be sensitive to the price assumptions used in the analysis, which correspond to the period between the 1976 and 1989 cane seasons. Under an alternative scenario of a more flexible Australian industry and lower world sugar price volatility, it was estimated that the average net farm revenue in the cane growing sector of the industry could be closer to $50 million a year, with the gains from increased production flexibility and better pricing of marginal cane being relatively small.

. . . but likely to underestimate gains from deregulation

However, the estimates obtained from this analysis are likely to be underestimates of the potential gains from deregulation for a number of reasons. The flexibility options in the model were restricted to exclude options such as standing over cane, late planting of cane and using alternative enterprises that would be available to increase production flexibility in some regions. In addition, the analysis is based on the existing industry structure and hence does not capture the potential gains from restructuring farm sizes under expansion or deregulation nor the opportunity for larger farms to adopt larger scale operations. Furthermore, the estimates do not include gains that would also arise in the harvesting and the transport, handling and milling sector from the more efficient use of industry capital. These gains are likely to result in lower average harvesting and milling costs.

Gains maximised if restrictions in other sectors are also relaxed

The greatest gains to the industry, however, are likely to arise only when all restrictions governing the growing, harvesting and milling of cane are removed. The potential for the industry to expand has been estimated to be even greater than the 30 per cent expansion modelled in this paper, although capital would be required to develop much of the additional area.

Increased production flexibility would help to stabilise world prices

Removal of the assignments system and hence restrictions on the sale and transfer of cane land would help to promote industry rationalisation toward the most efficient industry structure, which would result in even lower production costs. An additional benefit that might arise from increased production flexibility in the Australian sugar industry is that world sugar prices would be more stable and that the average price received may increase as the scope for other, usually high cost, producing countries to expand their protected industries would be more limited.

Introduction

Studies by Borrell and Wong (1986) and Connell and Borrell (1987) highlighted substantial economic gains available to the sugar industry from changing the regulations and controls affecting the harvesting, transport and milling of sugar cane. At the time these reports were prepared, annual industry gains of up to $130 million in the transport and milling sector of the industry and $53 million in the harvesting sector were estimated. Since then, many of the gains identified in those reports have been achieved through industry rationalisation and expansion.

Existing regulations and controls also have a major influence on the cane growing sector of the industry. In the absence of present regulations and controls, a much wider and more complex range of production choices would be available to growers. Existing controls limit the amount of cane produced and directly affect the input mix used for cane production. The controls also have a large influence on the crop management practices adopted by growers and reduce the flexibility with which growers can respond to changing economic conditions and exploit profitable opportunities.

The purpose in this paper is to analyse how growers might adjust their methods of production and level of output in the absence of these controls and to provide an economic assessment of the gains to the cane growing sector from reducing the degree of regulation.

To estimate the effects of changes in industry regulation on cane growers, an economic model of representative cane farms was developed. A broad range of potential and present economic choices that could be made on a cane farm are represented. Current controls and regulations are also represented, although not all controls could be modelled explicitly. In this form, the model can be used to provide valuable inferences about the impacts of key regulations and controls on the cane growing sector of the industry.

The origins and impacts of industry regulations

Regulations

'The basic dilemma of supporting farm prices and incomes above market clearing levels is that it inherently leads to increased production, thereby creating the incentives for further government involvement in agriculture through programs that control production.' (Knutson, Penn and Boehms 1983)

That intervention in the market place breeds further intervention is clearly illustrated in the history of the Australian sugar industry. The origins of the present controls can be traced back to the federal government's attempts to support sugar prices following Federation in 1901.

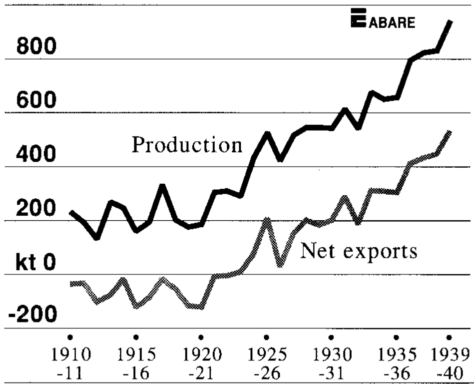
Original reasons for controls

In 1906 the Commonwealth government first intervened in the sugar industry by imposing import duties to protect the industry against the cost disabilities caused by the outlawing of the use of cheap Melanesian labour (Wood 1965, p. 22). The import duties were later replaced by an import embargo in 1923.

Higher labour costs and falling world prices squeezed growers' returns, leading to the 1915 *Sugar Acquisition Act*, which gave the Queensland government power of acquisition over the sugar cane crop and led to the introduction of domestic market price fixing by the Commonwealth government. The *Regulation of Sugar Cane Prices Act* was also introduced in 1915. Included in this Act was the formula to be used by millers to determine the price growers would be paid for their cane. With cane prices administratively determined it was also necessary to fix the terms of delivery of cane. The rate of harvesting became strictly controlled through a system of scheduling. Growers, either individually or in groups, were required to deliver cane evenly throughout a specified harvest period. Land assignments were also introduced at the same time to enforce the statutory rights and obligations of growers and millers, but were not used as a means of limiting production.

Under the pressure of increasing production (figure A), a two-price pool scheme was introduced in 1929. The highest output in any one year since 1915 was set as the limit to a mill's sugar production that would be

A Australian sugar production and exports: 1910–40



purchased at the no. 1 pool price — that price being the net average price received from sales to the higher priced domestic market. The limit was known as a 'mill peak'. All sugar produced above the mill peak from assigned or unassigned land was known as 'overpeak' sugar and was purchased at the no. 2 pool price — that price being the net average price received from the export of all overpeak sugar. The size of individual mill peaks relative to cane production in each mill area influenced grower returns and hence the allocation of mill peaks became a key issue as mill areas expanded.

In 1937 Australia acceded to the first International Sugar Agreement under which Australia was allocated an export quota of 400 000 tons. To ensure the quota was filled in all years, mill peaks were increased in 1939 in line with domestic market requirements plus the 400 000 ton International Sugar Agreement export quota. At the same time, 'farm peaks' were introduced to help enforce the controls at the farm level. A farm peak is a delivery quota that represents a minimum access right to supply cane to a mill from a particular assignment. The aggregate of farm peaks allocated to land assigned to a particular mill correspond to that mill's peak. Under farm and mill peaks, returns in the no. 1 pool were averaged over all sugar sales both domestic and export. To control overproduction, a nominal price of $1/t of sugar was set for sugar produced from cane grown on unassigned land, effectively preventing cane production on that land.

Since 1939, the peaks and assignments have continued to increase, although the peaks have not been changed since 1982.

Pressure for change

Despite increased pressure for change since 1983, industry controls have remained largely intact. Although the area of cane harvested has increased — through expansions under local awards in the assignments of existing growers and changes in the definition of assignment — the effect of assignments as a constraint on production remains unchanged.

Farm peaks, price pooling and cane delivery arrangements also remain in force although, commencing with the 1990-91 season, the no. 1 and no. 2 pool prices have been redefined. Under the new definition, the average price received in the no. 1 pool will be 12 per cent higher than that for the no. 2 pool in each season. The new pooling arrangements were introduced to resolve concerns that existing growers should not be liable for the costs of new sugar storage and handling facilities necessitated by any expansion of the industry.

It was largely because of these changes that the industry supported moves to increase land assignments. In January 1989 it was announced that land assignments would increase by 5 per cent. Then in May 1990, a further 8 per cent increase was announced. In both instances, farm and mill peaks were unchanged. All additional cane production would be sold as no. 2 pool production.

Some changes that have reduced the level of control within the industry are as follows:

- In 1986 the restrictions on the sale and leasing of assignments and farm peaks within a mill area were removed.

- In 1986 a provision known as 'roaming' was introduced. It allowed growers to produce cane on unassigned land, provided that at least 85 per cent of the area harvested was assigned land and the total area harvested did not exceed the original assigned area. Given that a common cane crop rotation is of a plant crop, four ratoon crops and a fallow period, it meant that about 16 per cent of a grower's assignment was under fallow. Effectively, roaming 15 per cent of growers' assignments meant that growers could harvest an additional area equal to what they would have fallowed each year. These roaming provisions were further modified under the *Sugar Industry Act* 1991 (section 9.1). Growers can now roam up to 100 per cent of their assigned area within the boundaries of their properties, so allowing growers to adopt less exploitive rotation practices. The area over which the assignment can be roamed, however, needs to be approved by the Queensland Sugar Corporation.
- On 1 July 1989 the embargo on imports of sugar and sugar products was replaced by a system of tariffs, to be reviewed by an Industry Commission inquiry in 1991.
- In 1989 the restrictions on the transfer of assignments and peaks between mill areas and regions were removed but required the agreement of both millers and the two mill suppliers' committees involved.
- Following negotiations between growers and millers, weekend harvesting and continuous crushing are gradually being introduced in some mill areas. In 1990, millers in the Burdekin region reached a five year agreement with mill suppliers committees in three of the four Burdekin mills to introduce weekend milling. With growers agreeing to harvesting at weekends, the company guaranteed a maximum season length, made a commitment that mill capacity would be increased to handle future larger crops within the specified season length and also agreed to underwrite the sugar cane content of cane if the crop was of such a size that the harvest would extend beyond the specified season length (Australian Canegrower 1990). Mackay mills are also introducing continuous crushing following the closure of two mills in recent seasons.

Sugar Industry Act 1991

In 1990 the Queensland government established a Working Party to recommend changes to the industry's regulatory structure in order to make the industry more responsive to changes occurring in the world sugar market. Subsequent to the release of the Working Party's report (Fitzpatrick, Watson and Soper 1990), the *Sugar Industry Act* 1991 was enacted. A new body, the Queensland Sugar Corporation, was established to replace the Sugar Board and the Central Sugar Cane Prices Board.

Among the changes introduced under the new Act were:

- the defining of assignments as an area within the boundaries of a designated area rather than as a specifically designated area,
- automatic increases in the aggregate assigned areas of at least 2.5 per cent a year for the next five seasons commencing in 1991 and

- the transfer of land assignments and farm peaks between mill areas being possible where there is agreement between the local boards involved.

