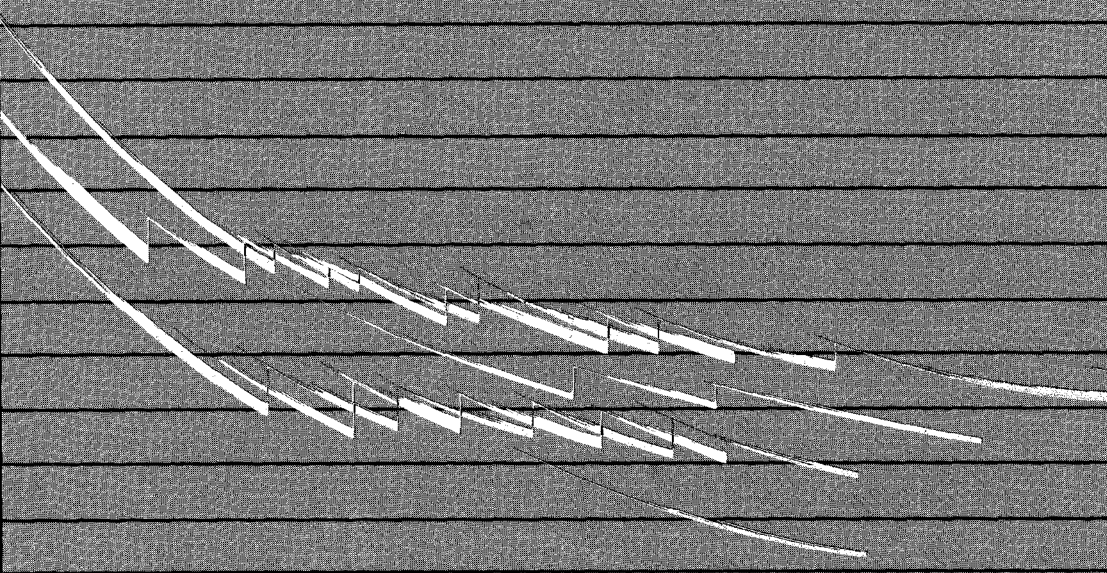
OCCASIONAL PAPER 101

COSTS AND REGULATION OF CANE HARVESTING PRACTICES



BUREAU OF AGRICULTURAL ECONOMICS

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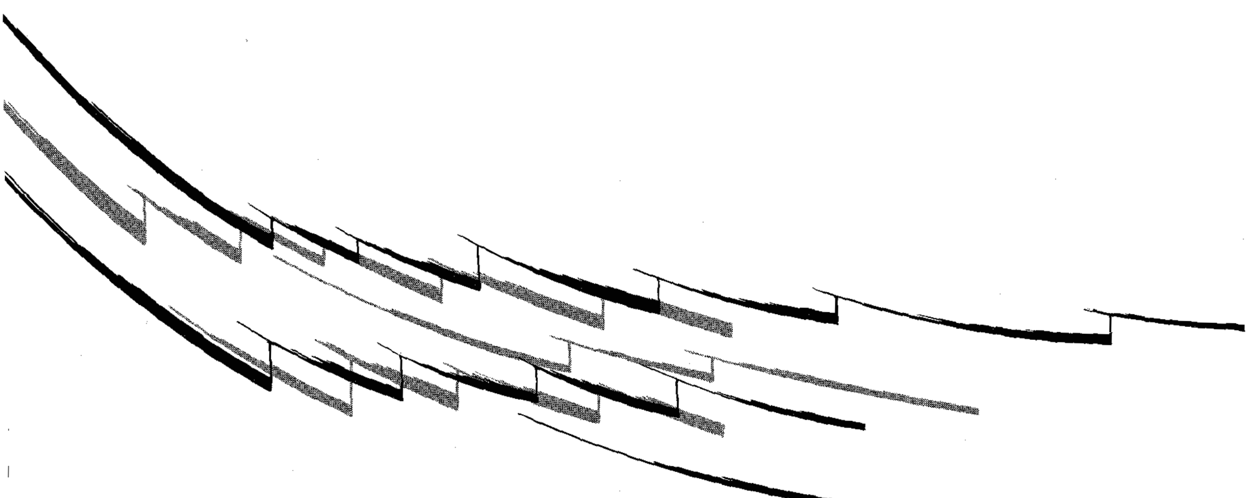
COSTS AND REGULATION OF CANE HARVESTING PRACTICES

PROJECT 42311

PETER CONNELL
AND BRENT BORRELL



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Foreword

In 1983 the Bureau made two submissions to the Industries Assistance Commission inquiry into the sugar industry. It was concluded that, though the industry was an efficient, low cost sugar producer, its regulations and controls had the potential to impede greatly the industry's profitability and development. Since then, the Industries Assistance Commission (in 1983), the Sugar Industry Review (in 1984) and the Savage Sugar Industry Working Party have all recommended similar and substantial changes to the nature and degree of government regulation of the industry. However, the changes which have followed these inquiries have been relatively minor compared to those recommended.

The reluctance of the industry to adopt changes seems to reflect a number of suspicions held by producers about the costs and benefits. To advance the debate on the regulation of the industry, the Bureau sees a clear need to quantify the potential advantages to the industry of structural and organisation changes, and to identify in detail the regulations and controls which currently prevent these gains being realised.

In August 1986 the Bureau released a report highlighting the effects of regulations on profitability in the off-farm sector of the industry. One finding of that report was that net gains of $130m a year were possible in the off-farm sector alone. The present study continues the Bureau's research into regulations by concentrating on the harvesting sector. Again, large gains in profitability are demonstrated to be achievable with a relaxation of industry controls and regulations.

The Bureau intends to continue its research to include a study of the effects of regulations on the cane growing sector of the industry. The work on regulations in the sugar industry will complement other work of the Bureau on the world sugar market and Australia's place in that market. The research on sugar being conducted in the Bureau appears timely in view of the possibility of another IAC inquiry into the sugar industry in 1988.

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June 1987

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SUMMARY

Cane harvesting is the single most costly operation in sugar cane farming. The effective use of harvesting and cane transport equipment has a major influence on harvesting costs. Yet the actual throughput of harvesters falls well short of their potential. In the decade to 1982 the average tonnage cut in Queensland per harvester in a season increased from 9.9 kt to 14.3 kt. However, in this period the potential seasonal throughput of a harvester operating for a single shift per day increased from about 20 kt (in 1974) to 45 kt.

Recent studies have confirmed that cane harvesting costs incurred by growers could be substantially reduced if fewer cane harvesters were used to cut the Australian cane crop. Why then are growers presently using so many harvesters? The purpose of this study is to provide an answer to that question and then to suggest changes in industry policy which would allow harvesting costs to be reduced.

Because 95 per cent of cane grown in Australia is harvested in Queensland, the study is confined to harvesting practices in that state.

Estimating harvesting costs

In this study, an economic model was used to estimate the potential cost savings from the better use of harvesting resources. Changes in practices which could occur following regulatory changes include the use of additional cane haulout units to maintain a continuous flow of cane bins to and from the harvester, and the choices of extended single-shift operation, two-shift operation and weekend harvesting.

Harvesting costs were estimated both from an economywide perspective and from the standpoint of harvester owners, taking into account the effects of depreciation provisions. The model was used to draw inferences about the effects of changes in taxation arrangements and interest rates, as well as in field conditions, on growers' and contractors' incentives for rationalising harvesting operations.

Estimated cost savings

Cost savings were estimated on the basis that, at present, the average cane throughput of a harvester is 18 kt. This is true of harvesters which are used to cut the cane of two or more growers. The present average cost of harvesting was estimated at $5.25/t. It was estimated that by increasing the availability of haulout bins, while still limiting harvesting to a single daily shift, annual harvester throughput could be increased to 32 kt and average harvesting costs reduced to $3.79/t: a saving of 28 per cent. At present, around 24 Mt of cane is harvested each year in Queensland, so savings of this magnitude, spread over the whole crop, would be worth $35m a year.

It was estimated that, if harvesters were operated for two shifts per day, their annual throughput would be up to 80 kt and costs could be reduced by 42 per cent, to $3.06/t. These savings comprise a 48 per cent saving in unit labour costs, a 49 per cent saving in unit machinery operating costs and a 29 per cent reduction in the unit cost of capital. Industrywide, at present levels of production, a 42 per cent reduction in costs would provide an annual economic gain of $53m.

Practices such as weekend harvesting and milling and the extension of the season length, if combined with two-shift harvesting, would further increase utilisation of harvesting resources. Though these practices would reduce unit capital costs, the savings would be partially offset by increases in other costs such as that of labour when weekend harvesting was undertaken. These practices can thus be regarded as approximately cost-neutral — they neither add to costs nor provide further economies of size.

There are some qualifications which should be made about the size of the apparent savings. Much of the existing harvesting capital was purchased at times when real interest rates were much lower than they are now. As well, tax treatment of capital purchases was more lenient in the past than it has been in recent years. Thus, from a grower's point of view, many past machinery purchases would have been more rational at the time than the same purchases would now be. These qualifications imply that, particularly from a grower's perspective, the estimated capital cost savings exaggerate what might be realised in the near future. They do, however, accurately represent the potential for achieving savings to society as a whole as the existing stock of capital is replaced.

Despite the above reservations, there are reasons for believing that the potential gains may be greater than the estimates provided in this paper. First, the cost savings reported here do not include any of the gains which could be achieved off the farm — such as in milling and transport — nor the gains which might arise from changes in cultivation practices. Second, the results presented are based on approximations for the performance and technical possibilities of harvesting crews and machinery. Because these approximations are themselves influenced by restrictions on current practices and technology, the possible gains may have been underestimated. The slow development and adoption of the 'two-row' harvester may be an example of how restrictions affect the availability and use of new technology. As long as the sizes of harvesting groups (see below) remain restricted, there will be little incentive to design high throughput harvesters.

Impediments to achieving the savings

Why do such large apparent savings remain unrealised? The main impediments to achieving the least cost harvesting practices appear to be certain of the regulations governing sugar harvesting and related activities. All controls on the industry — because they are interrelated — affect the harvesting sector, but those applying to the delivery, transport and scheduling of harvesting and milling have a direct and profound effect on harvesting costs. Many of the present harvesting regulations were drawn up when cane was cut by hand. The change to mechanical harvesting during the 1960s dramatically altered the technical opportunities in the industry, but this change was not fully matched by complementary changes in the regulations and controls.

In the 1950s the availability and cost of labour were major constraints on the expansion and improved efficiency of the industry, and the size of farms was dictated largely by the task of managing harvesting in these conditions. The development of mechanical harvesting toward the end of the 1950s provided a solution to this labour problem. So the emphasis when mechanical cane harvesting was first introduced was on reducing labour costs and the problems of labour availability. Other economic opportunities made possible by the new technology were overshadowed.

Three main institutional constraints underly the current cost structure. These relate to the growers' harvesting groups, the controls on cane output, and the transport of cane from farm to mill.

Harvesting groups

Within a mill area — the area served by one mill, typically including around 200 farms — growers are grouped together for the purpose of harvesting their cane. Prior to machine harvesting, similar groups were each served by a gang of canecutters.

Groups are generally of the order of four farms. Millers have considerable power over the size and composition of these groups, mainly because the miller is responsible for all costs between the designated cane receival point (usually a tramway siding) and the bulk raw sugar terminal.

The existence of many small groups can act as a form of insurance for millers against harvester breakdowns which could slow down the flow of cane into mills. Moreover, millers have little incentive to encourage the formation of larger groups because most of the resultant savings would accrue to growers. The only savings to millers likely to arise from fewer but larger groups would be through a reduction in the number of locomotives and bins and perhaps through improved scheduling of locomotives. Such savings would not be large and would not be realised immediately; they would be realised only when existing cane transport equipment needed to be replaced and after rationalisation of harvesting and scheduling arrangements.

At present there are also restrictions on the movement of individual growers between harvesting groups. Those remaining in the group from which a grower wishes to move can appeal to the miller or to a disputes tribunal — as can the harvester owner for that group — on the basis that reduced harvester throughput would increase average costs.

Production controls

With the move to machine cutting, controls on production (land assignments and farm peaks) replaced labour management as the principal constraint on the size of a farm. Potentially, mechanical harvesting could have released growers from their involvement in harvesting, allowing them to specialise in growing much larger crops while leaving harvesting to contractors. Because production controls prevented this expansion, the value (or opportunity cost) of growers' own labour was forced downward, and for many growers the next best use of their time and labour was to mechanically harvest their own cane.

Thus, because there was little opportunity for growers to harvest larger areas, harvesting remained a major commitment for growers despite the dramatic change in harvester technology. Growers did not regard harvesting as an obvious problem area, because production controls prevented them from growing more cane, and regular, small-batch harvesting fitted in well with traditional cultivation and other farm practices. Large scale cultivation and broadacre management techniques that were made possible by the ready supply of harvesting resources could not easily be adopted.

Further, with the phasing out of hand cutting, the restrictions imposed on weekend harvesting and milling of cane by the physical limits of hand cutters were also removed. Here again, there was no move to exploit the potential economies available from introducing weekend harvesting and milling, for the reasons already stated.

Transport scheduling

The third factor limiting improvements in efficiency has been the transport scheduling arrangements. During the hand cutting and early machine era, wholestick cane was harvested, which could be left in the field until wagons arrived. Using temporary in-field tramways, a large number of wagons could be left waiting until a locomotive was available to haul them away. Further, harvesting and associated work on farms usually took place in small batches each day (rather than farmers interspersing full days of harvesting with periods of related activities), so scheduling involved the delivery and pickup of a small number of wagons to and from a large number of farms each day. Tramway sidings therefore did not have to be very long.

With the introduction of chopper harvesters, cane had to be removed quickly to avoid spoilage, and in-field tramways were no longer useful. Continuous harvesting could be achieved only if there was a continuous supply of bins to transport chopped cane. This required longer sidings and new scheduling arrangements. However, transport was the responsibility of the millers, who under the industry's cane payment arrangements had little incentive to implement such a change.

Land assignments, farm peaks, the number and size of harvesting groups and the arrangements for transport scheduling are reviewed annually. However, the scale of regulations governing the industry limits the scope and incentive for speedy and effectual changes to industry controls. For instance, because regulations prevent harvesting contractors from working larger areas, there is little incentive for them to offer discounted rates to growers whose fields are well prepared to minimise harvesting time. Thus, growers have little incentive to reduce harvesting costs.

