Organization and profit-sharing in mechanized sugarcane harvesting: Is Australia's experience relevant to China?

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Abstract: China now grows about 1.5 million hectares of sugarcane and is the third largest sugar producer in the world. Almost all of that cane is still harvested by hand belabor in countryside areas has become more expensive and difficult to recruit. While the sugar mills prefer to crush the cleaner cane that manual harvesting delivers, some mills in areas where mechanical harvesting capacity has increased in recent years, have imposed restrictions on the quantity of machine cut cane that can be delivered each day. In the longer term, it is inevitable that the mills will have to accept a greater proportion of machine harvested cane.

It is therefore important that an institutional structure and operating rules to control the harvesting sector be developed as the transformation from manual to mechanized harvesting takes place in China to achieve the best possible outcome for the sugar industry.

Australia was the pioneering country that developed mechanized sugarcane harvesting but most of the organizational arrangements for mechanical harvesting of sugarcane were adapted from the manual cutting system that preceded mechanization. The cane payment system in Australia partly acknowledges the respective capital shares involved in the independent farms supplying cane and the mills which process it, and attempts to share revenue from sugar sales roughly in proportion to their respective historical capital investments.

When mechanical cane harvesting was introduced into the Australian industry, there was no attempt to recognize the capital investment of harvester operators as part of the whole supply chain. They have always been paid on a contract basis ($x per ton of cane harvested) which does not align the incentives for the harvester operator with the rest of the industry.

The paper describes the Australian way of organizing cane harvesting and some international systems of cane payment and so that each farmer shares equitably in the proceeds of sugar sales. These payment systems all exclude harvester operators from taking a share of industry revenue.

Some suggestions that might help the Chinese industry avoid similar problems are discussed.

Keywords: sugarcane harvesting, business organization, cane payment system, revenue sharing, equity

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1 Introduction

China now grows about 1.5 million hectares of sugarcane and is the third largest sugar producer in the world after Brazil and India. Almost all Chinese sugarcane is still harvested by hand but labor in countryside areas has become expensive and more difficult to recruit. The sugar mills prefer to crush the cleaner cane that manual harvesting delivers and some mills, in areas where mechanical harvesting capacity has increased in recent years, have imposed restrictions on the quantity of machine cut cane that can be delivered each day. In the longer term, it is inevitable that the mills will accept a greater proportion of machine harvested cane.

It is therefore important that an institutional structure and appropriate management strategies to control the cane harvesting sector be developed as the transformation from manual to mechanized harvesting takes place in China to achieve the best possible outcome for the sugar industry.

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harvesting of sugarcane were adapted from the manual cutting system that preceded mechanization. The cane payment system in Australia acknowledges the respective capital shares invested in the independent farms supplying cane and the mills which process it, and attempts to share the net revenue from sugar sales roughly in proportion to their respective historical capital shares.

When mechanical cane harvesting was introduced into the Australian industry, there was no attempt to recognize the capital investment by harvester operators as part of the whole supply chain. They have always been paid on a contract basis ($s per ton of cane harvested) which does not align the incentives for the harvester operator with the rest of the industry.

This paper describes the Australian system of organizing cane harvesting and some international cane payment schemes so that each farmer shares equitably in the proceeds of sugar sales. None of these systems include a way for harvester operators to share industry revenue.

Some suggestions that might help the Chinese industry avoid similar problems are discussed.

2 Industry organization in Australia

2.1 Ownership and control

Approximately 95 per cent of Australia's cane farms are owned and operated by sole proprietors or family partnerships with the remainder operated mainly by private companies. For most of the industry's history, sugar milling companies owned less than 2.5 per cent of total cane area, although there has been a tendency in recent years for them to acquire more land for cane farming. For harvesting, farms are formed into groups. A group represents a single harvesting agreement, although not normally supported by a formal contract, that includes the farms (or farm) harvested by a single harvester operator. Groups are formed by mutual agreement among the growers, subject to approval by the mill. Growers may cut their own cane, or arrange to have it cut by a contractor (Brennan and Wegener, 2003). Much of the following discussion about the organization of the Australian sugar industry is adapted from that paper.

Most of Queensland's 21 sugar mills, and the three in New South Wales, were established more than 100 years ago and were either cooperatively owned by growers or by Australian proprietary companies. In 1980, there were 19 milling companies operating 33 raw sugar mills in Australia. By 1997, there had been some mill closures and company mergers with 12 companies operating 29 mills. Since 2010, there has been a transformation in ownership of Australian sugar mills. Mitr Pohl from Thailand took a 19% stake in Maryborough Sugar Factory in 2010, the same year that Singaporean company Wilmar bought seven Queensland sugar mills from Sucrogen (formerly CSR Limited). In 2011, Chinese company COFCO acquired Tully Sugar Limited, formerly a growers' cooperative, thus reducing the number of milling companies operating in Australia to eight and the number of sugar mills to 24. About that time, Mitr Pohl assumed full ownership of Maryborough Sugar Factory and in 2012, Wilmar added Proserpine mill, another former growers' cooperative, to its portfolio.

In addition to producing raw sugar, mill responsibilities include coordination of harvesting, transport of sugar cane (mainly using narrow gauge railway) from farms to the factory, sampling and analysis of cane, delivery of sugar to bulk storage terminals, and maintenance of accounts to distribute the proceeds of sugar sales to growers.

The Australian raw sugar industry is usually considered to be comprised of two sectors: sugarcane growing and sugarcane milling. The interdependent relationship between growers and mills in relation to harvesting and transport arrangements, as well as other aspects of growing and milling, was reflected in the highly regulated nature of the industry over the past 100 years. Almost every aspect of cane growing, milling, and marketing was subject to rigid controls and regulated, until recently, by the Sugar Industry Act 1999 passed by the Queensland Parliament.

Historically, the industry operated under regulations which controlled the land on which cane could be grown, determined the terms of harvesting and delivery conditions, specified the mill to which cane had to be delivered, and provided the framework for distributing revenue between growers and millers. Under such controls, growers and millers had little scope to negotiate the price, quantity, or terms of delivery for cane. Compulsory acquisition of the sugar produced by the Queensland Government underpinned these regulations, and centralized raw sugar marketing completed the cycle. Following several industry reviews in the 1980s and 1990s demonstrating the economic gains from industry deregulation, the Sugar Industry Act 1991 and Sugar Industry Act 1999 liberalized some of the regulations, although many remained unaltered (Centre for International Economics 2002, cited by Brennan and Wegener 2003). More recently, the remaining regulations that mainly controlled the marketing of sugar have been removed and the industry now operates mostly in a deregulated commercial environment.

The cane land assignment system that was introduced in 1926, and the associated production quotas involving mill and farm peaks (which were maximum tonnages of sugar to be produced by each mill and each farm), were the principal constraints on the area and location of sugar production in Queensland for about 80 years.

These assignments essentially bound the grower and the miller in a contractual arrangement to grow cane on a specified area of land and deliver it to a designated mill. 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 during the hand-cutting era was dictated largely by the task of harvesting. The introduction of mechanical harvesting meant that land assignments replaced labor availability as the major constraint on farm size (Connell and Borrell 1987). Because of the small size or cane farms, most harvesting groups produced less cane than the harvester they employed could comfortably cut in a season.