The penalty for producing sugar from cane grown on unassigned land is now at the discretion of the Queensland Minister of Primary Industries.

Two reviews are to be undertaken over the next five years. First, the Corporation is to report to the Minister of Primary Industries within two years on what procedures should be followed to determine the distribution of moneys between growers and millers. Second, the Corporation is to review within the next five years the current differential pool pricing arrangements.

Impact of existing regulations

In an unregulated environment growers will aim to maximise profit by selecting a mix of technically feasible outputs and a combination of inputs that provides the greatest return to the resource base available to them. In a regulated environment, production decisions may be altered by artificial constraints placed on the resource base and by changes in the relative prices of the inputs and outputs.

The operation and effects of the various controls within the sugar industry are strongly interrelated. Growers and millers are not free to readily adjust the level or means of production in a way that ensures profits are maximised. Cane growers may be forced to adopt higher cost production strategies, and existing growers with spare land and those outside the industry who may wish to grow cane are prevented from doing so by industry controls.

Land assignments create an artificial scarcity of land for sugar cane production. The relative profitability of cane production is reflected in the fact that new peaks and assignments have in the past been taken up as soon as possible after their issue. It has recently been estimated that, in 1989, 63 per cent of present growers were landlocked, being unable to expand their cane area. On the other hand, in 1989 just over 200 000 ha (or 45 per cent of current assigned areas) of land suitable for growing cane was available in existing milling regions. Only about a third of this land was owned by existing growers (Fitzpatrick et al. 1990).

To increase production, existing growers are forced to use other more expensive inputs in place of land, increasing production costs. The cost of production, under the influence of the assignment constraint, may also be increased as a result of lower throughput in the harvesting and milling sectors and the operation of cane farms on a less than optimal scale.

Adoption of flexible production practices to exploit agronomic or market conditions may also be hindered by incentives to growers to fulfil their farm peak entitlements each year. Growers have had a strong incentive to preserve their farm peaks because the peaks entitle them to deliver their cane to the higher priced no. 1 pool, because farms are valued to a large extent according to the size of their peak and because new issues of assignments and peaks have been allocated by proportionally raising existing issues. A poor delivery record may have adversely affected a grower's claim to further issues of assignment and at worst could have resulted in a reduction in the farm peak entitlement.

Under the new sugar industry legislation, the emphasis on production controls has been shifted from the mill and farm peaks system to the land assignment system. Mill peaks have been preserved and carried forward from the repealed legislation, but the aggregate mill peak has been effectively frozen. However, while the emphasis has been placed on the land assignment system, the Queensland Sugar Corporation has the power to cancel all or part of an assignment if a grower fails to grow sufficient sugar cane to exercise fully the entitlement conferred by the assignment.

By limiting downside production flexibility, farm peaks may also constrain the management of the cane crop in a way that also reduces the upside production potential of the farm. For example, by constraining production to at least the farm peak each year, the opportunity to fallow and replant a larger proportion of the crop for harvest in an expected higher price year may be denied. Meeting the farm peak in each year may also result in higher cost production strategies, such as replanting a certain proportion of the crop each year to maintain production, when falling crop prices would otherwise encourage lower cost strategies such as continuing to ratoon a crop. Ratooned crops give lower yields than planted crops but incur

Box 1: **Cane farm management practices**

Sugar cane is a perennial crop grown along the north-east coast of Australia between Mossman in Queensland and Grafton in New South Wales. Because of differences in climate, topography and soil between regions the productivity and management of cane differs among the cane growing regions. Cane growing operations are scheduled according to the seasonal characteristics of the region and the crop. Most crop management operations take place during the dry months of the year. Harvesting occurs during the latter half of the year when the sugar content of the cane is highest.

The main tasks involved in cane production are soil preparation, planting, cultivation, harvesting and ratooning. All operations are highly mechanised and, with some exceptions in cane harvesting, are usually performed by the owner/operator.

Following the final harvest of an area of the cane crop, the soil is ploughed and usually allowed to fallow over the wet summer months. Planting then occurs at the start of the dry season, around March or April, using segments cut from mature cane stalks. The planted crop is allowed to grow for 12–16 months before the first harvest. The planting operation requires relatively high levels of labour and machine time. It is common for growers to share their labour to assist in this operation, although contract planting is becoming more popular.

Cane may also be replanted without fallow, prior to the wet season, to be available for harvest in the next season. This operation is restricted in most regions between the months of August and October. Late planted cane, as it is known, currently accounts for about 10 per cent of the cane crop. Because of the timing of replanting — just before the wet season — the risk of crop failure or reduced yield is slightly higher. Although annual yields are lower than for early planted cane, late planted cane produces more cane in total because two crops can be cut in the first two years of growth. One implication of a late planted lower production costs. Further, in periods of very low prices, alternative enterprises may be more profitable than producing cane up to the level of the farm peak.

Other regulations may also impinge on growers' production flexibility. Harvest scheduling arrangements (see box 1) restrict negotiation between growers and millers on price, quantity and terms of delivery for sugar cane such that neither group can fully exploit its own least cost strategies in supplying sugar cane or milling services.

The recent regulatory change to set the no. 1 pool price at 12 per cent above the no. 2 pool price, in effect, guarantees that resources currently excluded from the industry will receive lower returns than those already in the industry (ABARE 1988). This provision will reduce the incentive for the development of a non-entitlement sugar industry since, on average, over the long term it will force growers of cane on new land to cross-subsidise growers of entitlement cane and sugar. Further, under the new pool pricing arrangements all marketing decisions affecting the returns to entitlement sugar will have an impact on the price of non-entitlement sugar.

While most sugar is disposed of at ruling world prices, some is sold under long term contracts with the price set at

---

cane crop is that labour and machinery demands for planting coincide with those for harvesting, requiring additional labour and possibly also additional machinery to be hired.

Following planting the crop is usually cultivated until it is sufficiently high to exclude weed growth. Although mechanical cultivation is most common, chemical control of weeds is also practiced.

During harvesting, cane is cut into short lengths and loaded directly into bins towed alongside the harvester by a tractor. Full bins are taken from the field to a tramway siding or road haulage delivery point from which the cane is transported to the sugar mill for crushing. Cane harvesting is both a labour and machine intensive operation, accounting for a large proportion of cane growing costs. Although some cane growers harvest their own crops, most harvesting is carried out by grower controlled harvesting groups or by contract harvesters.

To prevent cane spoilage and to maximise cane sugar levels, cane must be crushed within 16 hours of harvest or else millers are penalised. As a consequence, the rate at which harvesting takes place is controlled through a system of scheduling. Growers, either individually or in groups, are required to deliver cane evenly throughout a specified harvesting period which usually extends from June through to December and occasionally longer.

Following harvest, the ground may be ploughed in preparation for a new plant crop or left to grow another crop, known as a 'ratoon' crop from the root that remains below the ground following harvest. Ratoon crops are fertilised and cultivated in a similar fashion to plant crops (Sugar Industry Information Service 1989). Between two and four ratoon crops are usually grown from a plant crop. Generally, yields for ratoon crops decline with age as a result of damage from pests and diseases and physical damage to the root in the harvesting operation.

In some of the drier regions, mature cane may be stood over and allowed to grow for another year. Cane that is stood over incurs little extra cost; however, the total yield is generally lower than that obtainable from two annual crops.

a given level or set within a given price band. Unlike the old price pooling scheme where overpeak cane received a price based on the world sugar price, the new scheme distorts the price of overpeak cane from the world price. As a result, it changes the relative prices of the outputs and the optimum point of production. When the world price is high and above the price received from long term contract sales, the 12 per cent rule will decrease the price for overpeak cane below the world price and reduce the incentive to grow more cane.

When the world price is low and below the price received from long term contract sales, the 12 per cent rule will raise the return on overpeak cane relative to the world price and increase the incentive to produce cane at the expense of more profitable alternatives. The formula therefore inverts the incentive structure that exists within a free market. Although producers respond rationally to the distorted price signals of the 12 per cent scheme, total farm revenue is likely to be reduced. Revenue is reduced because the price pooling arrangements only redistribute industry revenue by altering the relative prices faced by producers.

The original reasons for introducing the controls to restrict production are no longer valid. There is no evidence to suggest that the various International Sugar Agreements in place since 1937 have helped to stabilise or raise returns. The equity problems associated with allocating limited access to high priced markets can be dealt with more efficiently by using transferable market entitlements (Bureau of Agricultural Economics 1983a,b; Industries Assistance Commission 1983; Savage, Fitzpatrick, Stevens, Robinson, Bradley, Desmarchelier and Ferguson 1985) or by using a single price pool. The issue of funding new storage and handling capacity could be resolved by other means, such as issuing producers with shares in these assets and thereby providing them with a return from the operation of these facilities (ABARE 1991).

Only if Australia is in a position to extract significant premiums from overseas buyers or is able to gain significant benefits from economies of scale or scope in marketing, and is unable to achieve these in a competitive environment, can an argument be made for having central selling arrangements. Otherwise the absence of competition in marketing and the pooling of costs and returns casts doubts on whether marketing costs are being minimised and whether the development of alternative and innovative marketing approaches are being maximised.

The monopoly acquisition and marketing arrangements form an integral part of the central decision making processes which characterise the Australian sugar industry. Centralised marketing underpins the production controls and the pooling system used by the industry. Recent research shows that Australia is unlikely to be able to influence world prices to its advantage (Sturgiss, Connell and Tobler 1990). Therefore, continued production constraints, given the present cost structure and potential of the industry, limit the profitability of the industry.

Application of a cane farm model to industry deregulation

As discussed in chapter 2 the Australian sugar industry may be presently forgoing profitable opportunities in cane production as a consequence of the present regulations governing the growing of sugar cane. In a less regulated environment industry revenue could be increased through increased production, rationalisation of resource distribution and increased production flexibility. In this chapter a cane farm model is used to illustrate the potential benefits to the sugar industry of moving to a less regulated environment.