Millers who wish to vary cane delivery arrangements can enter into private agreements with growers. However, other growers have the right to appeal to the Central Cane Sugar Prices Board which has the power to overrule such agreements. To make any change to existing arrangements involves the agreement and efforts of many participants, whereas to prevent change only very few participants need to object. Over time, small changes have been achieved, and gradually group sizes have become larger. However, many restrictions remain as a legacy from hand cutting days and greatly inhibit the adoption of opportunities presented by mechanical harvesting.

Reducing harvesting costs

The rate at which the gains estimated in this paper could be obtained by the industry will depend on the incentives to growers, harvesting contractors and millers. Production controls, which do not allow for expansion, prevent harvester owners from realising capital and labour cost savings per unit of output. The potential reductions in unit capital costs can be achieved only when it becomes necessary to replace present equipment or when there is expansion of the industry as a whole. As well, the potential gains are concealed by the current restrictions on production and harvesting group size. Growers harvesting their own and other growers' cane may not be able to realise the potential labour cost savings unless they are able to use the saved time (or labour) in an alternative productive activity such as in expanding their cane production. Until then, growers may be better off continuing to use their own labour to harvest their cane.

As long as millers and growers cannot effectively negotiate to alter cane harvesting and delivery arrangements, millers will wish to retain direct controls and restrictions on harvesting because there is no other way for them to co-ordinate the scheduling of cane to mills. If growers and millers could negotiate more freely on delivery arrangements so that gains from larger harvesting group sizes could be reflected in price, quantity, delivery and other terms, there would be incentives for both parties to seek organisational changes that would be to their common benefit. Specifically, there would need to be more flexibility in cane payment arrangements between millers producing No.2 pool sugar for the world market and the growers supplying cane for that purpose.

In any move toward free negotiation between growers, contractors and millers, the benefits accruing to each group will depend on their relative bargaining power. It is possible that some high cost harvesting contractors may have insufficient bargaining power to compete in providing harvesting services. This group could be forced out of business. It is also possible that one sector of the industry could acquire excessive market power, which could hinder the establishment of competitive markets for cane, harvesting services or milling services and could also prevent the achievement of the benefits indicated in this report. Some safeguards are available under the Trade Practices Act to prevent the development of excessive market power. Should these safeguards prove insufficient, some form of government intervention may be warranted.

In order to realise the full potential cost savings, amendments would be required to the Regulation of Sugar Cane Prices Act which would permit incentives for growers and millers to make and uphold supply contracts independently of the appeal and enforcement powers of the Central Sugar Cane Prices Board. Further, to gain the full benefits of rationalisation and expansion it would be necessary to replace the land assignments and farm and mill peaks with a system of freely negotiable market entitlements.

There has been resistance in the past to moves to free up cane production. Part of this resistance has been from growers whose potential for expanding production is limited. Some growers fear that additional Australian sugar production would lower world market prices. However, because Australia is a price taker in the world sugar market, any expansion of this country's industry would be unlikely to affect world prices appreciably.

1. Introduction

Cane harvesting is a costly and time-intensive operation; in the 1984-85 season it accounted for approximately 25 per cent of all cash production costs incurred by growers (Queensland Cane Growers' Association 1986). Even as early as 1976, it was recognised that significant gains were possible from increased utilisation of harvesters (Westcott, Arbuthnot and Bugeja 1976). Page, Couchman and Bathgate (1985) have claimed that, by making better use of both capital and labour, growers could reduce the cost of harvesting operations by up to 20 per cent. Page et al. did not, however, indicate why these savings were not being achieved, nor what measures could be instituted to ensure they were.

In this paper, the analysis is conducted at three levels. First, there is a review of historical changes in technical and policy factors and their effects on the economic incentives to growers and millers. Because over 95 per cent of cane harvested in Australia is grown in Queensland, this study is confined to an examination of practices in that state. Second, an economic model is developed to identify the main technical and policy factors causing the present excessive harvesting costs. The model differs from previous models (Westcott et al. 1976; Page et al. 1985) in the use of a more accurate measure of the cost of capital per unit of output, taking into account the incentive effects of taxation treatment of farm income and costs. Third, the policy changes necessary to provide economic incentives for the industry to reduce costs are identified.

In chapter 2 the industry rules and regulations which affect harvesting operations are discussed in the context of the incentives and disincentives facing both growers and millers to reduce harvesting costs. The physical factors which influence harvesting operations are also outlined. The method of analysis used to estimate harvesting costs is described in chapter 3. Chapter 4 contains an analysis of the potential savings in harvesting costs that may be available to growers. In the final chapter, regulatory impediments to realisation of these savings are discussed, together with possible policy solutions.

2. Factors affecting cane harvesting operations

2.1 Regulations

The price of cane, the quantity of cane produced and the amount of sugar produced from that cane are determined largely by industry regulations. A formula is used to determine the cane price, rigid conditions govern the delivery, transport and scheduling of harvested cane, and a system of delivery quotas (farm and mill peaks) and land assignments is used to regulate cane and sugar production. These controls are enforced under two Queensland State Government acts — the Sugar Acquisition Act and the Regulation of Sugar Cane Prices Act. They are set up and administered by the central and local Sugar Cane Prices Boards — statutory authorities established under the second of these acts.

Under these controls, growers and millers cannot effectively negotiate on the price, quantity or terms of delivery for sugar cane (Borrell and Wong 1986). This has an important bearing on the organisation and structure of the harvesting sector of the industry. Controls are interrelated, so all affect the harvesting sector in some way, but those applying to delivery, transport and scheduling of harvesting and milling have a direct and profound effect.

Controls over price, quantity, delivery and scheduling terms are set out in local board awards which are administered by the central and local boards. The local board awards vary from mill area to mill area but, in relation to harvesting operations, all awards contain clauses covering the formation of harvesting groups, the procedures to be followed should growers wish to leave a group, the duties, powers and composition of a joint grower–miller committee which oversees the progress of harvesting operations, the procedures available to growers for appealing against decisions or rulings which affect their harvesting operations, and the duties, powers and composition of the disputes tribunal. As an example, the clauses of a local board award which cover harvesting matters are set out in appendix A. A harvesting group comprises a number of farms served by the same harvester (or, in the hand cutting era, the same cutting gang). There are around 200 farms per mill, and an average of four farms to a group.

Under present arrangements, growers are responsible for the costs of harvesting and of transporting cane to their nearest delivery point (usually a tramway siding), with millers then responsible for all other costs through to delivery of raw sugar to the bulk sugar terminal. Individually, however, growers have little choice about the timing and rate at which they harvest their cane, or — in some mill areas — about who cuts their cane. The rationale for miller control of harvesting and scheduling is that the miller is responsible for cane transport costs, and that milling costs can be minimised by ensuring a regular supply of cane through mills.

Millers face extreme difficulties in negotiating with growers on price, quantity and delivery terms for cane to ensure its efficient delivery. A grower can appeal to the Central Sugar Cane Prices Board against any private contracts between a miller and a grower. The Central Board has the power to override such contracts, and since any variations to a local board award must not be 'unfair or unreasonable' the outcomes of appeals tend to protect existing equities and industry arrangements. It is understandable that, lacking freedom to offer price incentives for timely delivery, millers should seek to retain direct control over supplies.

Typically, each group of growers sharing a harvester will be located near a common mill tramline. A number of delivery points or sidings are located on the tramline. Empty bins are delivered by the mill locomotive to these delivery points according to a schedule imposed by the mill. Each day the harvesting group is allocated a number of bins, usually supplied in two or more deliveries. The harvesting operation begins on many farms early in the morning, with the cane generally having been burnt the previous evening.

Cane is usually burnt before harvesting to remove foliage ('trash'). In the 1984 season, only 870 kt (3.4 per cent of total cane harvested) was cut 'green'. When considering the latter option, the potential additional costs due to the slower harvesting and higher trash content of green cane have to be weighed against the saving of labour from not having to burn cane, the potential gains from the earlier recommencement of harvesting after rain if cane is not burnt, and the slightly higher sugar content of green cane. It has been claimed that a CCS (commercial cane sugar) improvement of the order of 0.5 of a percentage point in green cane over burnt cane could be expected in northern Queensland (Baxter 1983). (In the past five seasons, the average CCS of cane harvested in northern Queensland was 13.1 per cent.) There are other less readily measurable benefits from green cane harvesting such as possible gains from the trash blanketing of the soil and minimum tillage farming.

Harvesting contractors often fill their daily allotment of bins by early afternoon or sooner. It can happen that the contractor, having filled the morning allotment of bins, must cease harvesting until the afternoon delivery. Thus, even allowing for wet weather interruptions and mechanical problems, there is considerable unused harvester capacity. Delays can also be caused by sidings being too small to take the required allocations of bins. Under present arrangements, the capacity of sidings is mainly the responsibility of millers, who have little incentive to increase siding capacity (see section 2.4).

Many of the controls set up to regulate harvesting were designed when cane was cut by hand. The change to mechanical harvesting during the 1960s dramatically altered the opportunities in the industry. Because this change was not matched by corresponding changes in the regulations, these now stand in the way of full exploitation of potential economies in mechanical harvesting.

2.2 Mechanical harvesting

Relatively high Australian labour costs have always provided an incentive for the industry to adopt labour saving devices. This incentive was strengthened in the late 1950s by difficulties in satisfying the increasing demand for canecutters which resulted from a gradual expansion in production limits (farm and mill peaks) (Department of Labour and National Service 1970).

The introduction of mechanical loading of cane onto cane wagons in the second half of the 1950s was one innovation which increased the productivity of canecutters. But the availability and cost of labour remained major constraints on the expansion and efficiency of the industry, and the size of a farm was influenced largely by the management of the harvesting resources available. Burning and harvesting were generally carried out in small blocks daily over the five–six month harvesting season. Cutting was restricted to eight hours a day between the hours of 6 am and 6 pm, and weekend breaks were mandatory under union awards to prevent canecutters becoming physically exhausted. Management and supervision of harvesting, and sometimes direct labour input into it, dominated the growers' time during the harvesting months. To expand farm size, growers required increased harvesting resources.

The development of mechanical harvesting toward the end of the 1950s provided a solution to the industry's labour problem. When mechanical cane harvesting was first introduced, the emphasis was therefore on reducing labour costs and the problems of labour availability. Other economic opportunities made possible by the new technology were overshadowed.

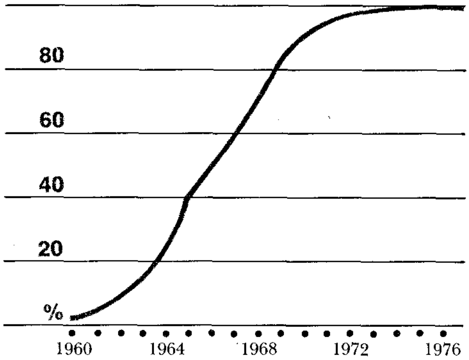
Certain changes in industry controls were necessary with the introduction of mechanical harvesting; in particular, changes were required to permit the use of chopper harvesters (one of the two main alternative systems). However, only where controls stood as direct impediments to mechanical harvesting were changes made, and then only after considerable debate between growers and millers, the final settlement being overseen by the Central Sugar Cane Prices Board.

Introduction: 1960–70

Mechanical cane harvesting began in Australia in the late 1950s, and by the end of the 1970 season less than 5 per cent of cane was being cut by hand (see figure A).

A Percentage of Queensland cane harvested mechanically

BAE chart



The rate of introduction of mechanical cane harvesters was not uniform, but was most rapid in the more northerly areas where there was the greatest shortage of seasonal workers. Initially, wholestick harvesters were favoured over chopper harvesters, being at that stage more technologically advanced and cheaper. Their drawbacks were that they were less effective in handling sprawled or flattened cane, and that they still required a separate operation of loading cane onto the wagons. By the mid-1970s, wholestick harvesters had disappeared from commercial use.

Chopped cane initially created some problems for millers, being more susceptible to spoilage by bacteria than whole sticks. Juice from cane thus contaminated can fail to crystallise satisfactorily in processing, leading to a decline in both the quantity and quality of sugar produced. There was no systematic approach among millers to the introduction of mechanical cane harvesting, although it was clear that transport and receival procedures had to be improved to overcome the spoilage problem.

Amendments to the Regulation of Sugar Cane Prices Act were introduced in 1966 to cope with the growing use of chopper harvesters. Growers could apply to the Central Sugar Cane Prices Board to order millers to provide containers or bins suitable for transporting chopped cane from the usual receival points; alternatively, millers could apply to the Central Board to require that all cane delivered to given receival points be in chopped form.

One of the advantages to millers of chopped cane deliveries was that they no longer needed to provide the portable in-field tramlines which had been required with wholestick harvesting — whether hand or machine — to cart harvested cane to the nearest delivery point (siding). On the other hand, millers had to finance the purchase of the bins to carry chopped cane. With chopper harvesters, bins are typically taken from tramway sidings into the fields on trailers which are towed by a tractor beside the harvester. The combination of tractor plus trailer is known as a haulout unit. When filled, bins are taken back to the siding and (if the haulout unit is of the conventional 'roll-on/roll-off' type) run off the trailer on to the rails for haulage to the mill. A switch to chopped cane deliveries thus required some rearrangement of delivery points. Where more than one grower delivered cane to a given delivery point, millers were unwilling to undertake this modification unless all the growers used chopper harvesters.

This was thus a difficult period for millers, putting them under pressure to streamline and improve the cane transport system. There were few immediate benefits to them from the introduction of mechanical harvesting, whereas there were potential problems in raw sugar manufacturing from increased cane spoilage, and they were called upon to finance and provide sufficient bins and to modify sidings. The consequences are described in more detail below.

It was recognised at an early stage that the introduction of mechanical harvesting might either advantage or disadvantage growers, depending on when their cane was harvested. The sugar content of cane varies throughout the year, reaching a peak about two-thirds of the way through the harvesting season. Under hand cutting, when rapid harvesting was not possible, as a rule all growers made deliveries of approximately equal tonnage each week throughout the season. Growers were paid for their cane on the basis of the average CCS (sugar content, as weight percentage) of their weekly deliveries.