Until the relatively recent reviews of the sugar industry legislation, the assignment system strictly controlled where and how much cane could be grown in Queensland. Although cane production had approximately doubled in the 10 years after the change to mechanized harvesting, farm size did not increase proportionately. The extra production was partly due to new entrants to the industry and increased area under cane, but most of it came from increased cane yields (Brennan and Wegener, 2003). The Industry Commission (1992) suggested that despite gradual increases in harvester capacity, small group harvesting might have been perpetuated by the small area of assigned land on most farms. Connell and Borrell(1987) argued that the introduction of mechanical harvesting could have released growers from their involvement in cane harvesting and allowed them to specialize in growing much larger areas of cane while leaving harvesting to contractors. Instead, production controls, which were set in place before mechanization of the harvest, prevented this expansion and the opportunity for growers to use their own excess labor in a more profitable way was denied. For many growers, the next best use of their time and labor, which could not be spent producing more cane, was to harvest their own cane.

There is another aspect to these controls on land that impacts harvesting. While growers could not easily expand the area of cane to be grown and harvested, they could readily increase their harvesting capacity. With the traditional cane farmers' love of machinery, and generous taxation concessions from the Australian Government for investing in new machines, individual cane farmers were inclined to buy harvesters to harvest their own cane when the economically rational option would have been to employ a contractor. This over-capacity in harvesting machinery existed in the industry for many years and kept contract cane harvesting rates below the real cost of the owning and operating the machinery. Once either farmers or contractors had invested in a cane harvester, it was regarded as sunk capital and depreciation, interest on invested capital, and even the owner's own labour to operate the machines, were often ignored in calculating the cost of harvesting with farmers believing they could harvest their own cane for little more than the cost of fuel in the harvester. Thus contract harvesting rates were set by the demand and supply of harvesting services, and not by their real cost, if all components of the cost of owning and operating a harvester were considered.

In popular industry publications during the 1960s, the practice of cutting one's own cane was recommended as cost effective and managerially sound and there were suggestions that harvesting technology would be refined to suit this practice (Vallance 1967, 1968). It is probable that this conclusion was based on inadequate economic analysis and failure to account for all ownership and operating costs of the machines. It was not evident until the late 1960s that the large capacity chopper harvesters would become the dominant design in the Australian and world sugar industries and growers and millers may not have fully anticipated this outcome when they were making long-term investment decisions. By 1972, the labor-saving large-capacity chopper harvesters had become established as the dominant design in the Australian industry, and almost all mills converted completely to receive chopped cane from their supply areas (Churchward and Belcher 1972).

3 Influence of manual cane cutting practices on mechanical harvesting arrangements

Driven by acute labor shortages in agriculture during and after the Second World War, the sugar industry in Australia successfully introduced mechanical cane harvesters ahead of any other cane growing country. Mechanical loaders, which loaded bundles of wholestalk cane onto railway wagons, were the first widely adopted mechanical innovation in the cane harvesting system and represented a major transitional step between manual harvesting and full mechanization. They eliminated the most burdensome of the manual harvesting operations. Mechanical loading was adopted throughout the Australian sugar industry from 1955, most rapidly in those parts of the industry that relied on resident farm labor for cane harvesting (Brennan and Wegener 2003). In the 1960s, a grower could choose from either a 'wholestalk' harvester, which was operated in conjunction with a mechanical loader, and was the first type of harvester to be adopted, or a 'chopper' harvester which chopped the cane into short lengths (billets) and loaded them into a bin on a trailer ready for transport to the mill.

The first chopped cane harvester to become commercially available, the Massey Ferguson 515, was successfully demonstrated cutting burnt cane in Mackay in Central Queensland in 1957. The rapid investment in mechanized farming and harvesting equipment that took place in the Australian sugar industry from the 1950s and 1960s changed the industry from a labor-intensive to a capital-intensive farming system; and group harvesting evolved as a structural response to this.

Prior to mechanization, harvesting was carried out by small groups of men (a gang) who were usually engaged by a single farm to cut their cane. With the development of commercial cane harvesters, they simply replaced the gang of men. During the late-1950s and early-1960s, ownership of harvesters was largely confined to individual growers purchasing their own machines (Vallance 1968, 1969, 1972). Mechanical harvesters were able to cut cane much faster than manual labor, and remove all the cane from a single farm in less time than the full crushing season so, with the rising cost of purchasing and maintaining harvesting equipment, growers quickly found alternatives to sole ownership of this equipment. The arrangements included cooperative group ownership by a number of farmers and contracting arrangements with other growers. Independent contractors also offered contract-harvesting services.

A breakdown of the types of ownership structure for cane harvesters in Australia for the 1995 season is presented in the following table. The percentages represent the proportion of total crop in the district. We are not aware of more recent data but believe the pattern of ownership is relatively unchanged. There are significant differences in ownership structure among the cane growing districts.

Table1 Categories of mechanical cane harvester ownership in Australia, 1995 season (percent)

District	Growers cutting own cane	Grower and contractor	Harvesting cooperative	Combination cooperative and contractor	Independent contractor
North Queensland	5.6	60.4	2.4	2.4	29.1
Burdekin	0.4	25.6	0	0	74.0
Central Queensland	13.6	32.5	11.7	11.7	30.5
South Queensland	na	na	na	na	na
New South Wales	0	0	100	0	0

Source: Adapted from Briggs (2010, p677)
Footnote: na - Data not available

Sugar cane harvesting technology developed in Australia in a way that permitted the establishment and perpetuation of a range of harvesting group structures. In the decade after the release of the first commercially available cane harvesters, the range of harvester makes and models available was much wider than is currently the case, reflecting the high level of inventive activity within the industry (Kerr and Blyth 1993).

Despite the availability and suitability of chopper harvesters, wholestalk machines remained popular in some areas for some time and together with the preference for growers to cut their own cane, contributed to a serious economic problem in the industry. The small group harvesting structure caused increased transport costs for the mills for many years (Vallance 1972; Brennan and Wegener 2003).

Since complete adoption of mechanical harvesting in the Australian sugar industry in the late 1970s using chopper harvesters, there has been a general trend for harvesting group sizes to increase. Groups were enlarged to provide sufficient cane supply for the efficient and economical operation of the larger harvesters that the manufacturers offered. The trend to larger harvesting groups continued as the incorporation of new harvesting equipment involved expenditure on large capital items that were indivisible, making their purchase difficult to justify economically for smaller enterprises (Brennan et al., 1997). This ongoing formation and gradual amalgamation of mechanical harvesting groups, resulting in fewer but larger groups, and fewer cane harvesters in the industry, has been a major feature of the evolution of cane harvesting systems in Australia.

The cane harvester manufacturing industry in Australia was reduced to a single manufacturer from 1984. They produced only one model of large capacity harvester for which a number of options in regard to operating features were available (Ridge and Dick, 1985). There has also been a continual increase in the size of cane transport vehicles, especially since the change to large-capacity railway wagons that stay on the mill tramline. Ridge and Dick (1985) noted that if harvesting contractors were to continue to maintain modern, reliable machines then an increase in group size would be necessary to contain cane harvesting costs.