The cane farm model is a linear programming model which contains a range of the potential management strategies currently available to cane growers. It is used to represent how growers might manage their properties in a volatile price environment. The key regulations governing the industry, such as land assignments, farm peaks and price pooling arrangements, can be modelled explicitly within the model. For instance, the area of cane a grower can harvest in any one year can be limited to the grower's assigned area.

The production relationships represented in the model were synthesised from data obtained from a variety of industry sources, including the Queensland Cane Growers Council (1985) and the Bureau of Sugar Experiment Stations (1985a). Unit cost data are based on prices applying during the 1985 cane harvesting season (Queensland Cane Growers Council 1985). These prices have been indexed up to their respective levels in the 1989 season. The model also contains an alternative enterprise (raising beef weaners) to capture the opportunity cost of cane production.

To simulate how growers determine their cropping strategy for the following year, the management of sugar cane is treated as a series of fallow and plant and ratoon crops. The cane farm model is structured as ten interlinked submodels, each representing one year in the production cycle of the farm. Although the entire model is solved simultaneously, the structure of the model can be conceptualised as a chronological sequence of events.

The objective of the model is to maximise total accumulated farm net revenue over the ten year period represented in the model. On the basis of the current year's price and expected prices over the next nine years, the model finds a solution by simultaneously selecting in all years: the optimum mix of the weaner and cane enterprises, the optimum rotation for the cane enterprise and the optimum management strategy and input mix for both enterprises.

An outline of the assumptions underlying the model is presented in box 2 and an assessment of the validity and sensitivity of the model in box 3. A detailed discussion of the structure of the model is contained in appendix A.

Modelling deregulation of the sugar industry

To represent the key features of the industry in its present state, the model was set up to represent two types of cane farm, those that have no land available for expansion, commonly referred to as being landlocked, and those with the capacity to expand. The resource endowments of the two farms were derived from industry survey data (Queensland Cane Growers Council 1987) and are shown in table 1.

Late planted cane and standover cropping production activities were excluded from the model to better approximate current management practices on an industrywide basis. Neither of these production techniques is applicable on an industrywide basis. Standover cane is limited in the northern regions by the higher annual rainfall, while few growers adopt a late planting strategy. Rotation options permitted in the cane farm model are represented in figure B.

In all cases, except the base scenario for the unconstrained farm, the alternative enterprise of raising weaners was 'switched off' to prevent this enterprise from being undertaken for short periods of time. This was done because the model does not fully capture the costs associated with establishing new areas of pasture or the risk of

Box 2: **Assumptions of the model**

To represent the highly complex technical and economic production system of a cane farm in a reasonably simple mathematical form a number of simplifying assumptions were required. It was assumed that all the economic activities that a cane grower can undertake are represented by the fixed set of linear relationships specified within the model. The opportunity cost of resources used for cane growing was represented by the inclusion of an alternative enterprise, weaner production. Industry personnel confirmed that raising cattle was the only significant industrywide alternative enterprise to cane production.

It was assumed that the maximisation of the total farm net revenue over a ten year planning period was the cane grower's only objective. However, some consideration of grower risk aversion, in the face of price uncertainty, was made by imposing a minimum production constraint — 80 per cent of the average level of cane production — in those scenarios where the farm peak no longer placed a minimum constraint on production. The assumption that growers meet their farm peak in all years was considered reasonable by industry personnel.

The model farms were assumed to have a fixed complement of resources (land, labour and capital), although activities which allow the hiring of additional labour and capital are included. Hired labour resources have diminishing marginal productivity but all land is assumed to be of uniform quality. Again the latter assumption was considered reasonable by industry personnel given that the main areas for expansion are in the more productive regions.

In modelling the cane farm with a ten year planning horizon, it was assumed that prices for inputs and output from the weaner enterprise remain constant in real terms. The model represents the cane farm as an isolated entity, the behaviour of which is independent of, and bears no consequences for, other cane growers.

1 Characteristics of landlocked and unconstrained cane farms in each model scenario

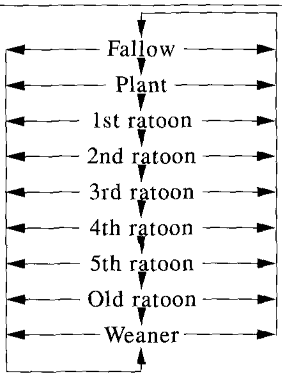
	Farm area	Cane area	Farm peak (FP) or risk constraint (RC)	Operator labour	Operator machinery
	ha	ha	t cane	hr	hr
Base scenario					
Landlocked grower	60	60	3 835 FP	1 600	2 000
Unconstrained grower	103	59.3	3 585 FP	1 600	2 000
Expansion scenario					
Landlocked grower	60	60	3 835 FP	1 600	2 000
Unconstrained grower	103	103	5 200 RC	1 600	2 000
Single pool scenario					
Landlocked grower	60	60	3 100 RC	1 600	2 000
Unconstrained grower	103	103	5 200 RC	1 600	2 000

Source: Derived from Queensland Cane Growers' Council (1987).

adopting the weaner enterprise for a two or three year period given the high level of uncertainty surrounding sugar prices.

To reflect the changing price environment in which growers operate and to capture the potential benefits of increased production flexibility, the model was run in a manner which allowed production decisions to change as prices and price expectations changed

B Rotation options in the cane farm model



ABARE

(figure C). The model was simulated recursively fourteen times to represent a fourteen year production period in the life of a cane farm (figure C). To represent how growers might alter production decisions in an environment of changing prices a ten year planning horizon was set up in each simulation. The price received for cane produced in the current year was used in the first year of the planning horizon, while expectations of future cane prices were used in the remaining nine years of the planning horizon.

The current cane prices used in each of the fourteen simulations correspond to those that occurred over the fourteen year period from the 1976 season to the 1989 season. The average sugar price over this period was around US13c/lb, in 1989-90 dollars, but the series contained some very high prices (US26c/lb) and some very low prices (US4c/lb).

To best represent how the price expectations of growers might be formed, the expectations used in the remaining

Box 3: **Model validation and sensitivity**

Because the model is designed to represent what should happen rather than to replicate what does happen, it is difficult to validate the model quantitatively. The validity of the results depends on the accuracy of the data, the assumptions used in developing the model and the structure of the model. The data used to formulate the model were derived from industry sources while the structure of the model is based on maximising compounded net farm revenue over a ten year planning horizon subject to a set of resource constraints.

The validity of the behavioural assumptions of the model and the results obtained were checked with industry personnel in a number of cane producing regions during 1988. Feedback generally supported the assumptions of the model and preliminary results obtained from the analysis.

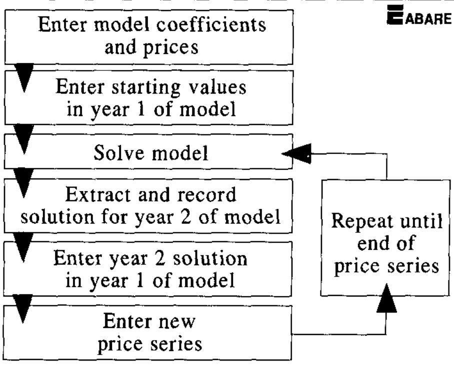
Some quantitative checks that do help confirm the validity of the model are: the implicit value of a hectare of land under cane production, generated within the base model, of around $5000, which is consistent with industry estimates for assignment of between $3500 and $5000 in 1990; a marginal cost of cane production of around $12.50/t compared with an equivalent industry estimate of $13/t to $15/t in 1990; a similar level of cane production when aggregated to the industry level to that produced in the 1988 and 1989 seasons and a similar number of ratoon crops (four) at average cane prices. When brought to an equivalent basis, the farm gross margin was roughly equivalent to that obtained from the Queensland Cane Grower's Council annual survey (ABARE 1989). For the 1988 and 1989 season, farm net revenues of around $47 000 and $70 000 respectively were estimated from the model, compared with equivalent industry estimates of $42 000 and $57 000 respectively.

The parameters of the model were varied to test the sensitivity of the results from the model to the parameter values used. The price of sugar and the cane yield were the most significant parameters influencing the solution. Changes in the costs of producing cane and the profitability of the weaner enterprise can also have a significant impact on the solution at low cane prices.

Sensitivity tests applied to the simulation results using a 10 per cent higher exchange rate between the US dollar and the Australian dollar, which lowered the cane price, and replacing the price expectations generated by the SUGABARE model (Wong, Sturgiss and Borrell 1989) with perfect forecasts had a relatively minor impact on the proportional gains and losses from the expansion and single price pool scenarios.

The world sugar price series used for the simulations included two very high prices and several very low prices. The sensitivity of the results to these very high and very low prices was tested by adjusting the price received for cane produced and applying these adjustments directly without rerunning the simulations. The cane price adjustment was based on reducing the pre-expansion sugar price in the high price years from around US26c/lb to US18c/lb and raising the price in the low price years from as low as US4c/lb to US10c/lb. These adjustments were sufficient to keep the average of sugar price unchanged at US13c/lb.

C Sequences for modelling with variable cane prices



nine years of each of the fourteen model simulations were derived using a combination of ABARE's world sugar model, SUGABARE (Wong, Sturgiss and Borrell 1989), and the average sugar price between the 1976 and 1989 seasons. Expectations generated from the world sugar model were used in years 2–6 of the model and the average sugar price in years 7–10 of the model. More detail on how the price expectations were formed is provided in box 4.

Initial start-up values for the rotation structure of the farm were imposed for the first of the fourteen simulations of the cane farm model. The start-up rotation values for each successive simulation of the cane farm model were derived from the outcomes in year 2 of the previous model simulation. For example, after running the first simulation, based on the 1976 season price, the rotational structure of the cane farm in year 2 of the model solution was used to start off the second simulation which was based on the 1977 season price.