With mechanical harvesting, a grower's crop could be cut in a short period. If cane payments were based solely on the CCS level of cane at the time of delivery and growers had the option of when they could deliver their cane, they would all have preferred to concentrate their deliveries in the period when CCS levels of cane were at their highest. Cane payment arrangements were therefore changed to take into account the fact that, with mechanical harvesting, growers would be making fewer cane deliveries, generally not at times of their choice. This was done by incorporating into each local board award a 'relative CCS' cane payment formula, whereby sugar content is evaluated relative to the current norm:

Relative CCS of cane	=	Growers' actual CCS for that week	—	Mill's average CCS for that week	+	Mill's estimated average CCS for the season

It can be seen that cane payments are inflated in the low CCS weeks of the season and deflated in the high CCS weeks. Growers do not compete against the seasonal influences but only against the mill average CCS for any particular week. Thus the price received should not depend on whether a grower supplies all cane in the first week of the season or in the peak CCS week: there should be neither a penalty in the first instance nor a benefit in the second.

The abovementioned changes in controls allowed farmers to introduce the new harvester technology and hence to overcome the problem of labour availability. Mechanical harvesting provided immediate and obvious benefits to growers and was adopted quickly (see figure A). However, though the industry regulations did not prevent the new technology from being workable and profitable, they still precluded realisation of much of the potential gains. Controls had been only slightly modified from those originally designed to regulate hand harvesting of cane. More significant changes, which would have allowed full use of this new technology, were not obvious at that time and were not made.

Three controls, in particular, have limited the achievement of economies of scale. They are:

- land assignments,
- restrictions on group size, and
- millers' control over length of tramway sidings.

The first of these requires some explanation. It refers to the specification of the areas of land on which sugar is allowed to be grown commercially. The purpose of land assignments has been to control production and to have a mechanism for allocating cane to designated mills. This production control dates from 1915.

With the move to machine cutting, land assignments replaced labour management as the major constraints on farm size. Potentially, mechanical harvesting could have freed growers from their involvement in harvesting and allowed them to specialise in growing much larger crops, by adopting new practices such as large scale cultivation and broadacre management techniques. This was prevented by the limits on the area on which cane could be grown (both in total and on each property) and thus on the amount of cane which could be harvested. For many growers the next best use of their time and labour was to harvest their own cane mechanically. In other words, the value (or opportunity cost) of growers' own labour was forced downward, providing a high incentive for them to become, or remain, directly involved in harvesting. Only those who could employ their spare time in some other more profitable farm activity or off-farm job could avoid this incentive.

The cutting rates of even the early harvesters were impressive in comparison with hand cutting. But within some local board awards, upper limits on group size were applied to both hand and mechanical cutting. In the South Johnstone mill area, for instance, for the 1965 season, an upper limit of 7 kt was placed on hand cutting groups, and a 9 kt limit on machine cutting groups (Queensland Government 1965). (The larger limit for machine groups indicates some recognition of the throughput required to recoup investment in a harvester.) Even by 1963, harvesting rates of up to 100 tonnes per day — equivalent to around 12 kt per season — were possible with mechanical harvesters worked on an 8-hour day (See and Crouch 1963). Moreover, given that physical fatigue is not a problem with machine cutting of cane, weekend harvesting and longer hours would technically have been possible. But, because of the small group sizes, there would not have been any gains from operating mechanical harvesters more intensively or by operating them during overtime hours.

The restrictions on group size, which had little effect on the cost of hand cutting, have as a result deprived growers of the advantages that machine harvesting contractors could have offered had they been able to compete to form large groups. Consequently, any small number of growers sharing one machine and contributing their spare labour could form a workable group similar to those of contractors. Because of the low opportunity cost of growers' own time, contractors employing labour at award rates were in most instances uncompetitive with these grower based operations. Regardless of whether the operators were growers or contractors, a larger number of machines was used to harvest the industry's cane than was technically necessary.

The third factor which restricted scale economies was the cane transport scheduling arrangements. The transport system and scheduling arrangements evolved during the hand cutting era. With hand cutting or wholestick mechanical cutting, harvesting could continue regardless of whether cane wagons were available for immediate loading. Cane could be left in the field until wagons arrived and, using temporary in-field tramways, a large number of wagons could be left waiting until a locomotive was available to haul them away. Further, as has been mentioned already, on many farms cane was harvested in small daily batches rather than intermittently in large quantities, so that millers had to deliver and pick up a small number of wagons each day from a large number of farms. As a result, tramway sidings did not have to be long.

With the introduction of chopper harvesters, continuous harvesting could be achieved only if there was a continuous supply of bins to transport chopped cane. Bins are delivered to a siding each day according to the miller's transport system schedule. Because there are many sidings in a mill area, the bins are widely dispersed. The harvester can operate only as long as empty bins are available at a siding, and even in that case may be idle if the haulout unit is moving between the harvester and the siding. If only one haulout unit is used, the harvester is idle for a time that depends on this 'haulout distance'. If two or more haulouts (again depending on the haulout distance) are able to keep up a continuous flow of bins to the harvester this delay is avoided. The bins at the siding can be quickly filled, and both the harvester and haulouts then lie idle until a new supply of empty bins arrives and the full bins are removed.

The efficiency of use of harvesters is thus dependent upon the transport system provided by the miller, who — as has been noted — has no incentive to undertake any more investment of this kind than is needed to ensure a steady input of fresh cane throughout the season.

Land assignments, farm peaks, the number and size of harvesting groups and the arrangements dealing with the scheduling of cane are all reviewed annually. However, it is argued by Borrell and Wong (1986) that the large number of industry regulations, and the procedures and bodies which oversee and manage these regulations, limit the scope for speedy and significant improvements in operating procedures. Over time, small changes have been achieved. Group sizes have gradually become larger, as have individual growers' land assignments and farm peaks and the length of sidings. However, restrictions remaining as a legacy of hand cutting days have greatly limited the adoption of management strategies and the attainment of economies of scale made possible by mechanical harvesting. With the phasing out of hand cutting and the consequent removal of the restrictions which the physical limits of hand cutters imposed on the intensity of harvesting and milling, there was no move to exploit the economies of scale that thus became available.

Developments: 1971–86

There has been continual improvement in harvester technology over the past twenty years. Mulkearns (1984) presented data showing that the capacity of harvesters operating on a single shift increased from about 20 kt per season in 1974 to 45 kt in 1982 — an increase of 125 per cent. In the same time, the real retail price of new harvesters increased by only 25 per cent, and the average tonnage of cane produced per grower has increased by approximately 31 per cent, mainly due to increase in assigned area.

As well as this increase in harvester throughput, substantial improvements have been made in reducing the trash accompanying the cane billets. Mulkearns reported that, though a need may be perceived for a cheaper machine with reduced capacity to meet the needs of small groups, it is the manufacturers' experience that harvester costs are directly proportional to the number of machine functions. The functions included in current harvesters are deemed to be necessary to produce the quality of cane demanded by millers, he argued, so that a smaller and cheaper machine designed to meet the needs of small groups would not necessarily reduce unit harvesting costs. While the capacity of harvesters has been increasing, the number of machines in use in the industry has shown little decline (see table 1). In fact, as the table indicates, in times of low world prices (such as the 1985

1 Number of harvesters and cane harvested in Queensland

Season	Number of machines	Cane harvested	Cane harvested mechanically	Harvest per machine
	no.	kt	kt	t
1971	1 899	18 410	17 862	9 406
1972	1 852	18 087	17 866	9 647
1973	1 794	18 279	18 201	10 145
1974	1 728	19 421	19 384	11 217
1975	1 719	21 069	21 058	12 250
1976	1 775	22 269	22 266	12 544
1977	1 791	22 331	22 327	12 466
1978	1 780	20 135	20 133	11 311
1979	1 760	19 860	19 860	11 284
1980	1 728	22 540	22 540	13 044
1981	1 717	23 588	23 588	13 738
1982	1 699	23 123	23 123	13 610
1983	1 709	22 723	22 723	13 296
1984	1 706	23 910	23 910	14 015
1985	1 724	23 003	23 003	13 343

Source: Queensland Canegrowers' Council.

season) growers sometimes resurrect small, previously abandoned machines and harvest their own cane in order to reduce cash outlays.

The option of expanding cane production so that harvester utilisation is increased is not readily available to cane growers and harvester owners. Cane production is strictly limited to assigned land. Increases in land assignments are linked to increases in farm and mill peaks (entitlements to No.1 pool sales). At present 360 000 ha are assigned to sugar cane in Queensland. The recent Sugar Industry Working Party (Savage et al. 1985) reported that a further 245 000 ha of land suitable for cane were available but not currently assigned. Admittedly some of this land would require improvements and clearing to bring it into production.

The census of harvester owners reported by Petersen et al. (1984) indicated that output per machine was strongly related to category of ownership (see table 2). Ownership of harvesters is still concentrated in the hands of growers, but throughput of cane is on average highest where the harvester is operated by a contractor. Because of the high capital cost of cane harvesting equipment, it would be expected that growers would try to achieve the significant size economies available in cane harvesting practices. Conditions of local board awards which hinder movements toward larger group sizes have been a major obstacle to size economies. If a grower wishes to leave an existing group to join a larger group, the savings in harvesting costs to that grower can be outweighed by the increased harvesting costs to the growers remaining in the group. These growers or the harvesting contractor can object to their harvester disputes committee about that grower leaving their group.

There are many growers with small assignments cutting their own cane. In fact, individual growers cutting less than 5 kt of cane per season at present comprise around 20 per cent of harvesting 'groups'. One reason for this, as has already been mentioned, may be that such growers would consider themselves under-employed if they did not harvest their own cane. The alternative farm activities during the harvest period include land preparation and rehabilitation of ratoon crops. Over recent years, with rising fuel costs and the increasing use of reduced tillage cultivation techniques, the time spent on these alternative activities is tending to decline. Though, technically, one way for growers to make more use both of their own labour and of their cultivation equipment would be to increase the area planted to cane, the industry's supply controls continue to prevent this.

Another explanation for many growers owning or having a part interest in a cane harvester lies in the relatively low cost of capital in the past. Real interest rates were at times very low — in some years, negative — in the period before deregulation of Australia's financial and foreign exchange markets. Also, when account is taken of taxation advantages resulting from the accelerated depreciation and investment allowances on farm machinery that were previously available, the annual cost of capital to individuals was less than the cost

2 Harvester ownership and machine throughput: 1982 season

Ownership category	Proportion of crop cut	Proportion off machines operated	Average harvest per machine
	%	%	t
Grower cutting own cane	11.3	28.9	5 751
Grower cutting own and others' cane	32.7	30.8	15 624
Group of growers cutting own cane	11.2	9.9	16 636
Group of growers cutting own and others' cane	6.4	4.2	21 682
Contractors (no cane grower involvement)	38.5	26.1	21 683

Source: Petersen et al. (1984)

to the economy as a whole (see appendix C). This reduced the private cost of capital relative to that of other inputs, encouraging the use of more capital than if all classes of input had have been taxed equally.

2.3 Technical factors

Factors which affect the intensity of use of a harvester can initially be broken down into two groups: those which affect the amount of cane cut per hour, and those which affect the hours of operation per day.

Cane cut per hour

A harvesting operation consists basically of a harvester cutting the cane, and a number of haulout units (tractor and trailer) transporting the billets of cane from the field to the tramway siding or other delivery point. The number of haulout units is determined by the harvester owner, but is largely a function of the size of the contract (that is, the total tonnage of cane grown by the members of the group) and the haulout distance. At present, the most common arrangement is two haulout units; as haulout distance increases, it becomes more difficult to maintain continuous operation of the harvester without a third unit.

The majority of haulout units are of the conventional roll-on/roll-off type, carrying rails for transferring the bins to and from the siding. During the 1982 season, such conventional units comprised 77.3 per cent of all haulout equipment used, with tipper bins making up 12.3 per cent and trucks 10.4 per cent (see Petersen et al. 1984). With the newer, tipper type of equipment, harvested cane is emptied from bins attached to the haulout into transport bins at the rail sidings. The reduced siding turnaround time achieved using this type of equipment needs to be weighed against its additional capital cost. As the haulout distance increases, the use of trucks can be warranted and cane can be hauled directly to the mill.

The capacity of haulout bins is determined by the miller from a range of standard bin sizes, from 2.5 t to 10 t. In about half the Queensland mill areas, 4 t bins are used (see table 3). It is also possible to have more than one bin on each haulout trailer. Upper limits on trailer loads are set by the Main Roads Department, taking into account trailer configurations, number of axles and number and type of tyres.

3 Capacities of tramway bins used in Queensland mill areas [a]

2.5 t	**4 t**	**5 t**
Qunaba	Hambledon	Mourilyan
Millaquin	Mulgrave	Kalamia
	Goondi	Plane Creek
3 t	Mourilyan	
Babinda	South Johnstone	**5.5 t**
Fairymead	Tully	Racecourse
Millaquin	Victoria	
	Macknade	**6 t**
3.5 t	Invicta	Pleystowe
Inkerman	Pioneer	Bingera
Cattle Creek	Proserpine	Isis
North Eton	Farleigh	
	Marian	**10 t**
	Plane Creek	Mossman
	Moreton	

a The mill tramway system is not used in the Maryborough and Rocky Point mill areas, where cane is delivered by trucks.
Source: Australian Canegrower (1981).

The distance from the field to the tramway siding and the suitability of access roads determine the rate at which haulout units can deliver full bins to the siding and return to the harvester with empty bins. The longer the haulout distance, the more harvester time may be lost waiting for bins if too few haulouts are used. Alternatively, harvester drivers can operate their machines at a slower rate so that the machines are not actually standing idle. The optimal number of haulouts depends on the trade-off between the opportunity cost of lost harvester time and the cost of operating an additional haulout.

Petersen et al. (1984) reported that their census results indicated that the average one-way haul from paddock to mill tramway siding was 1.74 km for tractor–trailer haulout units and 3.16 km for tipper bins. In a recent analysis of harvesting operations, Ridge and Dick (1985) derived equations to estimate lost harvester time due to haulout (see appendix B) and applied them to the specific cases of distances from one to five kilometres with a single-bin or a double-bin haulout, to obtain hourly cutting rates.