The increase in mill bin size had an impact on in-field transport costs. With the phase out of roll-on/roll-off transport units where small railway wagons were carried into the field to be filled by the harvester, tipper bins or elevating transporters became the preferred alternative. The capital cost of these more sophisticated and specialized units was high so advantages in capacity and speed of operation were needed to offset the increased costs. In the wetter cane growing areas, high-flotation in-field transporters on large types or tracks were needed to match the high capacity of tracked cane harvesters.

4 Sharing industry revenue

4.1 Cane payment system in Queensland

The arrangements to pay for cane supplied to sugar mills in Queensland are based on the sugar content of the cane and the price obtained for the sugar potentially made from it. Cane payment is one of the items in each Cane Supply Agreement that each cane grower has with the milling company to which cane is supplied. Much of this description in this section about how payment for cane is determined is based on information provided on the Australian Cane growers website.

Historically, like many sugar industries around the world, the Queensland industry operated for many years with a cane payment system and pricing formula that was arbitrated by government. The formula which determined cane price was designed to allocate net proceeds from sugar sales between millers and growers so that industry revenue was shared approximately in proportion to their respective investments in industry assets. There was never any serious consideration of sharing the proceeds with the other important industry sector – the harvester operators.

When it was introduced in 1916, the formula was based on industry production relativities at that time. Average recovery of commercial cane sugar (CCS), an empirical measure of recoverable sugar in the cane then was 90 (ie. 90 tons of sugar of a standard quality could be produced from each 100 tons of CCS in the cane) and the average CCS was 12 units. It was determined that, at base levels of efficiency, the proceeds should be split approximately in proportion to the estimated total value of mill and farm assets, or the ratio of two-thirds to growers and one-third to the miller for the average production situation – milling efficiency of 90% and cane of average quality (12 units CCS).

This efficiency level would entitle the miller to the proceeds from four of the 12 units of CCS for processing the cane with the remainder going to the grower. This gave a formula of the form:

$$Pc = Ps \times (90/100) \times (CCS - 4)/100$$

where Pc and Ps are price of cane and price of sugar respectively.

Over the years, the form of this formula remained unchanged, but a constant dollar amount was added to the calculation which increased over time. In 2000, it was $0.578.

Thus the formula became:

$$Pc = Ps \times (90/100) \times (CCS - 4)/100 + 0.578 \qquad (1)$$

The incentive built into this formula encouraged the mills to increase recovery efficiency without having to share the proceeds of their increased efficiency with growers. Because the formula specified a standard recovery of 90%, the benefits from any improvement in sugar recovery, usually due to capital investment, went totally to the miller. This encouraged Queensland mills to seek improvements in their sugar recovery levels and, as a consequence, recovery levels now are often over 102 tons IPS sugar for every 100 tons of CCS supplied by growers.

The formula also provided incentives for growers to improve the recoverable sugar content of their cane. Since the “one-third” of the returns due to the miller was embodied in the formula by the (CCS-4) factor, any improvement in recoverable sugar content in the cane resulted in increased income for the grower.

Government no longer has a part in negotiating cane supply arrangements but most still include a formula similar to the one described above. Some mills now pass on to growers some share of revenue from products other than sugar, such as molasses. One of the milling groups, the Mackay Sugar Milling Cooperative, has gone further, putting in place a formula that is based on a constant split of all mill income from sources such as electricity cogeneration and molasses and allocating payment to individual growers on the basis of a new formula for estimating sugar recovery knows as PRS (percent recoverable sugar).

The sugar price in the old cane payment formula was the same for all growers and was the outcome of a sugar marketing pool operated by Queensland Sugar Limited. Now, this price can vary from one milling company to another, depending on the markets into which the sugar is sold. Some mills now market their own sugar, something they were never permitted to do in the past. Many growers now use futures contracts to hedge the price of some of their cane against unexpected movements in the sugar price. If a farmer uses futures to lock in a particular price, that is then applied in the cane payment formula to determine not just what he or she is to be paid, but also the tonnage of cane that the tons of sugar hedged equates to.

4.1.1 Calculating CCS

For most of the industry's history, payment for cane in Australia was made on the basis of estimated sugar content or CCS. Now, growers may also receive part of their income from molasses, electricity, ethanol, or other products sold by the mill. CCS is calculated by a formula based on the assumption that sugarcane only contains pure sugar, impurities, water, and fibre. It assumes that only pure sugar is made, and that for every kilogram of impurities which leaves the factory after the cane is milled, half a kilogram of sugar accompanies it. These assumptions can be expressed in mathematical terms by saying that CCS is equal to the sugar in cane minus half the impurities in cane.

This formula assumed an estimate of sugar and of impurities in the cane juice could be made, since neither of those values could be measured directly when the formula was developed. The industry used a convention of measuring the sugar content in cane juice (called "pol") with a polarimetry which measures the way a clarified sugar solution affects polarized light. The specific gravity (or "brix") caused by all of the material that is dissolved in the juice is measured by hydrometer or brix spindle. Fiber was assessed by macerating a sample of cane in hot water and separating the soluble from the insoluble material by filtering. By taking the sugar content away from the total of dissolved material, anything dissolved, apart from sugar, was assumed to equal impurities.

So the calculation of CCS was made as follows (Reid, 1981):

CCS = sugar in cane – ½ impurities in cane

= pol in cane – ½ (brix in cane – pol in cane) (2)

Although brix and pol in cane are hard to measure directly, brix and pol can be measured relatively easily in juice. Unfortunately, the brix and pol in the juice is not the same as the brix and pol in the cane, so some correction factors were built into the formula. Fiber is one of the correction factors.

After fiber and other corrections were added, the formula became:

$$CCS = 3/2P\,(1 - (F+5)/100) - ½\,Bx\,(1 - (F+3)/100) \quad (3)$$

where, P = % pol in first expressed juice,

Bx = % brix in first expressed juice, and

F = % fibre in cane.

The procedures for measuring pol, brix, and fiber were set out in local cane analysis programs and generally followed methods described in a publication, the "Laboratory Manual for Queensland Sugar Mills" published by the Bureau of Sugar Experiment Stations (BSES). All of the analyses carried out in mill laboratories were subject to audit by check chemists.

Most mills now use an inferential analysis method based on Near Infra Red Spectroscopy (NIR) which permits direct measurement of fiber and CCS on each farmer's cane sample.

Other countries such as Brazil and South Africa operate similar cane payment systems to Australia

4.2 Pricing of sugarcane in Brazil

Approximately 70,000 independent farmers supply around 40% of the cane processed by Brazilian sugarcane mills. To help ensure a fair and equitable relationship between growers and mills, an innovative sugarcane payment system was introduced in 1999.

This voluntary program is overseen by a non-profit association known as Consecana – the Council of Sugarcane, Sugar and Ethanol Producers in the State of São Paulo. The group represents both sugar and ethanol processors (whose industry association is UNICA) and sugarcane growers (who belong to an organization called ORPLANA). The primary objective of the Consecana payment system is to share proceeds equitably. The system is based on two fundamental principles:

- The price paid to cane producers is proportional to their share of the factory's revenue. On average, sugarcane production accounts for 60% of total sugar and ethanol production costs. Therefore, sugarcane growers receive around 60% of the revenue from these products.
- The mills pay more for sugarcane with higher sucrose content. The value of sugarcane is based on the so-called Total Recoverable Sugar (or ATR in Portuguese). ATR corresponds to the amount of sugar available in the raw material minus the losses in the manufacturing process.