Box 4: **How growers' price expectations are formed**

To approximate how growers form short and long term price expectations, the following procedures were used. The SUGABARE model was used to generate price expectations for years 2–6 of the cane farm model that were consistent with the historical sugar price series selected for the analysis. Price expectations for the last four years of the planning horizon were set equal to the average sugar price between 1976 and 1989.

The expected prices for years 2–6 were obtained by successively running the SUGABARE model forward, in the absence of any random shocks, five years from each sugar price in the historical series between the 1976 and 1989 seasons. For example, to obtain the first five expected prices for the first simulation of the cane farm model — that is, for the 1976 season — the SUGABARE model was run using available data up to the 1976 season. To obtain the first five price expectations for the second simulation of the cane farm model — that is, for the 1977 season — the SUGABARE model was updated using available data up to the 1977 season and was then rerun. This step was repeated to generate price expectations for the remaining twelve simulations of the cane farm model. The average forecast error for one and two years ahead generated by the model based expectations was around 50 per cent. Price expectations for the last four years of the planning horizon were set equal to the average sugar price between the 1976 and 1990 seasons on the assumption that this might best approximate how growers form long term price expectations.

The production, revenue and rotation values presented in this paper are the average of the values derived from the first year of each of the fourteen model solutions.

Three scenarios modelled

Deregulation of the sugar industry was modelled under three scenarios. First, a base scenario was modelled, representing the industry in the 1989 season.

Second, an industrywide 30 per cent expansion of the cane area under the current price pooling arrangements of a 12 per cent price differential between the no. 1 and no. 2 price pools was modelled. In this scenario all of the expansion in the cane area took place on the unconstrained farm.

Third, the 30 per cent expansion in the cane area combined with the removal of farm peaks and the introduction of a single price pool was modelled. In this scenario, without farm peaks, a minimum production constraint was imposed such that growers would harvest at least 80 per cent of their average annual cane production in any one year. This constraint was imposed to simulate the impacts of grower risk aversion in the face of price uncertainty and the need to sustain a reasonable level of cash flow from year to year. In the absence of this constraint, the model could produce solutions that result in unrealistic production variability.

In converting the world sugar price, which is quoted in USc/lb, to an Australian cane price, an exchange rate of $A1 = US75c was used, which is close to the average over the past six years. In the first two scenarios, where current price pooling arrangements are retained, sugar revenue was assumed to be split into the no. 1 and no. 2 pools such that the no. 1 pool price was 12 per cent higher than the no. 2 pool price. In the third scenario, all cane was deemed to receive the same pooled price.

In the expansion scenario and the single price pool scenario, it is assumed that sufficient land equal in quality to that already used for cane production exists to support a 30 per cent expansion in the cane area harvested relative to the 1989 season. The expansion in cane area was limited to 30 per cent relative to the 1989 season, despite extra land being available for cane production (Fitzpatrick et al. 1990). This assumption was made on the basis of already proposed expansions in cane area announced since 1989 and existing excess capacity available in the transport and milling sectors through the introduction of continuous crushing. A 30 per cent expansion in the cane area, relative to the 1989 season, is equivalent to the recent expansion in assignments awarded to the industry in January 1989 (5 per cent) and in May 1990 (8 per cent), plus the proposed minimum 2.5 per cent annual expansions planned over the five years to 1995.

In the 1990-91 season, much of the previously awarded expansions in cane area had not been fully exploited. For an expansion greater than 30 per cent, the assumption of additional land being of equal quality is less likely to hold and additional capital would probably be required in all sectors of the industry, thus potentially altering production costs.

Results

Key farm level results from the various simulations are presented in table 2 for

2 Production and revenue statistics for the landlocked and unconstrained cane farms under the base, expansion and single price pool scenarios

	Cane production	Weaner production	Average proportion of area in fallow	Net farm revenue	Change in industry net farm revenue	Average cane price
	t	ha	%	$	$m	$/t
Base scenario						
Landlocked grower	3 876 (3)	–	17 (23)	71 800 (72)	–	29.8
Unconstrained grower	3 785 (9)	43.7	9 (50)	81 200 (67)	–	29.7
Industry	23.2 Mt	–	–		–	29.8
Expansion scenario						
Landlocked grower	3 876 (3)	–	17 (23)	69 400 (79)	–8	29.4
Unconstrained grower	6 536 (24)	–	19 (85)	107 100 (99)	64	28.0
Industry	30.1 Mt	–			56	28.5
Single pool scenario						
Landlocked grower	3 805 (19)	–	17 (85)	70 300 (91)	–5	28.5
Unconstrained grower	6 531 (24)	–	19 (85)	112 000 (98)	76	28.5
Industry	29.8 Mt	–			71	28.5

Note: Figures in parentheses are coefficients of variation.

a grower who is representative of the group that is able to increase cane production and for one who is representative of the group of landlocked growers. The results presented for the two farms have been adjusted to account for the impact of an expansion in Australian cane production on the world sugar price. It has been assumed that the average milling season would not be changed under the expansion as additional milling capacity would be installed if required. This is consistent with the arrangements adopted in the Burdekin area.

Industry level results are also presented in table 2. The industry estimates were derived by weighting together the results for the landlocked grower and the grower with capacity to increase the cane area according to the number of these growers in the 1989 season. The weight applied to the unconstrained grower in the aggregation process was set to reflect the additional area required to permit a 30 per cent expansion in the industry cane area. In doing this it was assumed that these farms would reflect the average of existing cane farms able to expand their cane area in terms of size and resources.

While the results obtained from the aggregation process should be broadly indicative of the level of benefits that could be achieved from the regulatory changes modelled, the actual potential benefits could be somewhat different from the figures presented. This is because the two model farms are only approximations of typical farm types and do not explicitly take account of factors such as differences in individual management capacities, specific farm resource endowments or the effects of regional differences on management practices. However, as discussed at the end of this chapter, it is considered that the results obtained are likely to be underestimates of the actual outcome.

Farm impacts of changes to industry regulations

In the base scenario, which was set up to be representative of the industry in the 1989 season, cane production averaged 3785 t a year on the unconstrained farm with spare land and 3876 t a year on the landlocked farm. Of this production, 95 per cent was accounted for by the farm peak on the unconstrained farm and 99 per cent on the landlocked farm. Because of the relatively high proportion of cane accounted for by the farm peak, production variability was quite low. Overall, the coefficient of variation (which is a measure of variability) on cane production on the unconstrained farm was a low 9 per cent while on the landlocked farm it was only 3 per cent.

In the highest price year, cane production on the unconstrained farm was 30 per cent greater than the peak while for the landlocked farm the production increase was limited to 13 per cent above the farm peak. The farm peak was binding in nine out of fourteen years for the unconstrained farm and eleven of fourteen years for the landlocked farm.

The low degree of production flexibility imposed by the farm peak system and its associated price pooling system is also apparent in the structural composition of the farm area. The coefficient of variation on the area under fallow or in early ratoon crops averaged around 23 per cent for the landlocked farm and around 50 per cent for the unconstrained farm where the farm peak constraint was less binding. The relatively stable production and rotational structure of the cane crop on both farms is typical of present cane growing operations.

Net farm revenue over the fourteen year simulation period averaged $81 200 for the unconstrained farm and $71 800 for the landlocked farm. On the unconstrained farm 13 per cent of net farm revenue was accounted for by the alternative enterprise, raising weaners. In both cases, net farm revenue was more volatile than production because of price variability. The coefficient of variation on net revenue was 67 per cent for the unconstrained farm and 72 per cent for the landlocked farm.

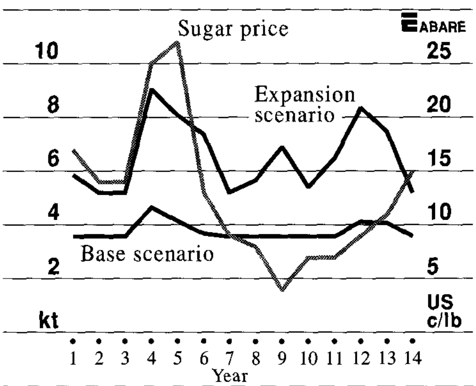
Under the expansion scenario the amount of spare land suitable for cane production on the unconstrained farm was assumed to be equivalent to a 30 per cent expansion in the total land area devoted to cane relative to the 1989 season. This was calculated to be equivalent to an increase in the cane area of around 70–75 per cent on the unconstrained farm.

Following the expansion, average cane production on the unconstrained farm increased from 3785 t to 6536 t of cane, a percentage increase roughly equivalent to the percentage expansion in the area available for cane production. In this case the farm peak of 3585 t of cane was no longer binding, the only specific constraint on production being the assumed lower production limit of 80 per cent of the average level of production used to simulate risk aversion by growers.

Replacing the more binding farm peak constraint with the 80 per cent rule allowed a much higher level of production flexibility (figure D). As a result, the coefficient of variation on cane production rose from 9 per cent to 24 per cent on the unconstrained farm, reflecting the increased ability to alter the rotational structure of the cane crop to exploit price variability. The coefficient of variation on the area under fallow or in the early ratoon stages increased under the expansion to around 85 per cent compared with 50 per cent in the base scenario.

For the unconstrained farm, two techniques are used to exploit periods of high cane prices with increased production flexibility. The first is placing a larger area of the cane land into the fallow/plant stage of the production cycle prior to periods of expected high sugar prices. The aim of this strategy is to synchronise having as much of the crop as possible in its most productive phase, plant or early ratoon crops, when prices rise. The second production strategy is to continue to ratoon the entire crop while prices are expected to remain high so that the entire area is producing cane, thereby avoiding the lost production encountered by fallowing and replanting part of the crop. The ability to ratoon the entire crop also avoids the need to engage in the high cost of replanting part of the crop to maintain production levels when cane prices are low.

D **Price and cane production on the unconstrained farm**



As a result of these strategies and the expansion in the cane area, average net revenue on the large farm increased by $25 900 to $107 100, an increase of around 32 per cent, after adjusting for lower cane prices. The variability of net revenue also increased, with the coefficient of variation rising from 67 per cent in the base scenario to 99 per cent under expansion. The increase in the net farm revenue demonstrates the high opportunity costs imposed on growers within the industry and those outside the industry by the current restrictions on cane production.