In a similar manner to haulout distance, the time taken to unload a full bin and push an empty bin on to the haulout trailer at the tramway siding will also influence the lost harvester time. Ridge and Dick (1985) estimated that for roll-on/roll-off units, the time to load and unload at the siding is approximately 2.3 minutes for a 6 t single-bin unit and 3.9 minutes for an 8 t double-bin unit (that is, a unit carrying two 4 t bins). Figure B shows the influence that haulout distance and bin size can have on actual harvesting rates, for both burnt and green cane.

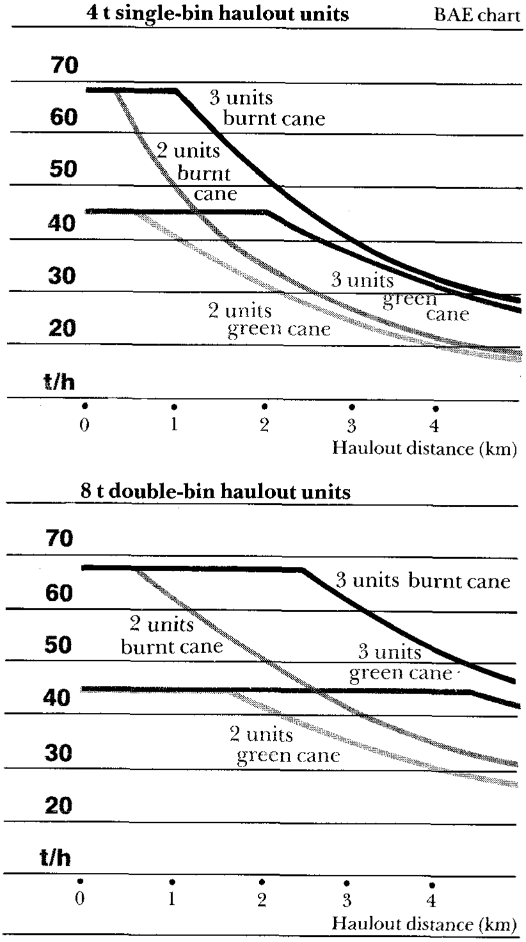
From the graphs it is possible to ascertain at what haulout distances harvester idle time is avoided using a given set of haulout equipment. For instance, it can be seen that, if three 4 t single-bin haulout units accompany a harvester cutting burnt cane, the harvester will be operating at its maximum rate of 67.3 t/h if the haulout distance is 1.2 km or less. At haulout distances beyond this, there will either be periods when the harvester is idle, or alternatively it will be operated at reduced throughput to minimise stoppages.

Harvesting rates are higher for cane which has been burnt than for green cane because the former contains less trash. Ridge and Dick (1985) estimated the above harvester cutting rate of 67.3 t/h in burnt cane, after allowing for turning at the end of rows and bin changeover, compared with 44.7 t/h in green cane — that is, about two-thirds of the burnt-cane harvesting rate. However, for a given combination of number and size of haulout units, the difference between the amount of burnt and the amount of green cane that can be cut in an hour diminishes as the average haulout distance increases.

In this paper the harvesting of burnt cane only is considered, since it constitutes over 95 per cent of all cane harvested in Australia.

Crop yield, crop height uniformity and the degree of lodging (plants bent or flattened) all influence the harvesting rate.

B Dependence of harvesting rate on haulout facilities and distance



The speed of a cane harvester along a row of cane is reduced where the cane is lodged and tangled, where stick height varies markedly and in heavier yielding crops. Lodging of cane depends largely on variety, yield and weather (for example, the occurrence of strong winds). Certain varieties, such as those with large tops and low fibre content, are more prone to lodging than others, as are high yielding crops which grow as stools with few but large sticks. In cane whose height varies markedly, more control has to be exercised over the cane topper if excessive top material is not to be fed into the harvester's extraction mechanism.

Harvester cutting rates are also affected by field conditions (soil type, wetness, length of rows, field layout and slope of the land), which are largely determined by farming practices. Wet conditions, especially in heavier soils, will reduce the speed of the harvester along the row, and of haulout units along rows, headlands and unsealed access roads.

The longer the rows, the less frequently the harvester turns, which reduces time lost and consequently increases cutting rates. Ridge and Dick (1985), in determining their harvester cutting rates, assumed a row length of 300 m, which is typical for the industry. Under present practices, with growers harvesting relatively small areas, there is a trade-off between field layout and the intensity of burning. Growers who deliver cane with excessive extraneous matter can be penalised. The intensity of a burn is maximised in square fields, which can have higher harvesting costs than long, rectangular fields.

The topography of a field also can influence the rate of harvesting. To prevent the harvester from tipping, harvesting speeds must be lower on steeply sloping land.

Hours of operation

The traditional harvesting operation has employed a single 8-hour shift within the hours 6 am to 6 pm. As has been noted, the availability of bins, which are supplied by the miller, is a major determinant of harvester output per day, and hence of the effective hours of operation.

In the Proserpine district in Queensland's central region, in the 1985 season, two-shift harvesting was employed on a trial basis. It was not continued in the 1986 season. Two specific shifts were worked, 4 am to noon and noon to 8 pm. This change required the agreement and co-operation of all the industry parties involved, and the harvesters and haulout units had to be equipped for night-time harvesting. Operating more than one shift per day can be viewed as an extension of the option of using overtime, and although incurring additional labour cost it permits greater daily harvester output. Two-shift harvesting does, however, require greater management skills.

Other factors

At present the milling operation is based largely on a five-day working week, and because the time between harvesting and milling is limited to a few hours to reduce spoilage, this implies a five-day harvesting week. (Some local board awards penalise millers if there is a long delay between picking up the cane and crushing it.) A move to weekend harvesting and milling (that is, operating on Saturday and/or Sunday) would allow greater throughput of cane per week, and hence greater use of capital equipment within a given season length, both on and off the farm.

The overall length of the harvesting period depends largely on the size of the crop in a mill area, as well as on daily rates of harvesting. A larger crop and an extension of the harvesting period would also allow greater use of capital equipment by reducing the time that the harvester and ancillary equipment (apart from tractors, in some cases) are idle.

2.4 Current incentives

The present harvesting arrangements create a pattern of incentives which can affect millers, growers and harvesters very differently.

For millers

Because the sugar content of cane changes systematically through the season, sugar production from a given volume of cane could be increased by using weekend milling to shorten the harvesting period. Under the cane payment arrangements, all growers would benefit from such a change in milling practices, because of its effect on the seasonal average sugar content (see the formula in section 2.2). Millers, in contrast, in many instances would not benefit — in fact, their net revenue could even decrease as sugar production increased: as the average CCS of cane deliveries increases, less cane is required to fill a mill's No. 1 pool entitlement, and more of the output goes to the lower priced No. 2 pool (Borrell and Wong 1986). There is therefore little incentive for mills to crush at weekends, and hence no requirement to harvest then.

In the mill awards specifying that harvesting groups are to be formed with the aim of ensuring the efficient transport of cane, efficiency of harvesting operations is generally a secondary consideration. As has already been pointed out, harvesters are at present underutilised, one cause being delays while operators wait for bins. The number of bins provided at one time is often limited by siding capacity. Under current arrangements millers will not invest in expanded siding capacity unless it can be shown that this will improve transport arrangements and reduce transport costs. Even if growers themselves were to invest in extra siding capacity, they would still require the co-operation of millers in scheduling larger pickups; this could require millers to purchase additional cane bins, and could impinge on their scheduling commitments to other growers. Because the millers cannot negotiate directly with individual growers but only with the mill-area committees (or through the Central Sugar Cane Prices Board, if agreement cannot be reached), scheduling arrangements cannot easily be changed. Also, groups would need to be enlarged, to use the extra harvester capacity made available, before growers would gain from such investments.

The existence of a large number of small groups can work as a form of insurance for millers against possible harvester breakdowns, which could slow down the flow of cane into mills. On the other hand, Mulkearns (1984) has argued that a smaller number of new, high capacity machines is likely to be more reliable than a larger number of older machines. Page et al. (1985) have found that only small savings could accrue to millers from increasing group sizes; such savings would result from a reduction, per unit output, in cane transport equipment and costs. Many of these savings, however, would not be obtained without thorough restructuring of harvesting operations. Therefore, only if millers were assured of substantial change to cane payment and delivery arrangements would they be likely to favour a rationalisation of harvesting operations.

For growers and harvesters

It was stated earlier that possible reasons for the preponderance of small harvester groups include taxation provisions (particularly in years of high sugar prices), the relatively low interest rates which in the past kept the overall purchase cost of harvesters lower than at present, and the production controls which prevented the full use of labour resources in growing cane. Another reason why growers may resist the move toward bigger groups is that it could mean that a grower's crop is cut in larger batches, to avoid wasting potential working time of the then more fully occupied harvesting equipment. Since cane is usually burnt just prior to harvesting, and the sugar content rapidly deteriorates after burning, there is always the possibility that bad weather or harvesting delays could cause economic losses to growers. Only if such damage is sufficient to cause the cane to be condemned can the grower obtain insurance compensation. The larger the burns, the greater the potential loss of income to the grower at any one time, even though, overall, the average income loss in a mill area over a season would be unchanged.

Because the sugar content of cane decreases exponentially once the cane has been harvested, growers have an incentive to minimise the time between harvesting and the scheduled pickup time for deliveries. This too provides some incentive for growers to belong to smaller groups (although this influence is probably very slight) because larger groups may have to do larger cuts, with burning and harvesting starting further ahead of the pickup time, to avoid wasting machine time.

Within harvesting groups, there is little differentiation of rates charged for harvesting to take into account growers' specific conditions such as field conditions and haulout distances. It might be expected that such conditions would affect harvesting charges. For example, because long haulout distances can cause a harvester to stand idle while awaiting the return of haulouts, contractors might employ additional haulout units, for which they would be expected to charge. However, because of the restrictions on group size, such expenditure would only enable contractors to cut existing crops more quickly; it would not increase the overall use of their machinery. Thus, their costs would increase with no benefit to them.

At present, with small harvester groups, idle harvester time due to long haulout distances does not impose an opportunity cost on contractors. If, in the absence of restrictions on group size, the harvesting of cane located in a remote area prevented a contractor from profitably cutting the cane of another grower, idle time would impose an opportunity cost. In that case, contractors would presumably be unwilling to cut on remote properties unless compensated. Because rates do not reflect the cost of idle time, all growers share this cost. If opportunity costs were reflected in contractors' rates, growers would have to pay a penalty where conditions required the use of more than normal harvesting resources, and would thus receive incentives to minimise the use of harvesting resources.

In the subsequent analysis it is proposed to estimate the additional costs that some of the above regulations and practices impose on harvesting operations. In the next chapter the budgetary model used to estimate harvesting costs is outlined.

3. Method of analysis

A computer simulation model based on industry harvesting cost data was developed to estimate the cost savings that might occur through economies of size in harvesting and haulout equipment. For a given set of assumptions about the number of haulouts available, the capacity of haulout bins, haulout distances and the average number of hours worked per shift, it was possible to estimate the annual volume of cane that could be cut by a harvester. The average cost per tonne for harvesting and transporting this volume of cane was then estimated.

The costs were estimated for burnt cane only, since at present only a very small, though growing, quantity of cane is harvested green. Haulout costs were calculated assuming use of the traditional roll-on/roll-off units, which comprise over 75 per cent of haulout equipment.

Estimates of the costs of harvesting and transporting cane were drawn mainly from industry sources: the Queensland Cane Growers' Association; recently published research into harvesting costs (Page et al. 1985; Ridge and Dick 1985); and discussions with various people in the industry. The Queensland Cane Growers' Association makes available, as part of its service to members, 'costing calculation sheets for mechanical harvesting' which give a standard method that growers and contractors can use to estimate harvesting costs. These sheets are widely used throughout the industry, and for this reason many of the cost assumptions in these sheets were used in this study.

Labour

Wage cost estimates were based on industry award rates for a five-day, 40-hour week, which for the 1985 season were $316 a week and $300 a week for harvester and haulout drivers, respectively. It was assumed that drivers would be paid on a weekly basis, although it is not unknown for work to be paid at piece rates. A holiday pay loading of 10 per cent was allowed for, while overtime was calculated at time and a half plus the 10 per cent holiday pay loading. Where weekend harvesting was costed, Saturday labour costs were estimated as three hours at time and a half and five hours at double time. For Sunday harvesting, hours were costed at double time. Finally, an overall loading of 6 per cent on all wage costs was added to account for workers' compensation insurance.

It has been assumed that within an 8-hour shift the maximum period of cutting would be six hours. Based on industry experience, an average of two hours' cutting per 8-hour shift was assumed to be lost throughout the season due to mechanical breakdowns, wet weather delays, industrial disputes, the burning of cane and the moving of equipment from field to field. To represent harvester idle time due to lack of bins at the siding, the number of hours worked per shift was varied from three to six; the additional time lost — if any — in waiting for haulouts was relative to these hours. Further calculations were done assuming that up to two hours overtime per shift was worked, entirely in harvesting operations.

For harvester throughputs up to 15 kt per season, overtime allowances of six hours a week for harvester drivers and three hours a week for haulout drivers were assumed, to cover weekly maintenance. (The higher allowance for harvester drivers reflects the higher maintenance requirements of harvesters.) For larger throughputs the allowances were ten hours for harvester drivers and five hours for haulout drivers. In that part of the year in which the mill was not crushing cane, some labour would be employed on preparing and maintaining machinery, the weeks thus employed increasing with throughput. Allowance has been made for such labour requirements at the rate of five weeks for throughputs up to 15 kt, six weeks for tonnages between 15 kt and 30 kt, eight weeks for tonnages between 30 kt and 50 kt, and ten weeks for tonnages in excess of 50 kt.

Fuel, oil and grease

Fuel use was calculated on a kilowatt-hour basis, the number of operating hours being based on the number of hours of cutting. Following the Queensland Cane Growers' Association method, for a harvester cutting six hours a day fuel costs were $60 a day and for haulouts just over $24 a day. An additional 12 per cent was allowed for oil and grease.

Repairs and maintenance

The approach used by the Queensland Cane Growers' Association for repairs and maintenance costs was adopted: that is, an annual charge of 4 per cent of the capital cost of the harvester and haulout units, and a throughput charge of 15c/t of cane harvested. In practice, the annual charges for repairs and maintenance would be expected to increase with the age and cumulated operating hours of the machinery. However, the industry's use of a standard annual charge seems to indicate that this effect is not large until late in the operating life; it is neglected in this study.