The money sugarcane growers in Brazil receive depends on the prices for sugar and ethanol sold by processors in domestic and foreign markets so transparency is crucial to this payment model. Price surveys of Brazilian and international markets are conducted by a neutral body, the Centre for Advanced Studies in Applied Economics (CEPEA), a research center within the University of São Paulo College of Agriculture (ESALQ). In addition, cane growers have the right to monitor mill laboratories 24 hours per day.

This information about the Consecana system was accessed from the sugar industry website (Sugarcane.org). It is a dynamic system and the group re-evaluates its rules every five years to adapt to new market developments. Other sugarcane producing states in Brazil consider this fair-pricing program a success, and many have either adopted a similar system or rely on information from Consecana.

4.3 The RV cane payment system, South Africa

At the start of the 2000/01 season, the Recoverable Value (RV) payment system replaced the previous payment system used in South Africa.

The RV system recognizes the effects of sucrose, soluble non-sucrose material, and fiber (insoluble material in the cane juice) on sugar production. Essentially, the front end of a sugar mill is designed to separate the fiber from the sugar solution in the cane stalk but some sugar is lost in the process by adhering to the cane fiber. The back end of the factory is designed to separate the soluble material in the cane juice by forming sugar crystals and removing them from the super-saturated sugar solution by centrifugation. Again some sucrose is lost by remaining with the non-sucrose material. This led to the development of the following identify:

Sucrose in cane – sucrose lost in fibre – sucrose lost with non-sucrose material = Recoverable Value

or $S - cF - dN = RV$ (4)

The RV formula is more commonly represented in the form:

$$RV\% = S - dN - cF \quad (5)$$

where S = sucrose % cane delivered

N = non-sucrose % cane delivered

F = fibre % cane delivered;

d = the relative value of sucrose lost from sugar production per unit of non-sucrose taking into account the value of molasses recovered per unit of non-sucrose; and

c = the loss of sucrose from sugar production per unit of fibre (South African Cane Growers Association, 2104).

Gross proceeds from sugar and molasses sales from which some industrial levies are deducted are shared by industry sectors, the growers and the millers. Their shares have been defined as 64% and 36% respectively of industry net divisible proceeds. Here again, there is no facility to allocate any of the industry proceeds to the harvesting sector. To calculate the return per ton to growers, the levy payable to the South African Cane Growers Association is deducted and divided by the tons of Recoverable Value that have been delivered (see diagram).

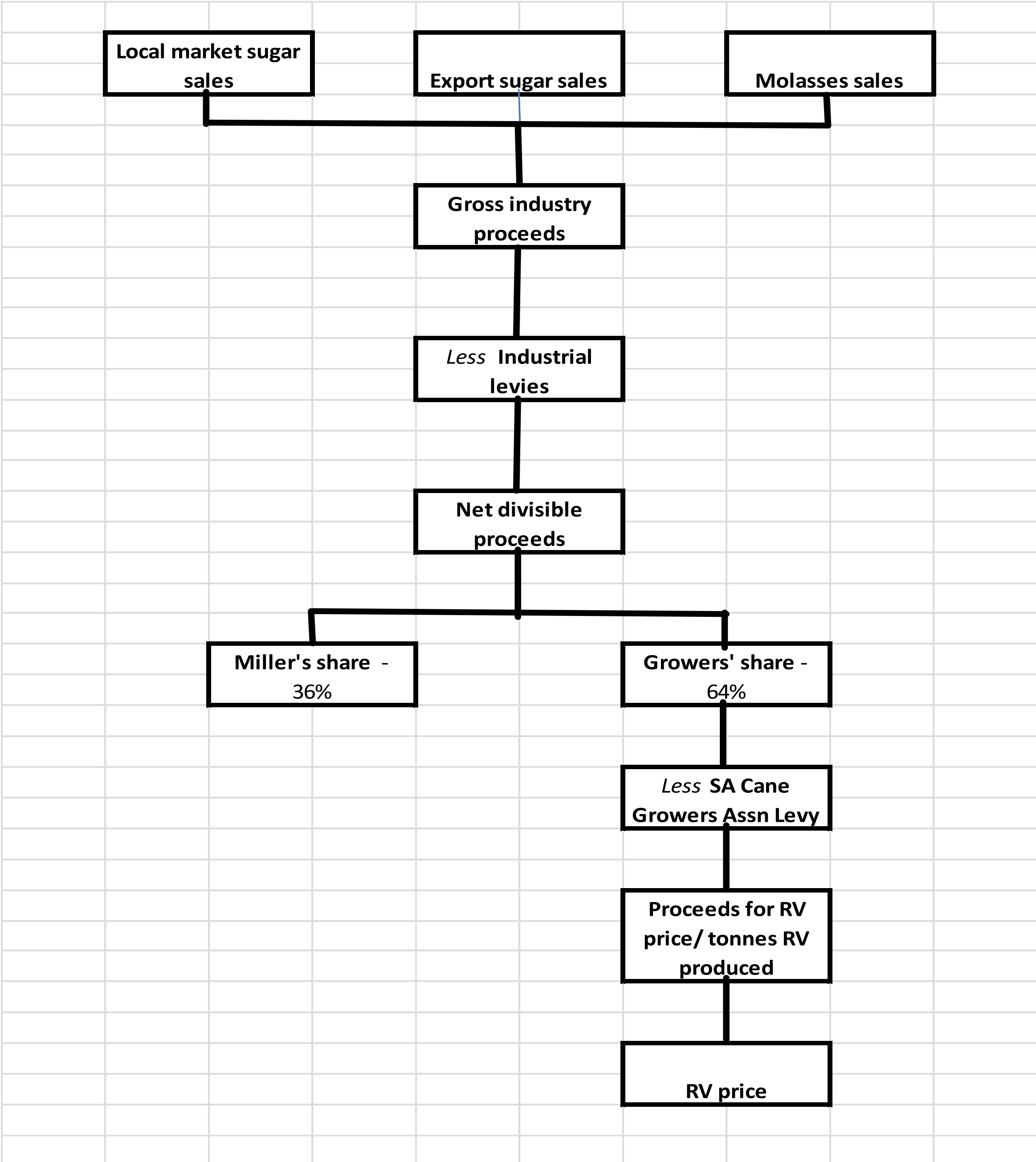

Figure1:Calculation of sugar payment according to RV system (South African Cane Growers Association 2014)

Another recently introduced cane payment system that is designed to improve mill performance and encourage growers to supply cane with higher sucrose content was introduced in Fiji in 2004 (Kroes and McFadden, 2004).

4.4 Payment for harvesting services

One aspect of the cane payment and harvesting system that has not been addressed adequately in the literature is whether the harvesting sector should be included along with the growers and the millers in sharing industry revenue. The cane payment formula used in Australia, and similar formulae used in other cane growing countries, provides for a sharing of sugar revenue on the basis of the respective historical investments in the industry contributed by growers and millers. This is understandable, given its historical origin, although not necessarily equitable. When cane was harvested manually, it was a labor intensive operation, and the workers were paid for their input of physical labor at a fixed rate per ton of cane. They did not contribute any capital that needed to be rewarded, a situation that changed with the introduction of mechanized harvesting where the operator needed to make a substantial capital investment in a harvester, haul-out tractors and trailers, and associated facilities such as a workshop and service vehicles.