The expansion in the total area devoted to cane production has little impact on the landlocked farm except through the slightly lower cane prices caused by the increase in Australian sugar production. With no change in area, landlocked farms are unable to alter their production strategies. Despite the lower prices received for cane after the expansion of the industry, production on the landlocked farm is largely unchanged. Overall, the average net farm revenue declined by around 3 per cent to $69 400 from $71 800, while variation in net farm revenue increased from 72 per cent in the base scenario to 79 per cent under industry expansion.

At the industry level, total average annual net farm revenue increased by an estimated $56 million. Average net farm revenue increased by a total of $64 million on farms able to expand, reflecting the increased profitability of cane production while total revenue to landlocked farms was estimated to decline by around $8 million because of the lower average cane prices.

Under the third, single pool, scenario (table 2), industry expansion is complemented with replacement of the existing price pooling arrangements and the farm peak system with a single pooled price. For the unconstrained farm, this change in regulations had only a limited impact on average cane production but increased average net farm revenue by a further $4900 compared with the expansion scenario. The increase in net farm revenue results from the change to a single price pool away from the 12 per cent differential between the no. 1 and no. 2 price pools that presently prevails.

Replacing the existing price pooling arrangements and the farm peak system with a single pooled price also has a positive impact on the average net farm revenue of landlocked growers. Landlocked growers can also exploit price variability to their advantage under these reforms. Overall, the benefits of increased production flexibility outweighed the loss of the subsidy provided to landlocked growers for peak cane under the 12 per cent differential rule of the current price pooling system.

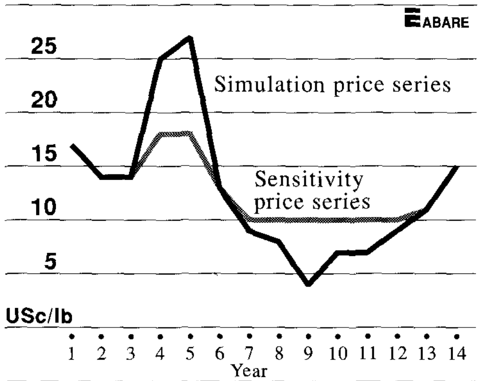
On the landlocked farms average annual net farm revenue increased to $70 300, compared with the expansion scenario level of $69 400 but was still below the base scenario level of $71 800. The increase in average net farm revenue occurred despite a fall in the average level of cane production from 3876 t of cane to 3805 t of cane. For the unconstrained farm, the increase in production flexibility also led to a sharp rise in the variability of net farm revenue from 72 per cent in the base scenario to 91 per cent in this scenario.

At the industry level, total average annual net farm revenue increased by a further $15 million over the previous expansion scenario as a result of the change in the farm peak and price pooling arrangements. Of the increase in average net farm revenue, $12 million accrued to those growers able to expand cane production and $3 million accrued to landlocked growers.

Qualification of estimates

The results presented above are based on sugar prices received between the 1976 and 1990 seasons. During this period some very high and some very low sugar prices were recorded. In a more flexible industry it could be argued that the variability in world sugar prices might be less. To check the sensitivity of the results to such an argument, the two very high sugar prices were reduced from around US26c/lb to US18c/lb and the four very low prices were raised from as low as US4c/lb to US10c/lb (figure E). These adjustments left the

E Sugar prices used in the cane farm model simulations



average sugar price unchanged at US13c/lb. These price adjustments were applied to the results directly without rerunning the simulations.

Following this adjustment, it was estimated that the average annual increase in net farm revenue in the cane growing sector of the industry from the expansion scenario could be around $50 million, while the extra gains from increased production flexibility and single pool pricing of cane would be relatively small.

However, the estimates obtained from the preceding analysis under any of the price assumptions are likely to underestimate the potential gains from deregulation of the industry for a number of reasons.

The estimates obtained from the modelling are based on the existing industry structure being maintained, whereas farm size is quite variable. Under the simulations performed in this study, only those farms with spare land change in size or structure, increasing their area by 70 per cent in order to reflect a 30 per cent expansion of the whole industry. In a deregulated industry, it is likely that the structure of the industry would change and that farm size would be much larger as growers aimed to maximise returns to capital and management. Further, the gains estimated for the unconstrained cane farm may be underrepresented because the adoption of larger scale operations would provide efficiency gains.

The gains estimated from increased flexibility may also be underestimates because the potential flexibility available to some growers is greater than assumed in the model. In those areas where cash cropping or other alternative enterprises are possible or where late planted cane and standover cropping is feasible, the results presented above will tend to underestimate potential production flexibility. Increased flexibility may also be achieved from the removal of other controls such as harvest scheduling.

Increased cane production will increase the average throughput of existing harvester and transport and milling facilities, thereby reducing average harvesting and milling costs. The work by Connell and Borrell (1987) suggested that average harvesting costs could be reduced by around $0.60/t of cane from a 30 per cent increase in throughput. Although some rationalisation has occurred within the harvesting sector of the industry since 1987, if average harvesting costs could be reduced further by around $0.30/t of cane as a result of a 30 per cent expansion in production, this would add another $9 million to the industry gains outlined above.

The work by Borrell and Wong (1986) suggests that there are also considerable gains to be had in the milling sector as a result of such an increase in the average cane throughput. These gains are likely to be achieved over the next five to seven years as cane production expands in response to recent and proposed expansions in land assignments.

CHAPTER 4

Implications

The results obtained from this work suggest that the legislated 30 per cent expansion in the assigned cane area, relative to the 1989 season, which is likely to occur over the next five to seven years, could see average net farm revenue in the cane growing sector of the industry increase by around $56 million a year. The replacement of current farm peak and price pooling arrangements with a single price pool was estimated to provide further gains of about $15 million a year as a result of increased production flexibility and improved pricing of marginal cane production. Overall, it was estimated that the increased production flexibility associated with the reforming of pool pricing arrangements would partially compensate landlocked growers for the negative impact of an expansion in Australian sugar production on the world sugar price.

Under an alternative scenario of a more flexible industry and lower sugar price volatility, it was estimated that the average annual increase in net farm revenue in the cane growing sector of the industry from the expansion scenario could be around $50 million, while the gains from increased production flexibility and single pool pricing of cane would be relatively small.

However, in both of the above cases, the estimates are considered to be conservative as they do not allow for the full flexibility available to some growers or the gains from a potential restructuring of farm sizes under expansion or deregulation and potential gains from the adoption of larger scale operations. Furthermore, the estimates do not include gains in the transport, handling and milling sector which should arise from the more efficient use of industry capital, resulting in lower average milling costs.

The greatest gains to the industry are likely to arise only when all regulations governing the growing, harvesting and milling of cane are removed. The expansion of cane assignments by 30 per cent was found to deliver significant benefits to the industry. However, the potential for the industry to expand has been estimated to be even greater than this, although significant capital would be required to develop much of this additional area.

Removal of assignments and hence the restrictions governing the sale and transfer of cane land would help to speed up industry rationalisation toward the most efficient industry structure. As a result, there would most probably be an amalgamation of smaller farms or the development of cooperative arrangements between growers that would allow the management of cane farms on a much larger scale of operation. Under such restructuring, farm machinery requirements per unit of cane land could be reduced, resulting in lower production costs.

An additional benefit from increased production flexibility in the Australian sugar industry is that it might result in increased stability in world sugar prices. It has been proposed that if sugar production in some low cost producing countries were less constrained by industry regulation, then increased production in these countries in response to rising sugar prices would limit the extent to which prices rose. This in turn may limit the pressure in other, higher cost producing countries to expand their protected industries. As a result, subsequent falls in sugar prices may not be as low or as long lasting.

APPENDIX A

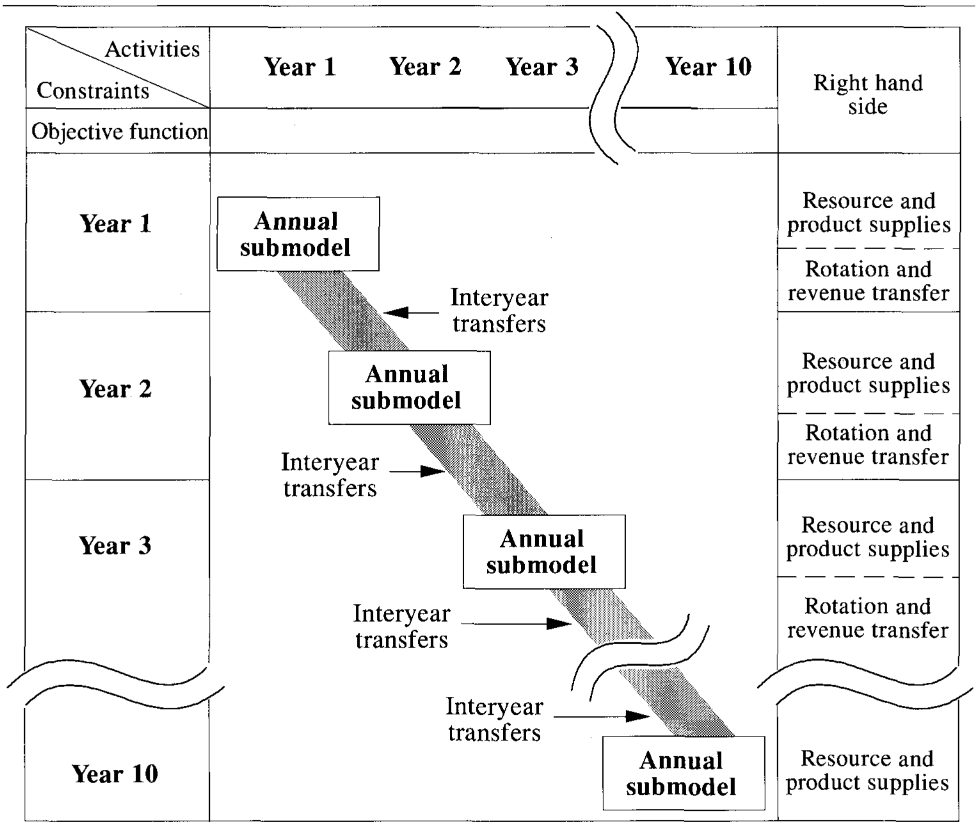
Overview and specification of the cane farm model

Overview of the cane farm model

To simulate the management of sugar cane as a series of plant and ratoon crops, the cane farm model is structured as ten interlinked submodels or a multiperiod model (figure F).