Cost of capital

The capital cost of a machine — leaving aside such factors as methods of financing and taxation allowances — is simply its purchase price. Because the life of a harvester has been specified in terms of tonnage cut, in the cost estimates presented in chapter 4 the implied timing of purchases differs from case to case depending on the tonnage cut per year. All other costs were most conveniently estimated either directly per tonne harvested or as annual costs. For this reason it was necessary to have a valid way to represent purchase prices of assets as streams of annual costs over their lives.

The mathematical details of the method used to express purchase prices as annual cost flows are given in appendix C.
The method which is widely used by the industry (for example, Page et al. 1985) involves estimating two capital cost components: return on investment and depreciation. Though this method has some intuitive appeal, and is consistent with some accounting concepts of costs, it provides only an approximation and can lead to either overestimation or underestimation of capital costs, as is demonstrated in appendix C.

In the present analysis, the costs of capital are examined from an economywide perspective: thus, the potential benefits to machinery owners, for instance, of being able to claim the capital costs against taxable income are excluded. The effect of taxation provisions concerning depreciation and interest can lead to quite large differences between the economywide costs and those to which individual harvester owners respond (see appendix C). For much of the recent past these provisions appear to have decreased the after-tax cost of capital relative to that of other inputs and to the after-tax value of income. This will have encouraged the use of more capital than would otherwise appear reasonable.

The life of a harvester or a haulout unit was taken to be around 200 kt of cane. This is in line with the assumptions adopted by Page et al. (1985). Of course, the life of a harvester would vary from group to group depending on how well the machine is maintained and on the topography and field conditions of the crops being harvested. Details of the assumptions used in expressing the 200 kt life of the machinery in terms of years are given in appendix C, as are estimates of the capital costs of harvesting equipment.

There are obvious difficulties in obtaining reliable and realistic estimates of the future salvage value of present harvesting equipment. Present salvage values of equipment now possibly outdated are of doubtful relevance, and a further uncertainty arises in relation to inflation effects. For simplicity, it was assumed that equipment had zero salvage value.

Other costs

This item included harvester, tractor and service vehicle registration and insurance costs, and office expenses.

4. Costs of harvesting

In this chapter, harvesting costs are estimated for a range of intensities of harvester use, and compared with an estimate of the current costs. The estimates of harvesting costs are given as single figures for the whole range of current harvester ownership arrangements, because the savings are here examined from an economywide perspective rather than from that of an individual harvester owner.

4.1 Present costs

It was assumed that the representative group produced 18 kt a year, using a harvester and two single-bin haulout units. This group output was chosen because it approximates the average tonnage of cane cut by all groups in the 1982 season, excluding growers who cut only their own cane (see table 2). The haulout distance was taken to be 1.74 km, the average distance travelled by conventional roll-on/roll-off units during the 1982 season (see Petersen et al. 1984). If the harvesting period were 20 weeks and the harvester operated for only one shift a day, it would be cutting for approximately 4.8 hours per day to cut 18 kt during the season. In calculating the costs of capital, a nominal interest rate of 15 per cent and an inflation rate of 8 per cent were used. Using the cost assumptions given above, the average harvesting cost was estimated to be $5.25/t.

This estimate of current harvesting costs may differ from the harvesting rates actually prevailing in the industry, for a number of reasons. First, in calculating the annual cost of capital a different method is used from that commonly used in the industry and, as pointed out in appendix C, the private cost of capital can differ from the public cost measured in this study.

Second, the calculations of the annual cost of capital and of repair and maintenance costs are based on the full current purchase price of the machinery and equipment used. In practice, old machinery is often operated in the field, either because of good maintenance practices and perhaps refurbishment or because secondhand machinery was acquired initially. Thus, the investment in capital equipment is reduced. However, this is a short run rather than a long run expedient, because contractors will eventually have to purchase new, or newer, machinery and should allow for the new replacement value in their contract rates.

Third, award rates have been assumed for harvester and haulout drivers. In practice, where harvester owners also work as either harvester or haulout drivers, they may apportion less than award rates to themselves when setting their harvesting rates if the opportunity cost of their time is low.

Actual and estimated rates may differ for other reasons. At present, there are groups of near average size operating with haulout configurations other than two single-bin haulout units. If the group operated with three such 4 t haulout units, an 18 kt cane crop could be cut with the harvester operating only around 3.2 hours a day, and the average cost would be

4 Recent reported harvesting charges

District	Rate
	$/t
Far North	5.38
Wet North	5.28
Herbert	4.84
Burdekin	4.32
Dryland Central	4.95
Irrigated Central	4.95
Bundaberg	4.43
Far South	5.79

Source: Queensland Cane Growers' Association (1986).

around $5.95/t. With two double-bin (8 t) haulout units, the cane could be cut in just under 3.4 hours a day at a cost of $5.31/t. In both cases, the costs are above the estimated costs of operating with two single-bin 4 t haulouts, and it is clear that the harvester and haulouts would be very much underutilised.

Actual rates charged in the industry can vary quite markedly. The average contract harvesting rates shown in table 4 are taken from the Queensland Cane Growers' Association survey of the financial position of growers in the 1985 season.

Although the estimates of present harvesting costs which have been derived may, for the reasons stated above, differ slightly from those currently being charged, they are useful as a basis for estimating the magnitudes of cost savings that could accrue to growers and to the wider economy through the fuller use of harvesting machinery.

4.2 Number of haulout units

Given the high potential throughput of modern harvesters, many existing harvesters appear underutilised. As was outlined in chapter 2, much of this underutilisation is a result of the regulations which at present restrict the formation of bigger groups. In this chapter it is assumed that these restrictions have been relaxed, so that costs with increased throughput can be compared with the estimates of current harvesting costs.

Initially it is assumed that the harvesting period is unchanged at 20 weeks and that harvesting is confined to weekdays. The potential avenues for increasing the throughput of a harvester include:

- increasing the available capacity of haulout equipment;
- increasing the hours of cutting per day, first assuming a continuation of single-shift harvesting, and second assuming two shifts per day.

These two options are obviously interrelated. For a given crop size, increasing haulout capacity may remove the need for overtime or a second shift. In table 5, the annual throughputs and resultant costs per tonne are given for single-shift harvesting, with four alternative haulout configurations. The number of hours that the harvester is available for use is represented by the number of hours when haulout equipment is operating (that is, when there are empty bins at the siding). During this time the harvester may be idle waiting for haulouts to return from the siding. For each

5 Harvesting costs for various haulout combinations a

Item	Unit	Haulout hours per day					
		3	4	5	6	7	8
Two single-bin haulouts available							
Annual throughput	t	11 250	15 000	18 750	22 500	26 250	30 000
Cost per tonne	$	7.78	6.01	5.07	4.61	4.36	4.22
Three single-bin haulouts available							
Annual throughput	t	16 860	22 480	28 100	33 720	39 340	44 960
Cost per tonne	$	6.30	5.18	4.44	4.30	3.89	3.90
Two double-bin haulouts available							
Annual throughput	t	16 020	21 360	26 700	32 000	37 380	42 720
Cost per tonne	$	5.90	4.70	4.18	3.79	3.67	3.68
Three double-bin haulouts available							
Annual throughput	t	20 190	26 920	33 650	40 380	47 110	53 840
Cost per tonne	$	5.75	4.81	4.50	4.23	3.80	3.49

a It is assumed that haulout distance is 1.74 km, the size of haulout bins is four tonnes, the harvesting period is 20 weeks and the working week is five days.

combination of haulout equipment and hours, the annual throughput indicates the size of group required to employ that harvesting capacity.

It has been assumed that, in an average season, approximately two hours of each 8-hour day would be lost through wet weather, moving equipment, mechanical breakdowns and industrial disputes; a full day is therefore represented by six hours. The cost of harvesting with the option of an average of up to two hours overtime a day is also examined.

It can be seen that, compared with the present representative group (18 kt a year; two single-bin haulouts; 4.8 hours cutting a day) the simple provision of an additional haulout unit and an increase in the hours of cutting to an average of six hours a day would increase the possible group size to 33.7 kt. In that case, rates would decline to \$4.30/t, a cost saving to growers of \$0.95/t. This saving arises from the more intensive use of fixed factors such as labour and the reduction of the unit capital cost.

Further savings would result from the use of double-bin haulout units. With two double-bin haulout units available, 32 kt of cane could be cut if the harvester were operated for six hours per shift, at an average cost of \$3.79/t. This is a potential saving of \$1.46/t compared with the estimated present cost of harvesting. The use of three double-bin haulouts, however, would be cheaper only if overtime harvesting were undertaken. (These results, it should be remembered, are all for a haulout distance of 1.74 km.)

These effects of varying the number of haulout units available per harvester are illustrated in figures C and D. The curves are saw-toothed because harvesting equipment is assumed to be purchased between seasons only, and hence working life does not vary continuously with annual throughput. For instance, a harvester is assumed to have a life of five years if the annual tonnage cut is between 33.3 kt and 40 kt; six years if between 28.6 kt and 33.3 kt; and so on. The estimated capital cost per tonne therefore decreases steeply as the amount of cane harvested increases within each such tonnage range. Note that, for this reason, interpolation between the figures in the table is likely to be misleading.

4.3 Double-shift harvesting

Another way harvester throughput could be improved is by operating the harvesters for two shifts per day. Throughput and cost figures for operating two shifts per day, for the same four configurations of harvester and haulout units as in table 5,

6 Harvesting costs when working two shifts a day [a]

		Haulout hours per shift			
Item	**Unit**	**3**	**4**	**5**	**6**
Two single-bin haulout units available					
Annual throughput	t	22 500	30 000	37 500	45 000
Cost per tonne	\$	5.57	4.70	4.14	3.84
Three single-bin haulout units available					
Annual throughput	t	33 720	44 960	56 200	67 440
Cost per tonne	\$	5.16	4.33	3.60	3.45
Two double-bin haulout units available					
Annual throughput	t	32 040	42 720	53 400	64 080
Cost per tonne	\$	4.47	4.01	3.33	3.22
Three double-bin haulout units available					
Annual throughput	t	40 380	53 840	67 300	80 760
Cost per tonne	\$	4.94	3.85	3.57	3.06

a Assumptions as in table 5.

are presented in table 6. The two shifts would probably operate between 4 am and noon, and noon and 8 pm. Labour costs for both shifts have been calculated assuming that harvester and haulout drivers are paid six hours at normal time and two hours at time and a half, which were the rates paid in the 1985 Proserpine trial. The management expertise needed to operate a two-shift operation is greater than for a one-shift operation, but no allowance has been made here for this additional cost.

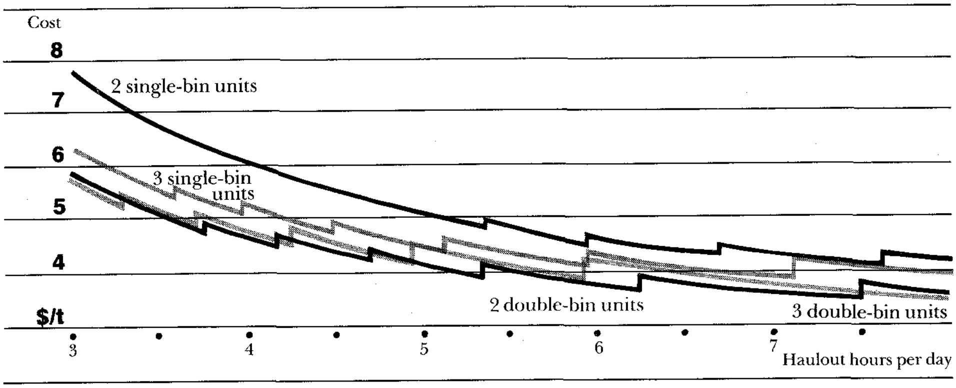
Two-shift harvesting would allow annual tonnages of up to 80 kt. Harvesting costs could be reduced to \$3.06/t if the machine were to cut for six hours per 8-hour shift and three double-bin haulouts were available. This would give a reduction in harvesting costs of \$2.19/t (42 per cent) from the estimated present rates of \$5.25/t. For such cost savings to be achieved, the group — though large by present standards — would need to be compact to minimise time lost in moving equipment from property to property.

4.4 Weekend milling

The introduction of weekend harvesting and sugar milling is seen as a method of concentrating harvesting and milling into the period when the sugar content of cane is at its highest. Weekend milling could also be introduced as a means of expanding production while maintaining

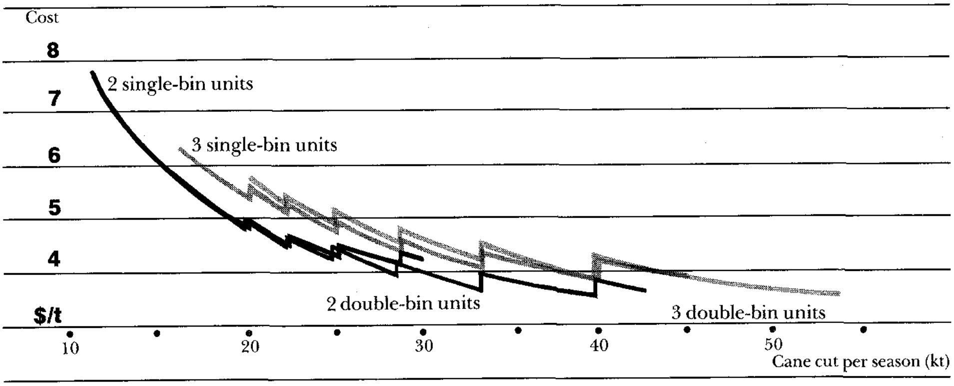
C Dependence of harvesting costs on cutting hours per day
Average haulout distance 1.74 km; season length 20 weeks

BAE chart



D Dependence of harvesting costs on tonnage cut per year

BAE chart



the same harvesting period. The effects of these two options on harvesting costs are analysed in this section. Here, weekend harvesting has been costed on the basis of a 13-day fortnight, with one shift per day and every second Sunday free for such purposes as mill maintenance. Saturday labour costs have been calculated at time and a half for the first three hours and double time for the remaining hours; Sunday labour has been calculated at double time.