There are two options by which this capital investment can be "paid for": by direct payment for harvesting services; or possibly by a share of industry revenue in the same way as the growers and millers do. When the harvesting equipment is owned and operated by a contractor, the costing method to determine the appropriate payment for harvesting is straight-forward. It is not so obvious when the machinery is owned by a farmer who cuts his own cane or possibly other farmers' cane. The contractor should be paid for the service provided at a rate that covers all ownership and operating costs. These would normally include depreciation on the machinery, interest on the capital invested, the operators labor, fuel and lubricants, repairs and maintenance, insurance, registration and other taxes or charges, and storage or shelter costs. These can be grouped into ownership and operating cost categories (Edwards, 2014).

4.4.1 Ownership and operating costs for farm machinery

Ownership costs are the usual fixed costs of owning the machinery and include depreciation, interest, insurance, taxes, and shelter and maintenance facilities.

Depreciation is a method of spreading the purchase price of the machinery over its working life and can commonly be calculated by either diminishing value or straight line method.

Annual depreciation ($) [straight line method]

$$=\frac{Initialcost(\$)-Salvagevalue(\$)}{Workinglife\ (years)} \quad (6)$$

With the diminishing value method, a constant rate of depreciation (%) is allowed each year and the asset's value declines by a declining amount each year until the residual value is reached. This is best illustrated by an example (in the following table), considering an asset with an initial value of $1000 and an annual depreciation rate of 40%.

Table 2: Example of calculating depreciation by diminishing value method

Year	Depreciation rate (%)	Depreciation expense ($)	Accumulated depreciation ($)	Residual value ($)
1 (Original cost = $1,000)	40	400	400	600
2	40	240	640	360
3	40	144	784	216
4	40	86	870	130
5	40	30	900	100 (scrap value)

When using the declining value method, the scrap or salvage value is not considered in calculating annual depreciation, but the book value of the asset being depreciated never falls below the scrap or salvage value. Depreciation ceases when either the salvage value or the end of the asset's useful life is reached.

Because the capital invested in harvest machinery could be used for other productive purposes, it has an opportunity cost. This is usually calculated at the appropriate interest rate on the average value of the capital asset.

Annual interest on capital ($)

$$=(Initialcost(\$) + Salvagevalue)/2 \quad (7)$$

The cost of taxes, insurance and shelter is usually much smaller than depreciation and interest charges but they are still a relevant cost of machinery ownership. Farm machinery may need to be registered to travel on public roads which is a form of taxation. Insurance should be paid on farm machinery to allow for its replacement in case of fire or other disaster. If insurance is not carried, the risk of loss is carried by the rest of the farm business. Current rates for farm machinery insurance are about 0.5% of the purchase price.

There is a tremendous variation in housing provided for farm machinery. Providing shelter, tools, and maintenance equipment will result in fewer repairs in the field and less deterioration of mechanical parts and appearance. That should result in greater reliability in the field and better re-sale prices. An estimated charge of 0.5% is suggested for housing costs.

These three small charges can conveniently be charged together as 1% of the initial purchase price of the machine.

Operating costs (also called **variable** costs) include repairs and maintenance, fuel, lubrication, and operator labor.

Repair costs occur because of routine maintenance, wear and tear, and accidents. Repair costs for a particular type of machine vary widely from one geographic region to another because of soil type, terrain, climate, and other conditions. Within a local area, repair costs vary from farm to farm because of different management policies and operator skill. The best data for estimating repair costs are records of the farm's own past repair expenses. Good records indicate whether a machine has had above or below average repair costs and when major overhauls may be needed. Without such data, repair costs must be estimated from average experience, in which case, total accumulated repair costs are often calculated as a percentage of the current list price of the machine, since repair and maintenance costs usually change at about the same rate as new machinery list prices. According to Edwards (2014), two- and four-wheel drive tractors accumulate repair costs at the rate shown in the following table.

Table3: Cumulative repair costs for tractors based on aggregate hourly usage (percent)

Type of machinery	Accumulated hours									
	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000
2-WD	1	3	6	11	18	25	34	45	57	70
4-WD tractors	0	1	3	5	8	11	15	19	24	30

Source: Edwards, 2014

For example, after 6,000 hours of use, total accumulated repair costs for a two-wheel drive tractor will be equal to about 25% of its new list price. Once total accumulated repairs have been estimated, hourly or per hectare rates can be calculated. A similar approach can be used for other types of farm machinery and for implements.

Fuel costs can be taken from farm records for each type of farm operation or be estimated. For example, the average amount of diesel fuel to harvest a ton of sugarcane in Australia is around one liter. This can be multiplied by the cost of fuel to calculate costs per hour for the machine, or reduced to a cost per ton or per hectare.

When records are not available, average fuel consumption (in liters per hour) for farm tractors on a year-round basis without reference to any specific implement can also be estimated as:

0.240 x maximum PTO horsepower for gasoline engines

0.176 x maximum PTO horsepower for diesel engines

Surveys indicate that total lubrication costs on most farms average about 15% of fuel costs. Therefore, once the fuel cost per hour has been estimated, multiplying it by 0.15 will provide an estimate of lubrication costs.

Because different sized machines require different amounts of labor to accomplish such tasks as planting or harvesting, it is important to consider labour costs in machinery analysis. Labor cost is also an important consideration in comparing ownership to custom hiring or contracting. Operator's labor is usually paid at an hourly rate and different wage rates can be used for operations requiring different levels of operator skill. Actual hours of labor paid usually exceed field machine time by 10 to 20%, because of travel and the time required for lubricating and servicing machines. Consequently, labor costs can be estimated by multiplying the wage rate by 1.1 or 1.2 to account for this inefficiency. Labor costs can be calculated as an annual charge, or converted to a per hectare or per ton rate if necessary.

After all these cost components have been estimated, the total ownership and operating costs per year can be calculated. Fixed costs have an important influence on cost per hour or cost per ton or per hectare as the following graph shows. The example is for a $350,000 machine, for example a cane harvester, capable of harvesting up to 100,000 tons of cane per year. Costs are shown for increasing intervals of 10,000 tons.

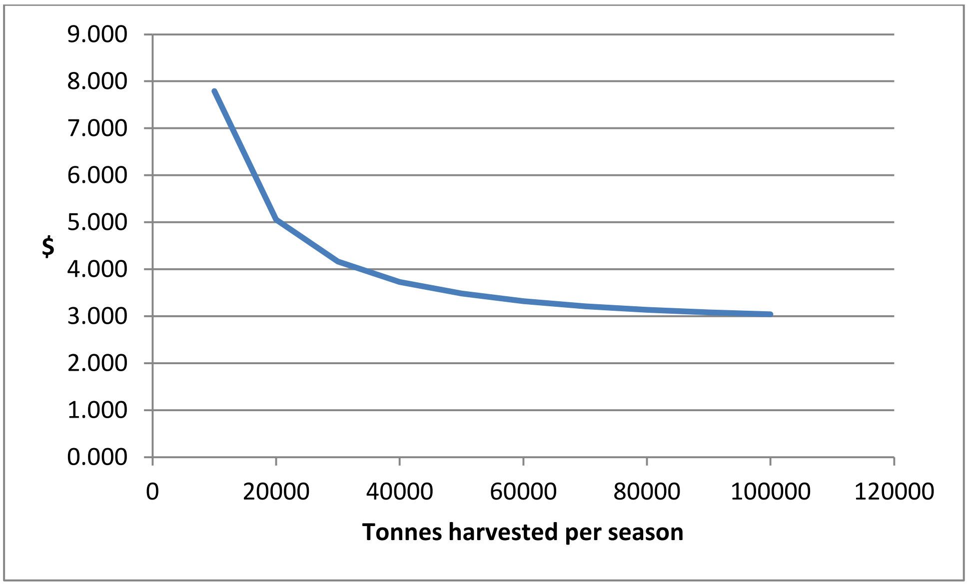

Figure2:Cost to harvest cane over a range of annual tonnages (based on estimates of average fixed and variable ownership and operating expenses)