Each submodel represents one year in the production cycle of the cane farm and consists of an identical set of production activities and resource constraints. The activities and constraints are linked by coefficients reflecting the technical production relationships of the farm.

F Diagrammatic representation of the annual structure of the cane farm model



Although the entire model is solved simultaneously, the structure of the model can be conceptualised as a chronological sequence of events. The linkages between the submodels transfer the accumulated net farm revenue from 'year to year' and ensure that only feasible rotation sequences are generated within the model.

The objective of the model is to maximise the total accumulated farm net revenue over the period represented. The model finds a solution by simultaneously selecting in all years: the optimum mix of two enterprises (raising weaners and cane production), the optimum rotation for the cane enterprise and the optimum management strategy and input mix for both enterprises.

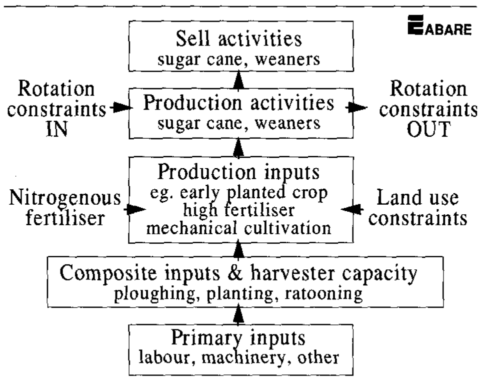
The production system in each submodel is based on three types of constraints — primary input constraints, land use constraints and rotation constraints. The primary input constraints reflect the physical resources available to the farm, such as machinery, labour and fertiliser. The land use constraints — used to represent land use — were included to allow control over the cane and weaner enterprise. Rotation constraints control the year to year rotational organisation of the farm.

The production activities of each submodel are arranged in a hierarchical structure (figure G). At the bottom of the hierarchy are the primary input activities. The primary input activities represent the purchase and supply of labour, machinery and other inputs. These activities add to the costs and subtract from the revenue of each submodel. Inputs supplied by the primary input activities are combined in various proportions by composite activities to generate composite inputs such as ploughing, planting and ratooning.

Production input activities combine the composite inputs, nitrogenous fertiliser, and the land use constraints to form management options for each production activity of the two enterprises — for example, an early planted crop with high fertiliser and mechanical cultivation. Production activities use the production inputs, harvester capacity and rotation constraints to produce the outputs of the submodel, cane or weaners. The sell activities represent the top of the hierarchical production system. These activities sell the cane and weaners to generate the revenue of each submodel.

The submodels are linked through two sets of transfer activities. The net farm revenue transfer activity transfers the compounded net farm revenue of the submodel and the previous submodels, with interest, to the next submodel. In the tenth submodel this activity transfers the accumulated net farm revenue to the objective function. The rotation transfer activities generate the rotation constraints for the next submodel.

G Structure of the production system of each submodel



Specification of the cane farm model

A diagrammatic representation of the equation system of the model is presented in table 3. A listing of the classes of activities within the model is contained in appendix B.

Maximising farm gross margin

The objective of the cane farm model is to maximise the compounded net farm revenue ($\prod$) over the ten year planning period of the model. The activity X_{14} transfers to the objective function the net farm revenue accrued over the ten year period of the model (C_1).

Objective function

$$\max (\prod) = X_{14}$$

Equation C_1 accumulates the net farm revenue generated in each year of the model and transfers it to the objective function. The activities X_2 to X_7 represent the input costs, while activity X_{11} represents farm revenue. The term $1.05X_{12t-1}$ transfers the accumulated net farm revenue from year t–1 to year t, compounding it at a rate of 5 per cent. The term $-X_{12}$ transfers the accumulated net farm revenue in year t to year t+1. In the first year of the model, the first of these terms is absent while in the tenth year of the model the second of these terms is replaced by the activity X_{14} which transfers the accumulated net farm revenue to the objective function, as shown above.

Transfer accumulated net farm revenue to year t+1

$$C_1 = -\Sigma a_{ij}X_2 - \Sigma a_{ij}X_3 - \Sigma a_{ij}X_5 - \Sigma a_{ij}X_6 - a_{ij}X_7 + \Sigma a_{ij}X_{11} + 1.05X_{12t\text{-}1} - X_{12} \geq 0$$

where i and j refer to rows and columns.

There are also two annual accounting identities in each submodel which are total operating costs (C_2) and total revenue (C_3). Activities X_2 to X_7 supply primary production inputs and add to costs, while activity X_{11} represents the sale of sugar cane and weaners, adding to revenue.

Total annual cost

$$C_2 = \Sigma a_{ij}X_2 + \Sigma a_{ij}X_3 + \Sigma a_{ij}X_5 + \Sigma a_{ij}X_6 + a_{ij}X_7 \geq 0$$

Total annual revenue

$$C_3 = \Sigma a_{ij}X_{11} \geq 0$$

Primary inputs to production

The total area of the property, the area that can be used for cane production and the farm peak are represented in equations C_4 to C_6 respectively. The amount of own and hired equipment capacity and the amount of operator and hired labour are represented in equations C_7 to C_{10} respectively. The b_i terms represent the exogenous constraints imposed on the model.

Property area

$$C_4 = \Sigma X_1 \leq b_4$$

Cane area ($C_5 = 1, \ldots, n$)

$$C_5 = \Sigma a_{ij} X_1 \leq b_5$$

where n refers to each subactivity within activity X_1 (see appendix B).

Farm peak

$$C_6 = a_{ij} X_{11} \leq b_6$$

On-farm supply of tractor capacity was estimated from industry data sources (Queensland Cane Growers Council, Bureau of Sugar Experiment Stations, personal communication, 1986). Machinery hours were set to reflect the supply of machinery during the main period of cane operations rather than the whole year. This was done in an attempt to capture timing constraints on machinery availability within the annual framework of the model. The on-farm supply of farm equipment other than tractors was set at an arbitrary, high level based on the assumption that capacity exists to meet demand under all simulations of the representative farm. Additional tractor capacity can be hired at a constant cost per tractor hour.

Unit costs of operating farm equipment are based on variable costs only (fuel, repairs and maintenance, tyres, batteries, etc.). Costs for machinery include all maintenance costs required to keep the equipment at its original operating capacity. The costs do not include that component of depreciation attributed to obsolescence of the machinery. These are assumed to remain constant throughout the planning period of the model. The costs of tractor use in conjunction with implements are included in the unit cost of the implements. Unit costs were based on 1985 season data derived from Hardman, Tilly and Glanville (1985) and Percival and Garland (1977) indexed to 1989 season values.

Own equipment capacity *($C_7 = 1, \ldots, n$)*

$$C_7 = X_2 \leq b_7$$

Hired equipment capacity ($C_8 = 1, \ldots, n$)

$$C_8 = X_3 \geq 0$$

The labour constraints reflect the amount of labour available during the main period of cane operations rather than the whole year. This was done in an attempt to capture timing constraints on operator labour within the annual framework of the model.

The on-farm supply of labour was estimated from industry data (Queensland Cane Growers Council, Bureau of Sugar Experiment Stations, personal communication, 1986). Three categories of hired labour are specified in the model to reflect diminishing marginal productivity of additional labour units. This was modelled by reducing the unit contribution to available labour made by successive labour hiring activities.

Own labour capacity ($C_9 = 1, \ldots, n$)

$$C_9 = X_4 \leq b_9$$

3 Simplified representation of the cane farm model [a]

			Allow alternative land uses	Supply own equipment capacity	Hire equipment capacity	Supply own labour capacity	Hire labour capacity
			X_1	X_2	X_3	X_4	X_5
Constraints		Unit	ha	hr	hr	hr	hr
Objective function	Π	$					
Net farm revenue	C_1						
– years 1 to 9		$		$-a_{ij}$	$-a_{ij}$		$-a_{ij}$
– year 10		$		$-a_{ij}$	$-a_{ij}$		$-a_{ij}$
Total annual cost	C_2	$		a_{ij}	a_{ij}		a_{ij}
Total annual revenue	C_3	$					
Primary inputs to production							
Property area	C_4	ha	1				
Cane area	C_5	ha	a_{ij}				
Farm peak	C_6	t					
Own equipment capacity	C_7	hr		1			
Hired equipment capacity	C_8	hr			1		
Own labour capacity	C_9	hr				1	
Hired labour capacity	C_{10}	hr					1
Farm equipment capacity	C_{11}	hr		1	1		
Farm labour capacity	C_{12}	hr				1	a_{ij}
Nitrogenous fertilisers	C_{13}	t					
Other primary inputs	C_{14}	*					
Production inputs and output							
Land use constraints	C_{15}	ha	1				
Composite inputs (excluding harvesting)	C_{16}	ha					
Harvester capacity	C_{17}	t					
Production inputs	C_{18}	ha					
Cane production	C_{19}	t					
Weaner production	C_{20}	hd					
Rotation constraints							
– year t, where t = 1	C_{21}	ha					
– year t, where t = 2 to 10	C_{22}	ha					
– year t+1	C_{23}	ha					

a Positive coefficients add to a constraint and negative coefficients subtract from a constraint. * Various units. **b** a_{ij} is the coefficient of transformation between constraint i and activity j. N potential objective function. L less than or equal to. G greater than or equal to. b_i are constraints set exogenously for a particular model experiment.