Extending milling operations to weekends in this way would allow the harvesting period to be reduced to 15.4 weeks, for the same annual cane output as would be produced in 20 weeks of five single-shift days, and this reduced period has therefore been used (compare table 7 with table 5). For a given annual cane output, unit costs would increase because of the higher average hourly wage rates. For example, costs per tonne for a group operating with two double-bin haulout units harvesting an average of six hours a day, with and without weekend milling, would be $3.94 and $3.79, respectively. However, while growers' harvesting costs would increase, their revenue would also increase significantly because of the overall higher sugar content of the cane.

The other main motive for weekend milling would be to increase output, with the harvesting period maintained at 20 weeks. The costs under this option are shown in table 8. The need for weekend milling could arise in a number of ways. It could be the result of increased cane production, if it were then decided to crush the extra cane within the normal period rather than extending the harvesting season. Mill mergers or rationalisation could also result in a need for weekend milling, if implemented without an extension of the harvesting period or an increase in milling capacity. A case in point is the closure of the Qunaba mill in the Bundaberg district at the end of 1985 season, that mill's peak being divided between the Bingera, Fairymead and Millaquin mills for the 1986 season (Australian Canegrower 1985).

For the mills to crush the additional cane (assuming the farm peaks remained unaltered and no additional mill equipment were installed), the harvesting period would either have to commence earlier, when the sugar content of cane is low, or mills would have to operate at weekends. There may be some resistance from growers to any lengthening of the crushing season. The extent to which weekend crushing would be required

7 Harvesting costs with weekend milling and a reduced harvesting period [a]

		Haulout hours per day					
Item	**Unit**	**3**	**4**	**5**	**6**	**7**	**8**
Two single-bin haulout units available							
Annual throughput	t	11 260	15 015	18 770	22 525	26 275	30 030
Cost per tonne	$	8.37	6.47	5.32	4.82	4.54	4.42
Three single-bin haulout units available							
Annual throughput	t	16 875	22 500	28 500	28 130	39 380	45 005
Cost per tonne	$	6.67	5.46	4.66	4.48	4.06	4.05
Two double-bin haulout units available							
Annual throughput	t	16 035	21 380	26 725	32 070	37 415	42 765
Cost per tonne	$	6.19	5.09	4.35	3.94	3.80	3.80
Three double-bin haulout units available							
Annual throughput	t	20 210	26 945	33 685	40 420	47 155	53 895
Cost per tonne	$	6.05	5.03	4.68	4.37	3.93	3.62

a Assumptions as in table 5 except for a 13-day fortnight and a 15.4-week harvesting period.

would depend on the spare capacity available in existing mill equipment.

As is indicated by a comparison of the harvesting cost estimates in tables 5 and 8, there would generally be small unit cost savings from introducing weekend harvesting provided that the increased throughput allows more intensive use of harvesting equipment. Cane throughput could be increased by up to 30 per cent if weekend milling occurred over the existing season length. The economic gains from more intensive use of equipment would be countered by the increase in average hourly wage costs. For a group operating with two double-bin haulout units and harvesting for six hours a day, 32.0 kt of cane could be cut at an average cost of $3.79/t without weekend harvesting, or 41.7 kt at an average cost of $3.92/t with weekend harvesting.

Utilisation of harvesting equipment could be further increased by a combination of both weekend harvesting and double shifts. Under such a schedule, over a 20-week season, up to 105 kt of cane could be harvested if three double-bin haulout units were used. If it is assumed that a harvester working at this rate has a working life of two years, harvesting costs would average $3.29/t. The increase in costs compared with double shifts without weekend harvesting (table 6) is due to higher unit costs of both labour and capital.

Harvester use could be further increased by extending the harvesting period. The benefits and costs of this measure have been argued elsewhere (see Borrell and Wong 1986). However, examining the decision purely from the standpoint of harvesting costs, if the season length were extended by three weeks to 23 weeks, working 13 days a fortnight and two shifts a day, the total cane cut would increase to nearly 121 kt per season, and the average harvesting cost would fall to $3.04/t.

4.5 Haulout distance

At present, harvester owners have little incentive to minimise cane haulout costs for individual growers, and tend to equalise costs over all members of the group. In principle, the formation of harvesting groups could be made more competitive, so that harvester owners would take haulout distances into account in setting contract rates for individual growers. The influence of haulout distance on harvesting costs and tonnages can be assessed by comparing table 5 with table 9 where the haulout distance is 3 km.

As haulout distance increases, harvester idle time also increases. With two double-bin haulout units available for six hours

8 Harvesting costs with weekend milling and unchanged harvesting period [a]

Item	Unit	Haulout hours per day					
		3	4	5	6	7	8
Two single-bin haulout units available							
Annual throughput	t	14 625	19 500	24 375	29 250	34 125	39 000
Cost per tonne	$	7.25	5.63	4.89	4.55	4.41	4.07
Three single-bin haulout units available							
Annual throughput	t	21 920	29 225	36 530	43 835	51 140	58 450
Cost per tonne	$	5.97	5.16	4.52	4.19	3.82	3.54
Two double-bin haulout units available							
Annual throughput	t	20 825	27 770	34 710	41 650	48 595	55 535
Cost per tonne	$	5.49	4.55	4.21	3.92	3.54	3.27
Three double-bin haulout units available							
Annual throughput	t	26 245	34 995	43 745	52 495	61 245	69 990
Cost per tonne	$	5.62	4.88	4.36	3.74	3.81	3.50

a Assumptions as in table 5 except for 13-day fortnight.

9 Harvesting costs with a 3 km haulout distance [a]

Item	Unit	Haulout hours per day					
		3	4	5	6	7	8
Two single-bin haulout units available							
Annual throughput	t	8 070	10 760	13 450	16 140	18 830	21 520
Cost per tonne	$	11.03	8.50	6.98	5.99	5.46	5.18
Three single-bin haulout units available							
Annual throughput	t	12 120	16 160	20 200	24 240	28 280	32 320
Cost per tonne	$	8.68	6.72	5.68	5.02	4.76	4.62
Two double-bin haulout units available							
Annual throughput	t	12 510	16 680	20 850	25 020	29 190	33 360
Cost per tonne	$	7.49	5.80	4.91	4.53	4.45	4.26
Three double-bin haulout units available							
Annual throughput	t	18 750	25 000	31 250	37 500	43 750	50 000
Cost per tonne	$	5.99	4.94	4.50	4.12	4.08	3.73

a Assumptions as in table 5 except for haulout distance.

per shift, if the average haulout distance is increased from 1.74 km to 3 km the volume of cane which can be cut per 20-week period falls from 32.0 kt to 25.0 kt. With three double-bin haulout units available, the fall-off in cane cut is less dramatic, from 40.4 kt to 37.5 kt. With a haulout distance of 1.74 km, unit harvesting costs are minimised when a harvester is operating with two double-bin haulouts. With a haulout distance of 3 km, unit harvesting costs are lowest using three double-bin haulout units; in fact, this becomes true once the haulout distance approaches 2 km.

The decreasing throughput of the harvester as haulout distance increases should be reflected in the minimum rates a harvester owner can offer. For example, using three double-bin haulout units for six hours per shift, if the haulout distance were 3 km the total cane harvested in a season would be 37.5 kt and the minimum rate $4.12/t, compared with $4.09/t for the same output if the haulout distance were 1.74 km (see figure D).

There are various in-field factors, such as length of drills, slope of field, crop conditions, and available turning room at the headlands, which can also affect the extent of idle time. All such factors should be taken into account when harvesting rates are being set.

4.6 Potential cost savings

Cost savings from an industry point of view should ideally be derived by, first, surveying all harvesting groups to obtain an estimate of the current costs of harvesting, and then comparing these costs with those that could be achieved if harvester numbers were reduced and the throughput of the remaining harvesters were increased. The difference would then be an accurate estimate of the industry savings which could result from modifying the controls over harvesting. In this study a modification of the above approach has been required, since it is clearly impracticable to survey all of the more than 1700 harvesting groups currently in operation in Queensland.

Three alternative methods were used. In the first, regional estimates of cost savings were derived using regional throughput data, and aggregated to the state level. In the second, instead of using regional data, individual mill data were obtained and aggregated to the industry level. In the third, an average cost saving per harvester was applied to the cane production of the whole state.

Region-based calculation

Estimates of the present average cost of harvesting for the four regions in

10 Estimated harvesting costs and cost savings, by region

Region	Share of total cane harvest a	Average group size a	Harvesting cost Current	Harvesting cost Feasible	Potential cost saving
	%	kt	$/t	$/t	$/t
North	34.7	16.6	5.68	3.79	1.89
Burdekin	16.1	27.6	4.06	3.79	0.27
Central	29.3	10.3	8.42	3.79	4.63
South	19.9	11.6	7.52	3.79	3.73
Average b		15.4	6.53	3.79	2.74

a Average of 1984, 1985 and 1986 seasons. **b** Weighted by cane deliveries.

Queensland are presented in table 10. It is noticeable that there are substantial differences between regions in the intensity of harvester use, the average Burdekin group size being over two and a half times as large as the average in the Central region. It has been estimated (table 5) that a harvesting cost of $3.79/t would be feasible, working five single-shift days a week with no overtime. This 'feasible' rate was deducted from the estimated current regional average costs to arrive at a weighted average potential cost saving of around $2.74/t. Since approximately 24 Mt of cane is harvested annually in Queensland, this saving would be worth nearly $66m a year.

Mill-based calculation

In the second method, group sizes are averaged over mill areas rather than regions. The average group size in each mill area for the three years 1984–1986 is presented in table 11. Within any one region, mill area average group sizes are relatively uniform. This method gives an

11 Average harvester group size, by mill area

Mill area	Cane cut a	Mill area	Cane cut a
	kt		kt
North region		**Central region**	
Mossman	14.6	Proserpine	13.0
Hambledon	12.3	Farleigh	11.4
Mulgrave	13.1	Racecourse	11.0
Babinda	10.7	Pleystowe	11.5
Goondi	17.4	Marian	9.9
Mourilyan	16.4	Cattle Creek	8.2
South Johnstone	16.5	North Eton	10.1
Tully	24.6	Plane Creek	8.4
Victoria	20.6	Average	10.3
Macknade	21.2		
Average	16.6	**South region**	
		Fairymead	18.8
		Millaquin	15.8
Burdekin region		Bingera	9.4
Invicta	24.2	Isis	15.0
Pioneer	30.0	Maryborough	8.7
Kalamia	28.0	Moreton	7.9
Inkerman	28.1	Rocky Point	6.3
Average	27.6	Average	11.6

a Average of the 1984, 1985 and 1986 seasons.

estimate of cost savings of just under $70m, very close to the preceding result.

Harvester-based calculation

Though the estimates of the potential cost savings by the above two methods are consistent, they may be overstated. For example, in the South and Central regions particularly, there are many harvester 'groups' with only a single grower. As was shown in table 2, these comprise nearly 30 per cent of all groups, but cut only about 10 per cent of the cane. There are reasons to believe that many of the growers cutting their own cane will continue to do so. As has been pointed out already, restrictions on growers expanding their cane production have the effect that the labour time of many growers is underutilised, unless they are involved in harvesting or have some alternative form of employment. (Even if production restrictions were eased, some growers might be unable to expand because their properties are landlocked).

Another reason why many growers may continue to harvest their own cane is that they operate older, secondhand machinery which — if they have some mechanical skills and are able to repair and maintain all but major mechanical breakdowns — gives lower unit capital costs per tonne than those used in this paper. (The option of purchasing such machinery is not available to contractors or growers harvesting for larger groups, because of the disruption to mill cane supplies that could be caused by a major breakdown.)

The average annual harvest of groups comprising two or more growers is 18 kt. Such a group typically uses two single-bin haulout units. If equipped with double-bin units, it could harvest 32 kt a year and thus reduce harvesting costs from $5.25/t to $3.79/t (table 5). This average saving of $1.46/t, applied across the whole crop of 24 Mt, would be worth $35m a year.

On balance this $35m estimate of the cost savings available to the industry from using harvesters more efficiently is probably more realistic than the preceding estimates, but should be regarded as conservative. There are likely to be some significant further savings which have not been taken into account. For example, if an extra two hours overtime were worked per 8-hour shift, harvester throughput over a 20-week season could be increased to nearly 54 kt, and average costs lowered to $3.49/t. With two harvesting shifts per day (table 6), harvester throughput could reach 80 kt per season, with average costs falling to $3.06/t, which is $2.19/t below the estimate of current average harvesting cost. Under the same assumptions as used above, this would represent an industry-wide saving of $53m a year.

A single figure for haulout distance, based on survey results (Petersen et al. 1984), was used in these calculations: 1.74 km. Actual haulout distances are distributed around this point estimate. Calculations were performed to test whether the results were sensitive to the distribution of haulout distances around the mean. Even under the extreme assumption that half the haulout distances were either 1.24 km or 2.24 km, the results were little different from the above. Potential unit savings are thus little affected by haulout distance, provided that the cheapest haulout configuration is used.

In table 12 a breakdown of unit costs for four levels of harvester use for a 5-day week is presented. In all cases there are significant savings on machinery costs from increased harvester use. This occurs mainly because the repair and maintenance cost has a fixed annual charge, which is spread over an increasing volume of cane. Cost savings in labour are also significant. In moving from an 18 kt to a 32 kt throughput, the idle time of the harvester operator is reduced and the productivity of each haulout driver is improved by the larger loads. Moving to a 40 kt throughput reduces the idle time of the harvester operator still further, but the third haulout driver is not fully employed.

Up to 40 kt throughput the savings in capital costs are not great — in fact, unit capital costs increase in the 40 kt case compared with the 32 kt example. Although in both the 32 kt and 40 kt cases the unit annual capital cost of each piece of machinery declines significantly, the purchase of larger haulouts or of an additional haulout unit largely offsets these savings. In moving from 40 kt to 81 kt, however, no additional machinery is required and the opportunity cost of capital is spread over a larger throughput.

If present restrictions on total cane area were removed and cane production allowed to increase, the additional cane could be crushed either by extending the harvesting period or by the widespread introduction of weekend harvesting. Either option would at the same time allow the cane throughput of harvesters to be further increased. However, the extra cost savings in harvesting would be relatively small; these practices can be regarded as being approximately cost neutral.

The cost savings reported here do not include any gains which could be achieved off the farm (see Borrell and Wong 1986), nor do they include gains which might arise from changes in cultivation practices. With changes in harvesting, growers could specialise in the non-harvesting aspects of cane production and adopt large scale cultivation and broadacre farm management techniques which could lead to the fuller use of farm resources.