5 Evolution of the cane harvesting system in Australia

5.1 Transition from manual to mechanized harvesting

Before the advent of mechanical harvesting, the raw sugar mills in Australia were able to operate efficiently by allowing the individual farmers to make their own harvesting arrangements. Hourly crushing rates at mills were low, cane deterioration was not recognized as a serious problem, and it did not matter that cane supply was slow or inefficient. Neither was it necessary for tight control to be kept on harvesting activities. Wholestalk cane could be left in the field until it was required at the mill. With the use of temporary in-field tramway lines, a relatively large number of wagons could be loaded with cane and left waiting until a locomotive was available to haul them to the mill.

The transition to chopped cane harvesting was a major departure from industry practice of harvesting wholestalk cane. The realization that chopped cane deteriorated much more rapidly and more severely than wholestalk burnt cane came slowly. In the first published paper on deterioration in chopped sugarcane, Vallance and Young(1959) emphasized the necessity for greater coordination between mills and the growers to reduce this problem. Ridge (1987) noted that mill transport systems needed to evolve to keep pace with harvester developments. Most mills in Australia use a narrow-gauge railway system to haul harvested cane to the mill so the transition involved designing bins to hold chopped cane in place of wagons for wholestalk cane. Initially, small capacity steel-framed cages were built on wagons that were used to haul wholestalk cane but these were gradually replaced with larger bins as the rail network expanded in most mill areas. Portable line that could be laid temporarily into cane fields disappeared to be replaced by permanent railway sidings and roll-on /roll-off trailers, or road transport in some cases, to take cane to the end of the railway line or directly to the mill. Controlled schedules for the cane railways were devised to organize collection of harvested cane and mills imposed tight controls on harvesting arrangements to address cane deterioration, availability of bins, transport scheduling, and wet weather harvesting.

Over time, the capacity of the railway wagons increased so that they all now stay on the line and various forms of tipper or elevator bins are used to transport cane from the field to the railway siding.

Such an evolutionary environment as described impacted on the diffusion of chopped cane harvesting technology in Australia. For example, it was common for mills to impose controls on harvesting arrangements to address problems arising from harvesting in wet weather, such as high soil and extraneous matter levels, lost milling time, and difficulty maintaining equity in allocating harvest quotas. For many years, the mills in some areas managed potential wet weather harvesting problems by encouraging more harvesters than needed to operate, accepting the operation of small groups, and overcapacity in harvesting resources. Also, harvester reliability during the period of innovation and development was not equal to the standard of modern machines and the existence of many small groups acted as a form of insurance against harvester breakdowns which could slow the flow of cane into the mills (Connell and Borrell 1987)

The mills' requirement for clean cane delivered to the mill always provided difficulties in the development of suitable harvesting machines. The increased popularity of chopper harvesters had important implications in regard to cane quality. Mills initially experienced difficulties processing large quantities of chopped cane and maintaining sugar quality. Another problem associated with widespread adoption of chopped cane harvesting was the need to invest heavily in tramway bins to deliver the chopped cane. Growers could not use chopper harvesters unless bins were provided by the mills.

The construction of mill transport infrastructure therefore had to occur more or less simultaneously with the rapid diffusion of chopped-cane harvesting. Initially, mills without the necessary transport infrastructure could only accept limited quantities of chopped cane. Likewise, all growers in a mill area could not supply chopped cane until the mill made a large investment in cane bins. Consequently, despite the growing pressure to supply chopped cane by growers, mills in several districts placed restrictions on the number of chopper harvesters that could supply cane to the mill. These restrictions were gradually eased and by 1978 all mills in Australia were receiving chopped cane exclusively.

Part of the mill infrastructure required to handle chopped cane in the Australian system was the construction of tramway sidings, approximately one for each farm, to hold both empty cane bins as well as those already filled by the harvester and waiting to be taken to the mill. This expensive infrastructure was quasi-irreversible because the long-term nature of the investment meant that the location and capacity of sidings were not likely to change significantly once constructed.

5.2 System considerations

An example of the inter-relatedness of harvesting issues is that the rate of adoption of harvesting technology was significantly affected by the geography of cane growing areas. This was a major challenge for the Australian sugar industry and production ceased in some parts of the existing cane growing area, particularly on steeply sloping land, when mechanization was introduced. This issue will be an even greater challenge for the Chinese industry, with so much cane grown on steep hillsides, as the development of machines that are able to handle the differences between localities, terrain, soil conditions, weather, and types of cane, including sprawled crops, will be necessary.

Specific in-field conditions in Australia, including heavy, clay soils in the Burdekin district which produces high yielding crops of irrigated cane that are often lodged, retarded the introduction of mechanized harvesting into that area (Willis 1972), and poorly drained land completely precluded mechanized harvesting in the northern New South Wales region until solutions such as field drainage and tracked harvesters and haul-out units were developed (Vallance 1970). Although the Burdekin district and NSW were late adopting mechanical harvesting, more efficient arrangements than apply in other areas evolved. Both regions now have the largest harvesting groups in Australia. Large areas of cane growing land in the Burdekin district were developed after the introduction of mechanized harvesting and, aided by larger farm sizes, farm layout could be designed to meet desirable harvest ability criteria, such as large blocks of cane with long rows. Similarly, the large harvesting groups now operating in NSW suggest that the region benefited from the late adoption of mechanical harvesting which did not occur there until the mid-1970s. When it did occur, the transition to mechanical harvesting in NSW was rapid, coordinated, and contrasted strongly with the continuous incremental changes that occurred in many Queensland cane growing districts. The transition in NSW involved a radical change in the system because the previous arrangement, largely based on riverboat transport, could not be refined and upgraded to accommodate chopped cane. The NSW industry was a late entrant into mechanical harvesting because a leap to a new level of technology was required. By the time mechanical harvesting was adopted in NSW, the large capacity chopper harvester was well established as the dominant design and so the industry entered the mechanical harvesting era with larger groups and high capacity equipment. Other cane growing regions in Australia may have been penalized for taking the lead in adopting mechanical harvesting. They embraced mechanical harvesting unassisted by the benefits of hindsight.

Now the New South Wales Sugar Milling Cooperative in Northern NSW has the most efficient harvesting and cane transport system in Australia. This milling group harvests and transports up to 2.5 million tons of cane each year to its three factories (Harwood, Broadwater, and Condong) using only 21 harvesters and 28 trucks. Cane is delivered to each factory every six minutes to maintain maximum processing capacity. There is little or no queuing of trucks at the mill, and few interruptions from field operations.