3 *continued*

Supply nitrogenous fertilisers	Supply other primary inputs	Supply composite inputs	Supply production inputs	Produce outputs	Sell products	Transfer farm net revenue to year *t*+1		Transfer rotation constraints to year *t*+1		Transfer farm net revenue to objective function		
X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}		X_{13}		X_{14}	Sign [b]	RHS
						t–1	*t*+1	*t*–1	*t*+1			
t	*	ha	ha	*	*	$	$	ha	ha	$		
										1	N	
$-a_{ij}$	$-a_{ij}$				a_{ij}	1.05	–1				G	0
$-a_{ij}$	$-a_{ij}$				a_{ij}	1.05				–1	G	0
a_{ij}	a_{ij}										G	0
					a_{ij}						G	0
											L	b_4
											L	b_5
					a_{ij}						L	b_6
											L	b_7
											G	0
											L	b_9
											G	0
		$-a_{ij}$									G	0
		$-a_{ij}$									G	0
1			$-a_{ij}$								G	0
	1	$-a_{ij}$									G	0
			$-a_{ij}$								G	0
		1	$-a_{ij}$								G	0
		$-a_{ij}$	a_{ij}	$-a_{ij}$							G	0
			1	$-a_{ij}$							G	0
			$-a_{ij}$	a_{ij}	$-a_{ij}$						G	0
				a_{ij}	$-a_{ij}$						G	0
				1							L	b_{21}
				–1				1			G	0
				1					–1		G	0

Hired labour capacity ($C_{10} = 1, \ldots, n$)

$$C_{10} = X_5 \geq 0$$

Equipment requirements for the range of farm activities are supplied by the own equipment capacity activity (X_2) and the hire equipment capacity activity (X_3). These activities supply machinery resources to the farm equipment capacity constraints by drawing from the own equipment and hired equipment constraints. The machinery resources supplied to the farm equipment capacity constraints are used by the composite input activities (X_8).

Farm equipment capacity ($C_{11} = 1, \ldots, n$)

$$C_{11} = X_2 + X_3 - a_{ij}X_8 \geq 0$$

The labour supply activities (X_4 and X_5) make available farm labour for planting, harvesting and general tasks by drawing resources from the own labour and hired labour constraints. Labour resources supplied to the labour capacity constraints are used by the composite input activities (X_8).

Farm labour capacity ($C_{12} = 1, \ldots, n$)

$$C_{12} = a_{ij}X_4 + a_{ij}X_5 - a_{ij}X_8 \geq 0$$

Nitrogenous fertilisers and other inputs such as chemicals, for both the cane growing and weaner enterprises are provided by input purchasing activities. The inputs supplied by these activities are used by the composite input activities (X_8) and the production input activities (X_9). Input requirements for the weaner enterprise were estimated from data in O'Sullivan (1985) while input requirements for cane production were estimated from industry data.

Nitrogenous fertiliser

$$C_{13} = X_6 - \Sigma a_{ij}X_9 \geq 0$$

Other primary inputs ($C_{14} = 1, \ldots, n$)

$$C_{14} = X_7 - \Sigma a_{ij}X_8 \geq 0$$

Production inputs and output

Land use activities (X_1) supply enterprise area units to the land use constraints (C_{15}) which are used by the production input activities (X_9) for fallow, cane and weaner production.

Land use constraints ($C_{15} = 1, \ldots, n$)

$$C_{15} = X_1 - \Sigma a_{ij}X_9 \geq 0$$

Composite input activities (X_8) draw inputs such as labour and machinery from the primary input constraints (C_{11}, C_{12} and C_{14}) and supply them in various combinations to composite input constraints measured in area units. Production input activities (X_9) use the various composite input constraints for different crop management operations. Composite input coefficients were estimated from data in Hardman, Tilly and Glanville (1985), Jones (1983), Percival and Garland (1977), Queensland Department of Primary Industries (1982), and industry data (Queensland Cane Growers Council Bureau of Sugar Experiment Stations, personal communication, 1986).

Composite inputs (excluding harvester capacity) ($C_{16} = 1, \ldots, n$)

$$C_{16} = X_8 - \Sigma a_{ij} X_9 \geq 0$$

Harvester capacity

$$C_{17} = \Sigma a_{ij} X_8 + \Sigma a_{ij} X_9 - \Sigma a_{ij} X_{10} \geq 0$$

Production input activities (X_9) combine composite inputs, composite permits and nitrogenous fertilisers in various proportions to create a set of production inputs which are supplied to the production input constraints (C_{18}). Each production input corresponds with a particular management strategy for a particular stage of the cane crop or for the weaner enterprise. The production inputs are consumed from the production input constraint by the output activities (X_{10}).

Yield differentials associated with alternative management strategies for the cane enterprise are incorporated in the production inputs. Each activity consumes units of cane and supplies units of harvesting capacity reflecting the difference in the yield of that management strategy with the yield of the standard management strategy of high fertiliser application. Yield coefficients are derived from industry data (Queensland Cane Growers Council, Bureau of Sugar Experiment Stations, personal communication, 1986).

Production inputs ($C_{18} = 1, \ldots, n$)

$$C_{18} = X_9 - \Sigma a_{ij} X_{10} \geq 0$$

The production activities (X_{10}) represent individual cane crop stages and the weaner enterprise and supply the outputs, cane and weaners to the cane and weaner constraints (C_{19} and C_{20}). Cane and weaners are drawn from their respective constraints by sell activities (X_{11}) which convert the outputs to revenue.

Two cane selling activities are included in the model, one for peak cane (with a cane price representing the no. 1 pool sugar price) and another for overpeak cane (with a cane price representing the world sugar price). The farm peak constraint in the model forces the peak cane selling activity into the solution at its maximum level, reflecting the assumption that the cane grower will aim always to produce a quantity of cane at least equal to the farm peak. Cane price coefficients vary between experiments depending on assumptions adopted about the sugar price, but in all cases, cane prices are based on average Queensland commercial content of sugar in the cane and are net of deductions such as mill penalties and industry levies, estimated to be around $1/t of cane.

Yield coefficients for the cane production activities were estimated using data from Bureau of Sugar Experiment Stations annual report (1985b), Wegener and Pollock (1986), Leverington, Hogarth and Ham (1978) and the Bureau of Sugar Experiment Stations (1985a) soil fertility monitoring site survey. Adjustment of experiment and survey data was required to correlate yields with industry average yield statistics.

Cane production

$$C_{19} = -\Sigma a_{ij}X_9 + \Sigma a_{ij}X_{10} - \Sigma a_{ij}X_{11} \geq 0$$

Weaner production

$$C_{20} = \Sigma a_{ij}X_{10} - a_{ij}X_{11} \geq 0$$

Each production activity also requires one unit of the corresponding rotation constraint and supplies one unit of rotation constraint (except in year 10) which influences the next year's production activities. The production permits are used in the model to restrict the flow of crop stages and the weaner enterprise from year to year to specific sequences which reflect normal crop and husbandry practices.

Rotation constraints have right hand side coefficients of zero except for year 1 in which production permits are set equal to the initial production activities required for the experiment being performed. After year 1, production permits required by production activities are provided indirectly by production activities in the previous year.

Rotation constraints year *t*
($C_{21}, C_{22} = 1, \ldots, n$)

Year 1

$$C_{21} = X_{10} = b_{21}$$

Years 2 to 10

$$C_{22} = -X_{10} + X_{13t-1} \geq 0$$

Rotation constraints year *t*+1
($C_{23} = 1, \ldots, n$)

$$C_{23} = X_{10} - X_{13} \geq 0$$

Listing of activities and constraints of the cane farm model

Explanation of symbols

'Management strategy *fc*' refers to each of four crop management options — low fertiliser with chemical cultivation, low fertiliser with mechanical cultivation, high fertiliser with chemical cultivation and high fertiliser with mechanical cultivation. 'Management strategy *.c*' refers to the two management options of chemical or mechanical cultivation.
'Cane crop stage *rr*' refers to each of the seven plant and ratoon cane crop stages.

Activities (X_j)

X_1 Allow alternative land uses

Cane fallow with assignments
Cane fallow with roaming
Cane fallow only with roaming
Cane fallow without restriction
Cane production with assignments
Cane production with roaming
Cane production without restriction
Weaner enterprise

X_2 Supply own equipment capacity

Supply tractor capacity from on-farm equipment
Supply harvester capacity from on-farm equipment
Supply haulout capacity from on-farm equipment
Supply planting equipment capacity from on-farm equipment
Supply ratooning equipment capacity from on-farm equipment
Supply spraying equipment capacity from on-farm equipment
Supply cultivating equipment capacity from on-farm equipment
Supply land preparation equipment capacity from on-farm equipment

X_3 Hire equipment capacity

Hire tractor capacity
Hire harvester capacity
Hire haul-out capacity
Hire planting equipment capacity
Hire ratooning equipment capacity
Hire spraying equipment capacity
Hire cultivating equipment capacity
Hire land preparation equipment capacity

X_4 Supply own labour capacity

X_5 Hire labour capacity

Hire primary labour category 1
Hire primary labour category 2
Hire primary labour category 3

X_6 Supply nitrogenous fertilisers

X_7 Supply other primary inputs

Hire harvesting labour
Buy weed control chemicals
Buy other pesticides
Buy other (non-nitrogen) fertilisers
Buy cane plants
Buy legume seed
Buy stock for weaner enterprise

Buy fertiliser for weaner enterprise
Buy vehicle services for weaner enterprise
Buy contract planting service
Buy contract spraying service
Buy full contract harvesting service
Buy mixed contract harvesting service (supply own haul-out service)

X_8 Supply composite inputs
Supply own planting operation
Supply contract planting operation
Supply ratooning operation
Supply own spraying operation, management strategy *.c*
Supply contract spraying operation, management strategy *.c*
Supply plant cultivating operation, management strategy *fc*
Supply ratoon cultivating operation, management strategy *fc*
Supply plough-out operation, management strategy *.c*
Supply land preparing for planting operation
Supply fallowing operations
Supply sundry operations
Supply plough-out of weaner enterprise pasture
Supply weaner enterprise operations
Supply own harvesting operation
Supply contract harvesting operation
Supply mixed harvesting operation