4.7 Effects of altered incentives

The results presented above are based on approximations and assumptions about the performance and technical possibilities of harvesting crews and machinery. For some circumstances, such as double-shift harvesting, little information is available on how harvesting equipment would perform in practice. It is possible that the approximations themselves reflect inefficiencies in current practices and technology, in which case the possible gains have been underestimated.

Current practices and technology have been adopted in response to the incentives that have faced growers, harvesting contractors and millers in the past. Regulatory and structural change could dramatically alter such incentives. For instance, if growers paid harvesting charges reflecting their particular field conditions they would face incentives to adopt the most efficient field layout for harvesting.

If limits to group size were removed, harvesting contractors and machinery makers might find it profitable to develop higher capacity machines. Development work has already been undertaken on a double-row cane harvester. Early trials have demonstrated that harvesting rates for green and burnt cane of up to 120 t/h and 200 t/h, respectively, are possible (Australian Sugar Yearbook 1986). For existing single-row harvesters the figures are around 50 t/h and 80 t/h, respectively, for green and burnt cane (Ridge and Dick 1985).

If millers could more freely negotiate with growers and harvesting contractors

12 Effect of operating mode on throughput and minimum unit costs a

Item	Unit	Present situation	Two double-bin haulouts, single shift	Three double-bin haulouts, single shift	Three double-bin haulouts, two shifts
Annual throughput	kt	18	32	40	81
Costs					
Labour	$/t	1.57	0.92	0.92	0.82
Machinery	$/t	1.39	0.96	0.90	0.71
Capital	$/t	2.09	1.81	1.92	1.49
Other	$/t	0.18	0.11	0.10	0.04
Total b	$/t	5.25	3.79	3.86	3.06

a 4 t bins available for up to 6 hours per shift; 5-day weeks; 20-week season. **b** Columns may not sum to the total due to rounding.

about the quantity and timing of cane to be delivered, they might have incentives to rationalise harvesting, transport scheduling and tramway sidings to exploit the benefits of larger group sizes. All such developments could encourage cost savings in excess of those measured in this study.

The rate at which the indicated gains can be obtained by the industry will depend on the incentives facing growers, harvesting contractors and millers. The low unit capital costs which in the past might have encouraged growers and contractors to buy harvesters no longer apply. Real interest rates have risen in recent years, and are unlikely to become negative or very low now that Australia's financial markets are no longer regulated. The taxation benefits to purchasers of farm machinery have been reduced in recent years, further reducing growers' incentives to purchase machinery. However, it is still true that in most circumstances (see appendix C) taxation concessions reduce the cost of capital to individuals relative to that of other inputs. As long as this situation exists, more capital will be used than is economically efficient. Continually increasing wage costs should also provide incentives, especially for contractors to reduce unit labour costs and hence to seek larger contracts.

However, as long as production controls — and, in particular, land assignments — remain in force, rationalisation of harvesting will be slow. It has been noted that restrictions on the quantity of cane that individual growers can produce lower the value (or opportunity cost) of growers' time and labour. Therefore, while unit labour cost savings from larger group sizes may be readily available to contractors and hence to growers using contractors, this may not be so for growers who now harvest their own cane. Such growers, if they presently value their own labour used in harvesting at less than the award rate for haulout drivers, or cannot obtain alternative employment at that rate, will not have the opportunity to make unit labour cost savings of the size indicated. Further, as long as present controls on total output remain in force, the large scale investment in harvesters made in the past must be regarded as a sunk cost. Better use of existing capital cannot be achieved in the short term: the potential reductions in unit capital costs indicated in this study will not be available until there is a need to replace present equipment or there is expansion of the industry.

Until growers and harvesting contractors stand to gain the full potential cost savings from rationalisation of harvesting, their incentives to seek change are limited. The current controls and regulations affecting harvesting make the gains less obvious. At present, any changes to harvesting group sizes or delivery arrangements can not be made easily between growers and millers. Without regulatory change, rationalisation of harvesting will be slow and the full economic potential of mechanical harvesting will remain untapped.

5. Implications for the sugar industry

The present controls on the sugar industry were initially designed during the period when cane was harvested by hand. The change to mechanical harvesting during the 1960s altered the opportunities of the industry dramatically. This change was not matched by similar changes in regulations and controls, many of which have stood in the way of developing the full potential of this new technology.

The release of the research paper by Page et al. in early 1985, in which it was shown that growers would gain substantially from a reorganisation of harvesting practices, has not precipitated any calls for such reorganisation. What is required is some form of incentive for millers and growers which will lead to the formation of larger harvesting groups and hence to greater throughput per harvester. Certain changes to the revenue sharing arrangements and to the system of land assignments and farm peaks would seem necessary to open the way to savings in harvesting costs.

The cane payment arrangements which at present govern the distribution of industry revenues between millers and growers are barriers to change. Although it is possible for individual mill areas to introduce changes to pricing arrangements, the right of both growers and millers to appeal to the Central Sugar Cane Prices Board, should they feel disadvantaged by any proposed change, is in itself an impediment to change along this route. This problem is discussed in detail by Borrell and Wong (1986), who have also argued that the present pricing and supply arrangements stand in the way of mills introducing weekend milling, which could be profitable to the industry as a whole. These same arrangements also stand in the way of rationalising harvester numbers.

Because, under the cane payment arrangements, millers are responsible for all costs between cane delivery points and the bulk sugar terminal, decisions about group formation are guided by effects on cane transport arrangements and milling schedules rather than by effects on growers' harvesting costs. If millers wish to minimise delays or disruptions to their cane supplies, under current cane payment and harvesting arrangements they will prefer overcapacity in harvesting equipment, which confers flexibility. They cannot, under the present regulations, trade off that advantage against the financial benefits of larger groups, since these benefits flow to growers. Mill expenditure may even increase with group size if efficient harvesting requires siding capacity to be expanded.

On the other hand, the recent research by Page et al. (1985) has indicated that improved scheduling of cane transport, in conjunction with fewer but larger groups, can result in small savings to millers. Savings to millers from better transport scheduling would arise from a decrease in the numbers of locomotives and bins required. However, since these are items that have already been purchased, there would be delays in most of these benefits being received (in the form of reduced capital expenditure at some future time). Also, many of these savings would not be obtained without thorough restructuring of harvesting operations, and millers would therefore have little incentive unless they were assured of quite substantial changes.

It has been pointed out that there may be some reluctance on the part of growers to move toward larger group sizes, which may require bigger burns and hence bigger potential individual losses through wet weather. Payouts from present insurance schemes are made only if the cane is condemned by the miller as being unfit for milling, not if its quality is merely reduced. The present cane payment arrangements, by precluding direct negotiation of price, quantity and delivery terms between millers and growers, may prevent the development of efficient mechanisms for spreading any risk attendant upon scale economies in harvesting. Over an entire mill area, the risk of bad weather to the mill is not affected by sizes of harvesting groups or of individual paddocks of burnt cane, but only by the absolute amount of burnt cane affected. Millers would therefore be in a very good position to spread the risk of bad weather and to supplement the coverage of present insurance schemes to cover partially damaged cane, if they were able to negotiate with growers directly.

Borrell and Wong (1986) have argued that if the gains from such practices as weekend milling could be reflected in the price, quantity and delivery terms between growers and millers, both parties could interact closely on specific economic terms to seek an optimal milling strategy. If the gains from larger harvesting group sizes could also be reflected in these terms, this could provide incentives to both parties to seek organisational changes that would be to their common benefit. Present cane payment arrangements do not allow this to occur. Negotiations between growers and millers take place only through the Central Sugar Cane Prices Board, where the emphasis is on protecting existing equities across the whole industry (Borrell and Wong 1986).

In the past there has been some opposition from some sections of the industry to an expansion in cane production. This opposition has come mainly from growers who cannot readily expand; it is feared that any expansion in cane and sugar production could lower world sugar prices. However, Australia is a price taker on the world sugar market, so any additional cane and sugar produced would not affect world prices appreciably.

If growers and millers could be encouraged to negotiate through their local boards on price, quantity, location, harvesting, timing and transport, this would greatly increase the scope for achieving the types of gains identified in this study. If individual growers could expand production and have contracts with millers to crush the resulting extra cane, the opportunity cost of their own labour would be increased. This in turn would lessen growers' incentives to harvest their own cane and would allow for larger contract harvesting operations. Further, millers would not require strict controls over harvesting to facilitate scheduling — they could make individual contracts with growers to supply specified quantities of cane at specified times. This might involve negotiating the siding lengths and the timing and rate of delivery of bins. Discounts and premiums on the cane price might be used to reward adherence to the specific conditions of delivery; conversely, if the delivery of bins were late and disrupted harvesting, the miller would be forced to pay the opportunity cost of lost harvesting time, and would thus have an incentive to ensure a constant flow of bins that would minimise idle harvester time. Reducing harvester idle time and growing more cane would enable the costs of harvesting to be spread over a larger volume of cane and would thus allow for the more efficient use of harvesting resources.

Because there would be no need for millers to regulate harvesting directly, growers could negotiate with harvesting contractors in a competitive market. In these circumstances contractors would not be constrained by the mill as to the quantity of cane they could cut, and would therefore probably base their rates on the time they expected to take cutting a particular paddock, rather than on tonnage. In this way, how much a grower paid for harvesting would also depend on field conditions and layout. This would give growers an incentive to improve field conditions so that their cane could be cut in the shortest time possible. Because delays would impose an opportunity cost on contractors, they would charge extra for delays, and growers would therefore do everything possible to reduce idle time.

If freer negotiation did come into operation, one option in some mill areas might be for the millers' responsibilities to be extended to harvesting and the associated cartage. Millers would benefit from this option in two ways. First, if weekend milling were introduced, they could schedule weekend harvesting in those areas close to the mill to minimise transport and overtime costs. Second, after wet weather they could schedule harvesting to those areas that were least affected by rain or where soil conditions allowed the earliest resumption of harvesting. It is unlikely, however, that millers would undertake the harvesting and in-field cartage from their own resources. Instead they would probably arrange for these operations to be carried out by contractors. In this way, contractors could bid to harvest given areas or volumes of cane, and thus competitive harvesting rates could be established.

The above gives some indication of the type of change which might occur. An important point, regardless of the exact form that the market takes, is that if freer negotiations can be established between growers, contractors and millers, ultimately the shares of benefits will depend on the bargaining powers of each group. It is possible that some high cost harvesting contractors may have insufficient bargaining power to compete in providing harvesting services. This group could be forced out of business. Because it is also possible that any one sector of the industry could develop excessive market power, no assurance can be given that a perfectly competitive market for cane, harvesting services or milling services would be established. Thus, allowing freer negotiation may not, of itself, lead to the full realisation of the economic gains identified in this report. Some government safeguards may be necessary.

As has been suggested by Borrell and Wong (1986, p.38), if safeguards available under the Trade Practices Act are insufficient to limit market power '. . . a specific industry policy for correcting instances of excessive market power . . . should be favoured over current policies. Current policies severely constrain the normal workings of decentralised markets and distort prices'. In that study it was concluded that, to achieve technically feasible gains estimated at $130m a year in the off-farm sector of the sugar industry, 'movement toward a more decentralised and flexible decision making environment seems essential'. The same implication arises in this study.

To provide the level of flexibility needed would require the removal of land assignments and other quantity restrictions which at present govern the production of sugar for spot sale on the world market (the No.2 pool). It would also require the development of arrangements to allow effective negotiation between growers and millers on price, quantity, location, timing and transport terms, all of which directly or indirectly affect the harvesting of cane. This would require amendments to the Regulation of Sugar Cane Prices Act so that growers and millers would have incentives to make and uphold supply contracts independently of the appeal and enforcement powers of the Central Sugar Cane Prices Board. To gain the full benefit of better use of harvesting resources would also require replacing the present land assignments and farm and mill peaks affecting No.1 pool sales with a system of freely negotiable market entitlements.

Appendix A Local board awards

The following extract is taken from the 1985 season Rocky Point Local Board Award (Queensland Government 1985). It covers the clauses which directly govern harvesting matters.

(m) Formation of Groups for Harvesting

A number of growers may agree amongst themselves to form a group and shall notify the millowner in writing not later than the end of June.

The formation of each group shall be subject to the approval of the millowner, but such approval shall not be unreasonably witheld. In the absence of agreement, groups may be formed by the millowner.

No grower being a member of a group properly formed shall cease to be a member of that group without the prior consent in writing of the millowner. Such consent shall not be unreasonably withheld.

Each group shall decide the rotation in which its members shall harvest cane and shall notify the millowner thereof. In default of such notification, the order of cutting shall be decided by the millowner.

Each member of a group shall have the whole of the truck allotment of the group for a fair proportional period to be determined by the group concerned or in default of agreement by the millowner.

(n) (1) A Harvesting Equity Committee consisting of two representatives of the Mill Suppliers' Committee, one of whom shall be chairman of the equity committee, and two representatives appointed by the millowner, shall be constituted.

(2) The Harvesting Equity Committee shall meet at such times as its chairman may consider necessary to review the harvesting position of all groups of growers and of individual growers.

(3) The Harvesting Equity Committee may at any time, in order to ensure the equitable and efficient harvesting of the crop and the effective, orderly and equitable utilisation of available labour and harvesting machines:

(i) recommend the alteration in composition of harvesting groups;

(ii) recommend the alteration or cancellation of the allotment of any group or grower. Consent by the millowner shall not unreasonably be withheld.

Appendix B Estimating time lost in harvesting operations

The percentage of time that a harvester is actually cutting cane depends on a range of factors. It can be assumed that a harvester has some maximum cutting rates for burnt cane and for green cane. The actual time taken to harvest a given quantity of cane will vary according to the amount of time taken to turn at row ends and on the availability of cane bins. The degree of utilisation of the harvester will therefore depend the number of haulouts available, the size of cane bins, the distance travelled to delivery points and bin unloading time, as well as on the length of cane rows. Ridge and Dick (1985) derived equations to estimate the percentage of total harvester operating time lost. These equations, which are set out below, are used in this analysis.