The harvesting and transport of sugarcane to a factory represents a significant proportion of the cost of processing cane and manufacturing sugar or related products, accounting for around one third of all on-farm costs (Hassuaniet al., 2005;Salassi and Barker, 2008; Dines et al., 2012). Reducing costs in harvesting and transport has been a significant driver of the NSW Sugar Milling business. Average harvesting costs across four regions in Australia (10 factories) in 2000 were reported to be $6.04 per ton (Higgins and Muchow, 2003), and $9.01 per ton in a central canegrowingregion in Brazil in 2010 (Oliveira and Balieiro, 2010). Harvesting costs in Louisiana, USA in 2006 were reported at $6.45 per ton (Salassi and Barker, 2008), while they were reported to be between $2.80 and $3.81 per ton in South Africa in 2000 (Meyer et al., 2000), while the cost at Sezela mill in South Africa in 2006 was reported as $4.47 per ton (Giles, 2006). Sugarcane transport costs were reported as $3.43 to traditional factories and $3.05 to new factories Brazil in 2011. In contrast, cane harvesting costs in NSW in 2006 were $5.63 per ton(Dines et al., 2012). They note that in its innovative adaptation of technology over the past 15 years, NSW Sugar Milling Cooperative has demonstrated how to simplify the use of resources and reduce capital investment, while reliably collecting and delivering cane to its factories in a ‘just in time’ operation.

Continuous innovation has substantially improved the efficiency of harvesting and transport operations in the NSW sugar industry. Increasingly automated systems, and improved communication and visualization technologies, mean fewer human resources are required to monitor real time operations. Mill staff can monitor operations from any location using mobile technology while real-time feedback to field operators enabled significant productivity improvements. Their harvest management systems are being increasingly centralised across the three factories the group operates, improving flexibility and providing management with access to strategic data in real-time, assisting them in improved decision making

A typical harvesting group in NSW operates one, sometimes two harvesters, and three or four six ton haul-outs to remove harvested cane from the field to a nearby trans-loading pad (Dines et al., 2012). Haul-outs were gradually being converted to carry 10 ton loads when their paper was published in 2012 and the following description of harvesting group activities is largely drawn from that source. The harvester driver is usually the group supervisor, and one of the haul-out drivers electronically consigns full bins at each trans-loading pad to the cane receivals information system using a touch screen installed in the tractor cab.

The harvester and haul-out drivers communicate by radio. Group haul-out drivers who do not have touch screens advise their colleague by radio as they fill bins and he then consigns them. Each consignment is identified by bin number and pad location, cane ownership and block information, as well as other attributes including whether it is green or burnt cane. All of this information is created and stored by simply entering the bin number. Other information connected to the bin and the property will have been pre-entered by the system, ensuring consignment data is accurate and simplifying the work of the haul-out drivers.

At the start of every day, farm numbers, block numbers, harvester group name, and pad identifications are recorded. This information is automatically attached to each bin as it is consigned. All harvesters are tracked using GPS which records and transmits the tracks of the harvester as they move up and down the cane fields. Integrated data loggers record machine productivity information and ensure accurate tracking of harvester operations when actually cutting cane. In addition to recording the identity of the block being harvested, the consignment form is automatically filled with other relevant farm information.

This arrangement is designed to transmit consignment information quickly to the cane receivals system, as it determines when a trip will be scheduled to pick-up filled bins.

Harvesting groups earn incentives when haul-out drivers fill each bin with between 21 and23 tons of cane, the target bin weight. Penalties apply to bins loaded below 20 tons and above 23 tons. No incentive is provided for bins filled between 20 and 21 tons of cane.

Trans-loading stations are located at optimum points throughout the cane growing areas and the average distance between a cane block and a trans-loading station is 800 meters (Prestwidge et al., 2006).

Bin weights and cane quality information including soil content is recorded when cane is received at the factory and reported back to each harvesting group within 30 minutes. Harvesting groups can therefore monitor their performance and modify their operations to maintain productivity and achieve target bin weights.

NSW Sugar replaced the older steel bins they used for cane transport with lighter aluminum bins in 2006 and 2007. These bins weigh 3.74 tons when empty and have a maximum carrying capacity of 90 m^3 of mechanically harvested cane. Each truck loaded with a single full bin of cane should ideally arrive at the factory weighing 43 tonnes. Like harvesters, prime movers are tracked using GPS/modem devices so that location, and waiting and loading and unloading times, can be continuously recorded.

Trips by the haulage trucks are allocated when a full bin of cane is consigned by the harvesting group. A delivery is allocated to the next available vehicle by providing a printed trip ticket to the truck driver at the mill weighbridge when the full bin is delivered. Across the factory group, the average trip distance from factory to the loading pad and back is 27 km.

Because each full bin of cane is consigned at the loading pad, the factory is aware of the number of full bins, their location, and amount of cane available, well before it arrives at the factory so deliveries can be matched to crushing capacity. With this system, high levels of harvester, prime-mover, and bin productivity minimize the need for capital investment and minimize operating costs.

6. What can China learn from the experience of other mechanized sugarcane industries?

The Chinese sugarcane industry has expanded rapidly in recent years and now faces the difficult challenge of mechanizing its operations. A mechanized cane farming, harvesting, and delivery system which is currently being introduced into China involves a combination of complex integrated production and logistics systems. The transition from manual cane growing and harvesting to mechanized farming and harvesting involves massive and difficult changes in farming practices, the utilization of labor, substitution of labor by machinery, and substantial capital investment by farmers, and the mills. It will require the development of a whole new sector in the industry, the harvesting sector, driven in China's case by significant innovation in harvester and cane transport design. Because of the industry's geographic location, the hilly topography of much of the cane growing area, and the small farm size, only about 10% of the area growing cane in China can be harvested by the large cane harvesters used in Australia, Brazil, and the United States so that innovative machinery will need to be developed to permit successful transition of a large part of the industry to mechanized production.

In Australia, when mechanized cane harvesting was introduced, cane growing was already highly mechanized. Only the harvesting remained as a labor-intensive operation and the earliest cane harvesters tried to duplicate the manual cutting process by harvesting wholestalk cane. Mechanical loaders were introduced to eliminate one of the most burdensome parts of the cane harvesting process. Manual cane cutting, by gangs of four to six men collectively harvesting 60 to 70 tons cane per day, facilitated relatively easy mechanization. In contrast, the work rate in China is only 1-1.5 tons per person per day so that a similarly sized group of people would together cut 6-9 tons of cane per day. This has several implications. The boost to productivity by replacing manual cutting by a machine will be relatively greater than it was in Australia, even if the machine cuts a relatively small tonnage per day, so the change-over should be attractive. However, the increased output from the machine will put much more pressure on the associated transport and milling infrastructure.

The output of the early model cane harvesters in Australia was superior to a gang of men, but other constraints such as reliability of the machines, poor in-field transport, and limited supply of cane bins by the mill, restricted their productivity and that is also likely to be the case in China. Now that cane harvesters are much more reliable in operation, and can deliver an output as high as 100 tons cane per hour, it is essential that the back-up infrastructure is able to handle such large volumes of cane. In Australia, an adequate number of haul-out units is necessary to deliver cane to the railway system without causing delays to the harvester. Likewise the supply of empty bins by the mill needs to be adequate and timely so that the harvester and associated haul-out equipment can continue to operate without interruption.