X_9 Supply production inputs
Supply production input for fallow following fallow
Supply production input for fallow following cane production, management strategy .c
Supply production input for fallow following weaner enterprise
Supply production input for early plant cane, management strategy *fc*
Supply production input for ratoon cane, management strategy *fc*
Supply production input for weaner enterprise following cane
Supply production input for weaner enterprise following fallow
Supply production input for weaner enterprise following weaner enterprise

X_{10} Produce outputs
Fallow following fallow
Fallow following cane production
Fallow following weaner enterprise
Cane production by plant crop
Cane production by first ratoon
Cane production by second ratoon
Cane production by third ratoon
Cane production by fourth ratoon
Cane production by fifth ratoon
Cane production by old ratoon
Weaner production following cane production
Weaner production following fallow
Weaner production following weaner production

X_{11} Sell products
Sell peak cane
Sell overpeak cane
Sell weaners

X_{12} Transfer farm net revenue to year t+1

X_{13} Transfer rotation constraints to year t+1
Transfer fallow to fallow
Transfer fallow to weaners
Transfer fallow to early plant crop
Transfer cane crop stage *rr* to fallow
Transfer cane crop stage *rr* to next cane crop stage
Transfer cane crop stage *rr* to weaner enterprise

Transfer weaner enterprise to fallow
Transfer weaner enterprise to weaner enterprise

X_{14} Transfer farm net revenue to objective function

Constraints

C_1 Transfer accumulated net farm revenue to year *t*+1

C_2 Total annual cost

C_3 Total annual revenue

C_4 Property area

C_5 Cane area
Assigned area
Roaming area

C_6 Farm peak

C_7 Own equipment capacity
Own tractor capacity
Own harvester capacity
Own haulout capacity
Own planting equipment capacity
Own ratooning equipment capacity
Own spraying equipment capacity
Own cultivating equipment capacity
Own land preparation equipment capacity

C_8 Hired equipment capacity
Hire tractor capacity
Hire harvester capacity
Hire haulout capacity
Hire planting equipment capacity
Hire ratooning equipment capacity
Hire spraying equipment capacity
Hire cultivating equipment capacity
Hire land preparation equipment capacity

C_9 Own labour capacity

C_{10} Hired labour capacity
Hired labour category 1
Hired labour category 2
Hired labour category 3

C_{11} Farm equipment capacity
Tractor capacity
Harvester capacity
Haulout capacity
Planting equipment capacity
Ratooning equipment capacity
Spraying equipment capacity
Cultivating equipment capacity
Land preparation equipment capacity

C_{12} Farm labour capacity

C_{13} Nitrogenous fertilisers

C_{14} Other farm inputs
Weed control chemicals
Other pesticides
Other (non-nitrogen) fertilisers
Cane plants
Legume seed
Stock for weaner enterprise
Fertiliser
Vehicle services for weaner enterprise

C_{15} Land use constraints
Land to be used for cane fallow
Land to be used for cane production
Land to be used for weaner production

C_{16} Composite inputs
Planting operation
Ratooning operation
Spraying operation, management strategy .c

Plant cultivating operation, management strategy .*c*
Ratoon cultivating operation, management strategy .*c*
Plough-out operation, management strategy .*c*
Land preparing for planting operation
Fallowing operations
Sundry operations
Plough-out of pasture
Weaner enterprise operations
Own harvesting service
Full contract harvesting service
Mixed contract harvesting service (supply own haulout service)

C_{17} Harvester capacity

C_{18} Production inputs

Production input for fallow following fallow
Production input for fallow following cane production management strategy .*c*
Production input for fallow following weaner enterprise
Production input for early plant cane, management strategy *fc*
Production input for ratoon cane, management strategy *fc*
Production input for weaner enterprise following cane production
Production input for weaner enterprise following fallow
Production input for weaner enterprise following weaner enterprise

C_{19} Cane production

C_{20} Weaner production

C_{21} and C_{22} Rotation constraints required

Rotation constraints required by fallow following fallow
Rotation constraints required by fallow following cane production
Rotation constraints required by fallow following weaner enterprise
Rotation constraints required by early plant crop following fallow
Rotation constraints required by first ratoon crop following early plant crop
Rotation constraints required by second ratoon crop following first ratoon crop
Rotation constraints required by third ratoon crop following second ratoon crop
Rotation constraints required by fourth ratoon crop following third ratoon crop
Rotation constraints required by fifth ratoon crop following fourth ratoon crop
Rotation constraints required by old ratoon crop following fifth ratoon crop
Rotation constraints required by old ratoon crop following old ratoon crop
Rotation constraints required by weaner enterprise following fallow
Rotation constraints required by weaner enterprise following cane crop
Rotation constraints required by weaner enterprise following weaner enterprise

C_{22} Rotation constraints supplied

Rotation constraints supplied for fallow following fallow
Rotation constraints supplied for fallow following cane production
Rotation constraints supplied for fallow following weaner enterprise
Rotation constraints supplied for early plant crop following fallow

Rotation constraints supplied for first ratoon crop following early plant crop
Rotation constraints supplied for second ratoon crop following first ratoon crop
Rotation constraints supplied for third ratoon crop following second ratoon crop
Rotation constraints supplied for fourth ratoon crop following third ratoon crop
Rotation constraints supplied for fifth ratoon crop following fourth ratoon crop
Rotation constraints supplied for old ratoon crop following fifth ratoon crop
Rotation constraints supplied for old ratoon crop following old ratoon crop
Rotation constraints supplied for weaner enterprise following fallow
Rotation constraints supplied for weaner enterprise following cane crop
Rotation constraints supplied for weaner enterprise following weaner enterprise

References

ABARE (1988), The effect of regulations and controls on the productive capacity of the sugar industry. Submission to the Central Sugar Cane Prices Board, Canberra, November.

ABARE (1991), *The Australian Sugar Industry in the 1990s*, Submission 91.5, to the Industry Commission, August 1991, AGPS, Canberra.

—— (1989), *Farm Survey Report 1989*, AGPS, Canberra.

Australian Canegrower (1990), 'First continuous crushing agreement recognises growers' need', *Australian Canegrower* **12**(2), 6.

Bureau of Agricultural Economics (1983a), Long term assistance for the Australian sugar industry. A submission to the Industries Assistance Commission, Canberra, March.

—— (1983b), A proposal to relax controls on production of over-peak sugar. A supplementary submission to the Industries Assistance Commission, Canberra, October.

Borrell, B. and Wong, G. (1986), *Efficiency of Transport, Milling and Handling in the Sugar Industry: A Case Study of the Mackay Region*, BAE Occasional Paper 96, AGPS, Canberra.

Bureau of Sugar Experiment Stations (1985a), Soil fertility monitoring site survey data, Brisbane (unpublished).

—— (1985b), *Annual Report 1985*, Brisbane.

Connell, P. and Borrell, B. (1987), *Costs and Regulation of Cane Harvesting Practices*, BAE Occasional Paper 101, AGPS, Canberra.

Fitzpatrick, E.N., Watson, D.N. and Soper, F.J. (1990), *Report of the Sugar Industry Working Party*, Queensland Department of Primary Industries, Brisbane.

Hardman, J.R., Tilly, L.G.W. and Glanville, T. (1985), 'Agronomic and economic aspects of various farming systems for sugar cane in the Bundaberg district', in Egan, B.T. (ed.), *Proceedings of the 1985 Conference of the Australian Society of Sugar Cane Technologists*, Bundaberg.

Industries Assistance Commission (1983), *The Sugar Industry 1983,* Report No. 332, AGPS, Canberra.

Jones, K. (1983), 'A study of sugar cane cultivation practices in the Central District', in Egan, B.T. (ed.), *Proceedings of the 1983 Conference of the Australian Society of Sugar Cane Technologists*, Mackay.

Knutson, R.D., Penn, J.B. and Boehms, W.T. (1983), *Agriculture and Food Policy*, Prentice Hall, New Jersey.

Leverington, K.C., Hogarth, D.M. and Ham, G.J. (1978), 'The influence of time on harvest yields in the Burdekin area' in Egan, B.T. (ed.), *Proceedings of the 1978 Conference of the Australian Society of Sugar Cane Technologists*, Townsville.

O'Sullivan, S. (1985), *Enterprise Budgets for the North West of N.S.W.*, Complan Handbook No. 6, New South Wales Department of Agriculture and the University of New England, Armidale.

Percival, R.H. and Garland, P.J. (1977), *Tractor Costs: How Much to Run Your Tractor*, Economic and Technical Bulletin No. 17, New South Wales Department of Agriculture, Tamworth.

Queensland Cane Grower's Council (1985), Annual grower survey, Brisbane (unpublished).

—— (1987), Annual grower survey, Brisbane (unpublished).

Queensland Department of Primary Industries (1982), *A Guide to Calculating Farm Machinery Costs*, Information Series QI82004, Brisbane, May.

Savage, R.J., Fitzpatrick, E.N., Stevens, N.R., Robinson, I.B., Bradley, G.P., Desmarchelier, J.A. and Ferguson, G.A. (1985), *Sugar Industry Working Party Report*, Queensland Department of Primary Industries, Brisbane.

Sugar Industry Information Service (1989), Notes on the Australian sugar industry, Brisbane.

Sturgiss, R., Connell, P. and Tobler, P. (1990), 'Australia's influence on world sugar prices', *Agriculture and Resources Quarterly* **2**(1), 47–55.

Wegener, M.K. and Pollock, J.S. (1986), *Yield of Ploughout/Replant Crops in the Burdekin District*, Proceedings of the Australian Society of Sugar Cane Technologists, Townsville.

Wong, G., Sturgiss, R. and Borrell, B. (1989), *Economic Consequences of International Sugar Reform*, ABARE Discussion Paper 89.7, AGPS, Canberra.

Wood, C.T. (1965), *Sugar Country*, for Queensland Cane Growers Council, Brisbane.

ABARE

9 780644 227988

B91/22090 Cat No. 91 1670 3