With two haulout units,

(B1) $T = 100[(U+4D-C/P) / (U+4D+C/P)];$

with three haulout units,

(B2) $T = 100[U+4D-2C/P) / (U+4D+C/P)];$

where T is the percentage of total harvester time lost; U is the bin unloading time (minutes); D is the distance to tramway sidings (kilometers); C is the bin size (tonnes); and P is the harvester cutting rate (tonnes per minute).

Ridge and Dick assumed that the maximum harvester cutting rate for burnt cane was 80 t/h. The rate is reduced from this because of time lost as the harvester turns at the ends of rows. Taking crop yield as 100 t/ha, row length as 300 m, and time lost at the ends of rows as 0.50 minutes per turn, the maximum cutting rate becomes 67.3 t/h, and P is 1.12 t/min. Bin unloading and loading times were taken as 2.3 minutes for single roll-on/roll-off bins, and 3.9 minutes for double-bin haulouts. The coefficient of D is arrived at on the assumption that haulout speed is 0.5 km/min.

Appendix C Unit costs of capital

In order to estimate the total costs of harvesting equipment per tonne of cane harvested, it is useful to express the initial purchase price as a series of annual payments spread over the life of the equipment. This allows a straightforward comparison between capital costs and other cost items, such as expenditure on fuel, which are ongoing.

The purchase price of a depreciable asset can be expressed in terms of a stream of payments, of equal real value for each year of the asset's expected life, such that:

$$\text{(C1)} \quad x \sum_{j=1}^{n} (1+r)^{-j} = P$$

where x is the annual cost of asset; r is the real interest rate; n is the life of the asset in years; P is the purchase price of equipment; and r is greater than 0.

It can be shown that (C1) implies:

$$\text{(C2)} \quad x = P(1+r)^n r/((1+r)^n - 1),$$

which can be written as $x = PA$, where A is termed the annuity factor.

Defining Q as the tonnage handled over the lifetime of the asset, the capital cost per tonne, y, is:

$$\text{(C3)} \quad y = (Pn/Q)\,(1+r)^n r/((1+r)^n - 1).$$

C.1 Real interest rates and private capital costs

In this study, the cost of capital has been measured from an economywide perspective. This cost can differ from that faced by the individual harvester owner. In this section the method of calculating the cost for the individual harvester owner is derived.

From an economywide perspective, the real interest rate, r, is given by:

$$\text{(C4)} \quad r = ((1+i)/(1+p)) - 1$$

where i is the nominal interest rate and p is the rate of price increase.

From the perspective of an individual harvester owner, the effects of taxation of nominal interest earnings and of depreciation allowances are important. Any nominal income earned by the individual has an after-tax value of $(1-t)$ times the gross value, where t is the individual's marginal tax rate. The real after-tax interest rate for an individual, $r(t)$, is therefore:

$$\text{(C5)} \quad r(t) = [(1+i(1-t))/(1+p)] - 1.$$

Under the existing depreciation provisions, harvester owners are allowed for taxation purposes to write off the nominal capital cost of equipment in equal annual amounts. The owner's taxable income is accordingly reduced by an amount, d, whose real value in year j is:

$$\text{(C6)} \quad d_j(t) = t(P/m)(1+p)^{-j}$$

where m is the number of years over which equipment is allowed to be written off for taxation purposes (at present, five).

The real net present value of the depreciation allowances at the time of purchase of the equipment is therefore:

$$\text{(C7)} \quad D(t) = \sum_{j=1}^{m} d_j\,[(1+i(1-t))/(1+p)]^{-j}$$

$$= t(P/m) \sum_{j=1}^{m} (1+i(1-t))^{-j}.$$

Using the logic underlying the derivation of (C2), it can be shown that:

$$\text{(C8)} \quad D(t) = tP \, \frac{(1+i(1-t))^m - 1}{mi(1-t)(1+i(1-t))^m}.$$

It follows that, at time of purchase, the total after-tax cost, $P(t)$, of the equipment is:

$$(C9)\quad P(t) = P\frac{1-(t/m)[(1+i(1-t))^m-1]}{i(1-t)(1+i(1-t))^m}$$

Until the recent cessation of investment allowances, producers were entitled to claim an additional percentage, a, of the purchase price as a deduction from taxable income in the year of purchase of equipment. The actual net cost to the individual was thus given by:

$$(C10)\quad P(t,a) = P\frac{1-at-(t/m)[(1+i(1-t))^m-1]}{i(1-t)(1+i(1-t))^m}$$

When the total after-tax cost, $P(t)$, is represented as an annual cost spread over the life of the equipment, this annual cost is:

$$(C11)\quad x_t = P(t)A$$

where A is the annuity factor, defined (from equations C2 and C5) as follows:

$$(C12)\quad A = \frac{[(1+i(1-t))/(1+p)]^n[(1+i(1-t))/(1+p)-1]}{[(1+i(1-t))/(1+p)]^n-1}$$

No accurate information is available on the marginal tax rates actually faced by cane growers and harvesting contractors, so it is not possible to estimate the full effects of past and present policies on the behaviour of farmers and contractors. There are nevertheless important general effects which can be described.

The effect of current taxation provisions is to reduce the private cost of capital, in two ways: through the effect of depreciation allowances, as expressed in equations (C9) and (C10), and by reducing the real interest rate faced by individuals. It can be shown that a decrease in the real interest rate will give rise to a decrease in the real unit cost of capital, as follows. From (C2):

$$(C13)\quad \frac{\partial x}{\partial r} = ((1+r)^n-1)^{-2}Pnr(1+r)^{n-1} \times \times[((1+r)/nr)((1+r)^n-1)-1].$$

This is positive if and only if

$$(1+r)^n > 1+nr/(1+r),$$

which is true for all positive values of r and n for which (C2) is valid.

In fact, as Hogan, Kirby and Urban (1986) have argued, the relationship between domestic taxation policies, real and nominal interest rates and exchange rates can be quite complex. It would not be possible to estimate the full effects of a taxation change on individual capital cost expenditure without following through the economywide relationships between t, $r(t)$ and i in (C9). Here, however, the essential point is the general observation that private costs of capital are reduced by depreciation allowances and taxation of interest income. What is important is not just that the after-tax unit cost of capital is less than the pre-tax cost, but that the reduction may be different from that for other inputs. For most forms of income and for inputs such as fuel and labour, the after-tax value is simply $(1-t)$ times the pre-tax value. But the condition $x_t = x(1-t)$ will not generally hold for capital purchases.

13 Effect of a 21 per cent tax rate on the effective purchase price of equipment

Nominal rate	Adjustment factor excluding investment allowance (C9)	Adjustment factor including investment allowance (C10) a = 0.20	Adjustment factor including investment allowance (C10) a = 0.40
10 per cent	–0.168	–0.210	–0.252
15 per cent	–0.138	–0.180	–0.222

For primary producers who paid tax, the average tax rate faced in 1982-83 was 21 per cent (BAE 1985). Using this tax rate in (C9) and (C10), the effective purchase price of farm machinery is adjusted downward as shown in table 13.

The after-tax reduction in the cost of capital is less than that of other inputs (0.21) except for high levels of investment allowance (a), given a nominal interest rate of over 10 per cent. However, when the purchase price is spread over the life of the equipment, the annual after-tax cost of capital equipment depends not only on the interest rate and taxation rate, but also on the expected life of the equipment and on the inflation rate (equations C11 and C12).

In table 14, a range of values is given for the annuity factor required to spread the capital cost of a piece of equipment over its life, when examined both from the public viewpoint, as defined in equation (C2), and from the individual harvester owner's viewpoint, as defined in equation (C12). Also given are estimates of how much the annuity factors calculated from the individual's viewpoint are reduced, relative to the annuity factor calculated from the public viewpoint, by the effects of taxation provisions. This 'annuity reduction factor' is $(x - x_t)/x$ (see equation C2 and C11), and x_t is $A(1 - P(t))$ (see equations C9 and C12).

Neglecting the investment allowance provisions, which have not been considered in this exercise, there are two areas where taxation provisions have an effect on the annuity paid by an individual harvester owner. First, the initial purchase price is reduced because of the depreciation allowance provisions, as set out in equation (C9). Second, interest earnings accruing from the annuities set aside each year over the life of the equipment are subject to tax. The real after-tax interest rate for individual, $r(t)$, is defined in equation (C5).

In calculating the individual annuity factors, as set out in table 14, an average tax rate of 21 per cent has again been assumed. Note that the most influential variable in determining both public and individual annuity factors is n, the life of the equipment.

In all cases shown, the individual annuity factor is less than the public factor. The difference between the individual and

14 Annuity factors for calculating the annual cost of capital, from public and individual standpoints

Nominal interest rate	Inflation rate	Annuity factors		Reduction factor c
		Public a	Individual b	
Equipment life 4 years				
10 per cent	5 per cent	0.281	0.267	0.207
20 per cent	5 per cent	0.345	0.318	0.208
13 per cent d	10 per cent	0.267	0.255	0.205
20 per cent	10 per cent	0.309	0.284	0.210
Equipment life 7 years				
10 per cent	5 per cent	0.172	0.159	0.229
20 per cent	5 per cent	0.235	0.207	0.241
13 per cent d	10 per cent	0.158	0.147	0.244
20 per cent	10 per cent	0.199	0.174	0.246
Equipment life 10 years				
10 per cent	5 per cent	0.128	0.116	0.249
20 per cent	5 per cent	0.194	0.165	0.268
13 per cent d	10 per cent	0.115	0.103	0.259
20 per cent	10 per cent	0.156	0.131	0.277

a Derived from equation (C2). **b** Derived from equation (C12). **c** Based on difference between public and individual annuity factors, but with the latter adjusted to allow for tax as in equation (C9). **d** The lowest nominal interest rate at which, with realistic taxation assumptions, real interest is positive given a 10 per cent inflation rate.

the public annuity factors widens for higher real interest rates, higher inflation rates and machinery with a longer life. In recent years, interest rates have risen substantially, and the effective rate of tax on capital items has been increased by the removal of investment allowances and the extension from three to five years of the period over which the nominal purchase price can be claimed as depreciation. Each of these changes has increased the unit cost of capital to individuals. However, over a wide range of conditions the taxation provisions reduce the opportunity cost of capital more than the costs of other inputs. For an inflation rate above 5 per cent, nominal interest rates above 10 per cent and equipment with a life over four years, the cost reduction factor on capital is greater than the 0.21 applying to other inputs at a tax rate of 21 per cent. While taxation provisions have this effect, more capital will be used than would otherwise be the case. The investment allowances, when they applied, would have intensified this effect.

In the analysis reported in this paper, a nominal interest rate of 15 per cent and an annual inflation rate of 8 per cent have been used.

C.2 Industry estimates of capital costs

The method used by the industry to express purchase prices of assets as an annual cost per tonne (outlined in Page et al. 1985) involves breaking capital costs into two components, depreciation (d) and return on investment (R). These are defined as follows:

$$\text{(C14)} \quad d(q) = (P-S)/Q$$

where $d(q)$ is the depreciation charge per tonne of cane harvested and S is the salvage value of the asset; and

$$\text{(C15)} \quad R = i((P+S)/2)n/Q$$

where R is the annual return on investment per tonne of cane harvested.

Because realistic estimation of salvage values would be extremely difficult, a zero salvage value is assumed. Combining (C14) and (C15), and using the definition of i in terms of p and r implicit in (C4), the total capital cost per tonne, C, is:

$$\text{(C16)} \quad C = (P/Q)[1+n((1+r)(1+p)-1)/2].$$

The difference, V, between this estimate, which follows Page et al., and the actual real unit costs implied by (C3) is:

$$\text{(C17)} \quad V = (P/Q) \times \times \frac{1+n((1+r)(1+p)-1)/2-nr(1+r)^n}{((1+r)^n-1)}$$

The value of V may be either positive or negative, and thus the Page et al. approach

15 'Industry' and Bureau estimates of the unit cost of a harvester

Nominal interest rate	'Industry' estimates	Bureau estimates: 4 per cent inflation	Bureau estimates: 8 per cent inflation
	$/t	$/t	$/t
Life of harvester 5 years, 40 kt cut per year			
10 per cent	1.12	1.06	0.95
15 per cent	1.24	1.20	1.08
20 per cent	1.35	1.35	1.22
Life of harvester 8 years, 25 kt cut per year			
10 per cent	0.79	0.72	0.61
15 per cent	0.90	0.86	0.74
20 per cent	1.01	1.02	0.88

may lead to either an overestimate or an underestimate of unit costs, depending on the relations among r, i and n.

It is not possible to provide a simple general condition for $V > 0$. However, it is possible to give some indication of the effect of using the Page et al. industry method on the accuracy of estimates of costs and cost savings. For constant real interest rates:

$$\frac{\partial V(\bar{r})}{\partial p} = nP(1+r)/2Q > 0$$

The likelihood that costs are overestimated by equation (C16) is therefore greater, other things being equal, the greater the inflation rate. This is illustrated in table 15, which shows a comparison of the two types of estimate — the industry method and that developed in this paper — for the unit cost of a harvester with a purchase price of $180 000 and a life of 200 kt. It can be seen that the industry cost estimates are greater than the Bureau estimates except when there is a low inflation rate and a high nominal interest rate.

C.3 Capital cost assumptions

The estimates used for the capital costs of the individual pieces of equipment were:

Harvester	$180 000
Tractor with a single-bin haulout trailer	$32 000
Tractor with a double-bin haulout trailer	$42 000
Service vehicle	$18 000
Push-up tractor for use at siding	$4 000

Thus, for a harvesting group comprising two double-bin haulout units, the equipment would comprise a harvester, two tractors each with a double-bin haulout trailer, a service vehicle equipped with spare parts to cover routine maintenance and minor repairs, and an old tractor which is kept at sidings for pushing empty cane bins onto the haulout trailer. The total capital cost of equipment in this group would be $286 000.

It has been assumed that the life of harvesting equipment in terms of cane harvested is 200 kt. It has further been assumed that new machinery would be purchased only at the beginning of a season: a new harvester would not be purchased partway through a season at the time when just 200 kt of cane had been harvested, but would have been purchased at the start of that season. Thus, for years of operation of harvesting equipment, the following schedule was adopted:

Lifetime Years	**Annual throughput** kt
10	<20.0
9	20.0–22.2
8	22.2–25.0
7	25.0–28.6
6	28.6–33.3
5	33.3–40.0
4	40.0–60.0
3	>60.0

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