After chopped cane harvesters were introduced in Australia in 1957, and the major manufacturers limited the machines they offered to that design, the sugar mills were under much pressure to upgrade the transport infrastructure to match the increasing capacity of the harvesters. That meant substantially increased investment in the narrow-gauge rail system that most mills in Australia use to transport cane from the farms to the mill by extending the mill-owned tramlines and supplying many more railway wagons. The mills also needed to upgrade both front-end and back-end processing equipment in the factory. Facilities to handle and tip bins of chopped cane into the cane carrier were required and high capacity shredders to prepare the cane more intensively for crushing were installed. While this improved juice recovery, it usually involved a change from steam-driven to electrically driven shredders and crushing mills requiring an upgrade of the mill boilers and electricity generating capacity. Additional investment in clarification, crystallization, centrifugation and sugar handling capacity was also required. Some of this increased investment was needed to deal with the increased deterioration that occurs in chopped cane. Rarely did the mills undertake all of this expanded investment totally willingly. With the introduction of mechanized harvesting, the farmers were able to expand production more readily than the mills were willing to expand crushing capacity. The industry was highly regulated at that time with the area of assigned land, as well as farm and mill peaks for sugar production, were under the control of the Central Sugar Cane Prices Board. Each year, the Board issued "mill peaks" or the maximum quota of sugar that each mill could manufacture. These quotas were subsequently allocated among farms under the Local Board awards. Thus there was legislative control over farm and mill production and a certain incentive for mills to upgrade capacity or else miss out on increased sugar quota. Nevertheless, there were frequent challenges by the growers under the arbitration system that was set up by the legislation to ensure that mill crushing capacity matched their capacity to grow and harvest cane.

In the early 1960s, some mills introduced a rental payment system to supply bins for chopped cane to farmers with chopper harvesters but the Central Board over-ruled the practice, arguing that cane growers should not be required to contribute towards the capital cost of the bins or their maintenance as they remained the mill-owner's property (Briggs 2010). There was a lot of dissatisfaction by growers at the ability of sugar mills to supply bins for transport of chopped cane and in 1965 the Regulation of Sugar Cane Prices Act was amended to compel mills to accept mechanically harvested chopped cane and to supply sufficient cane bins or other containers to receive it. The Central Board then began hearing applications for cane bin supply, and in most instances, unless the sugar mill was severely hampered by lack of finance because of its commitments to mill upgrading, reached suitable arrangements to facilitate the increased supply of chopped cane.

Most other sugar industries around the world rely on trucks rather than a railway system to deliver cane to their mills but the need to put a reliable and efficient transport system in place still exists. The New South Wales section of the Australian sugar industry has developed the most efficient cane harvesting and transport system in Australia based on a limited number of harvesters that are worked to maximum capacity and road transport using special high-capacity bins for the cane.

While the problems associated with the introduction of mechanized sugarcane harvesting are similar, these arrangements used in Australia where the industry was strongly controlled by government for most of its existence, may have little relevance for a country like China where mechanical harvesting is being introduced much later in time. Nevertheless, the changes to be introduced will have a profound impact on the industry, although the benefits of change are mainly in the long term. In the presumed absence of government direction, the industry needs to adopt a strongly cooperative attitude to overcome the apparent conflicts between the interests of growers and the objectives of mills, to achieve a mutually beneficial outcome for the industry.

The introduction of chopped cane harvesters into the Australian industry brought two significant problems that other industries ought to consider seriously before making the change. These were juice and cane losses in the harvesting process by which a high proportion of the cane grown by the farmer is thrown away by the harvester and never gets to the sugar mill. The other significant source of loss is due to cane deterioration which is much more rapid in chopped cane.

The transition from manual to mechanized cane harvesting in Australia meant that a gang of manual cane cutters was usually replaced by a machine. In the early days of mechanized harvesting, farms were small, machine output was low, their capital cost was not prohibitive to the individual farmer, the industry was quite affluent, there were tax incentives to encourage machinery ownership by farmers, and the cost of harvesting by machine was lower than hand harvesting so that it was natural for many farmers to own their own machine and harvest their own cane. Rather quickly it became obvious that individual farms could not justify ownership of a harvester just to cut their own cane and many farmers with harvesters became involved in harvesting cane on neighboring farms. This arrangement was encouraged by mills which began to roster the harvesters that were available to harvest cane on small groups of farms and to control harvesting to establish equity among farms in the amount of cane that was cut and delivered in each part of the season. The substantial cost of a modern harvester, the associated haul-out equipment, and workshop facilities has encouraged a significant number of pure harvesting contractors to become established in the Australian industry. Unlike Brazil where sugar mills own their own large farms, and the United States where the mills do the harvesting, mills in Australia have not become involved in cane harvesting but this might be a viable option for China to consider.

A cane payment system that encourages cane growers to grow cane with higher sucrose content and for mills to increase milling efficiency will benefit the whole industry. However, that requires the ability to assess and evaluate each individual farmer's cane which would be impossible with the small deliveries from most current Chinese farmers. However, some form of farm amalgamation will be needed to enable cane harvesters to work efficiently but we recognize that there will be all manner of constraints and restrictions to bringing that about.

Managing the transition from small scale farming to mechanized cane growing and mechanized harvesting is going to be a big challenge in China. Most of the industries that have made this change and which could serve as examples for China are very different to the Chinese situation so the management systems, and the physical machines they use, could have limited scope for adoption in China. However, there seem to be some basic concepts that should underlie the plan for this transition in China.

Because the physical nature of the sugar industry in China is so different, a research and innovation project in cane growing and harvesting systems led by the South China Agricultural University research group is being conducted. The purpose of the project is to develop appropriate machinery and suitable systems for the unique situation that exists in China. Six sub-projects are being conducted in Zhanjiang, Guangdong, as well as Guangxi and Yunnan provinces. There are six different machinery and operating systems being developed.

The ways in which mechanized cane harvesting services can be introduced economically into the Chinese sugar industry needs to be further investigated. It would seem appropriate for the mills in China to own and operate a fleet of cane harvesters as they do in Brazil but the mills are now reluctant to make that investment, and more effort is required to encourage them to change their attitudes. Another way is to finance contractors into the industry and organize farmers into sufficiently large groups to facilitate efficient harvesting of their small farms. Perhaps leads from other industries such as corn, grains, and rice where mechanized harvesting is already much more widely established in China than in sugarcane would provide useful examples or how to introduce machines.

In industries where contract harvesting services are widespread, contractors get paid for the services they provide, ideally by a charge based on the ownership and operating costs for the machines they use but their ability to achieve full cost recovery depends on the market for harvesting services, which initially at least includes both manual and machine harvesting. In Australia's case, there has traditionally been an over-supply of harvester capacity, thus forcing contractors to accept a $ per tonne payment that did not cover all of their machine ownership and operating costs. Contractors need to receive a full cost recovery price for contracting services if they are to maintain and replace their machines at the appropriate time.

Perhaps China could do something innovative that no other sugar industry has done and give contractors a share of industry revenue in the same way as the proceeds are divided between growers and millers. These shares are usually based on capital contribution, or proportion of total industry costs, contributed by growers and millers. However, such an approach would mean that harvester operators would share the cost of unprofitable times in the industry just as growers and millers now do.

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