THE ECONOMIC FEASIBILITY OF PRODUCING ETHANOL FROM SUGAR-CANE IN SOUTH AFRICA

BY

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Submitted in partial fulfilment of the

requirements for the degree

DOCTOR OF PHILOSOPHY

in the

Department of Agricultural Economics
University of Natal
Pietermaritzburg

March 1985

I hereby certify that, unless specifically indicated to the contrary in the text, this dissertation is the result of my own original work.

G.F. Ortmann

To

Erika, Frank and Liesel

ABSTRACT

The study is an evaluation of the economic feasibility of producing ethanol from sugar-cane in South Africa. With the depressed state of the sugar market and recent substantial increase (40% in January 1985) of liquid fuel prices in South Africa, the study is of a topical nature. A regional linear programming model is used which simulates current production patterns in 22 areas of the South African Sugar Industry. The model incorporates demand functions for crops, substitution in demand between crops, supply functions for labour and variance-covariance matrices to account for risk in production. The model is used to evaluate the effects of alternative sugar policies, namely a pool scheme and a free market for sugar, with particular emphasis on ethanol production.

Results show that the total ethanol cost (including opportunity cost) per litre in an industry producing one billion litres a year was over twice the refinery-gate or pre-tax petrol price around 1979/80 but similar to the pump price of petrol. More recently (1985) petrol prices have increased relative to ethanol costs due to the weakening of the rand against other major currencies. Ethanol costs are now (1985) about 25% above the refinery-gate petrol price and below the pump price of petrol. SASOL's petrol costs at present appear to be similar to fuel costs based on crude oil and below ethanol costs (from sugar). For new SASOLs the capital cost is expected to increase substantially due to the relatively weak rand. This may make ethanol production from sugar-cane more competitive.

A strong positive correlation is evident between sugar-cane production and labour employment. With a subsidized billion-litre ethanol industry labour employment is estimated to increase by 45 000 (34%) under a pool scheme and by 25 000 (19%) under a free edible sugar market compared with current employment. Development costs per worker are estimated to be

about R30 000 compared with over one million rand per worker for a new SASOL plant.

In a free market the area under sugar-cane is estimated to decrease by about 50% and labour employment by 26%. Areas moving out of cane production include Pongola, Hluhluwe, Nkwaleni Valley, Tala Valley, Umfolozi Flats, Zululand hinterland, South Coast, Natal Midlands (North and South). No sugar would be exported. The local equilibrium sucrose price is estimated to be about 9% below the producers' price under the current policy (that is, up to and including the 1984/85 season) and 17% below the A - pool producers' price under the pool scheme. Social costs of the current policy are estimated as 6.8% of total sucrose value compared with 4.7% under a pool scheme with A - pool quotas transferable only within Mill Group areas and 2.3% where A - pool quotas are transferable between regions. Ethanol production would add to social costs.

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to my supervisor, Professor W.L. Nieuwoudt, for his expert guidance during the course of this study. I am also grateful to Professor H.I. Behrmann for his comments on an earlier draft and to my colleague Mr. M.C. Lyne for many hours of fruitful discussion on various aspects of this work.

My sincere thanks are also extended to members of the South African Sugar Association, to Mr. E.J. Buchanan, Mr N.H. Frean and other members of the South African Cane Growers' Association for providing me with data.

A special thanks is extended to Mr. J. de Villiers of Adminkor, Malelane, for data and his willingness at all times to discuss various aspects of farming particularly in the Eastern Transvaal. Appreciation is also expressed to all farmers and farming companies who provided data.

I also wish to thank the members of the Computer Services Division of the University of Natal for their guidance, and in particular Mrs. E. Price for writing the programmes for calculating demand and supply functions. My thanks to Miss N. Vojkovich for typing the dissertation and to Mrs. R. Reed for her assistance.

A very special thanks goes to my wife, Erika, for her patience and support during the course of my studies.

Above all, I am grateful to my Creator.

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INTRODUCTION

Sugar prices on the world market have been depressed for a number of years. This is mainly due to protectionist policies in producer countries which keep domestic prices high thereby discouraging consumption and increasing production. Surplusses are dumped on the world market which is considered a residual one and is sensitive to changing demand and supply of sugar. High domestic sugar prices in certain countries have also led to increased consumption of alternative sweeteners such as High Fructose Corn Syrup (HFCS). For example, in the USA HFCS is expected to account for about 25% of the sweetener market in the future (Carman, p. 626). This may lead to an irreversible backward shift in the demand for cane and beet sugar. Under the above circumstances low world sugar prices may be a longer-term feature of the sugar market.

The depressed state of the export market is considered a major cause of the South African Sugar Industry's current financial problems (Nourse, 1983, p.11). The Industry currently (February 1985) owes R327 million (Hudson) and intends introducing a pool scheme in the 1985/86 season with the view of introducing more flexibility in the marketing of sugar.

The low world market sugar prices coincide with a depressed world crude oil market. Oil prices increased by over 300% in real terms during the period 1972 to 1980 (OECD, p.160). In South Africa the depreciation of the rand against other major currencies, and in particular against the U.S. dollar with which crude oil is traded, prompted the government to increase liquid fuel prices by over 40% in January 1985, despite the depressed oil market. South Africa is also faced with the threat of trade boycotts, which may include oil. Although the fuel-from-coal projects (SASOL) in South Africa are estimated to supply over 40% of the country's liquid fuel needs, Dutkiewicz (1983, p. 25) has termed transport fuels the "Achilles heel" of South Africa. With the depressed sugar market, the depreciating rand (which will also affect new SASOLs) and South Africa's fuel security position the economic viability of producing ethanol from sugar-cane needs consideration. The policy issue is whether ethanol production would be cheaper than extracting liquid fuel from coal.

The major objective of this dissertation is to study the potential, economic viability and effects of an ethanol-from-sugar industry in South Africa. The Sugar Industry, including potential sugar-cane expansion areas, is divided into 22 relatively homogeneous regions. Sugar-cane production costs in white farming areas, which comprise 16 homogeneous regions, were based on data received from a total of over 1 700 farmers over four years. A regional linear programme is built which simulates current cropping patterns in the 22 regions. To facilitate simulation negative sloping demand functions for various crops, substitution in demand between crops, positive sloping supply functions for labour and variance-covariance matrices to account for risk in production are incorporated into the model. This model is used to evaluate a multiple pool scheme and a free market for sugar. The analysis is extended to examine the economics and impacts of various levels of ethanol production under these two policies on resource use and enterprise mix in various regions of the Industry. Effects of unsubsidized water tariffs are also evaluated. Social costs of the current sugar policy (that is, the policy up to and including the 1984/85 season), the proposed pool scheme and of ethanol production will be estimated from model results.

The outline of the dissertation is as follows: Chapter 1 is an overview of the world energy balance with particular reference to the major fossil fuels, namely crude oil and coal. This is followed by a brief review of the effects of oil prices on the economy of countries and on agriculture. Some policy aspects of energy are discussed towards the end of Chapter 1.

The potential of using various renewable energy sources is studied in Chapter 2. The emphasis is on the use of biomass since the major concern lies with liquid fuels. Sugar-cane appears to have the greatest potential of all agricultural crops in South Africa. With sugar-cane taken as the major subject of study the structure, performance and problems of the South African Sugar Industry are discussed in Chapter 3.

Chapters 4 and 5 outline the development of the sugar-cane model with the simulation results discussed towards the end of Chapter 5. Alternative sugar policies, namely a multiple pool scheme and a free market for sugar, are evaluated in Chapter 6 with particular emphasis on ethanol production. Effects of unsubsidized water tariffs are also studied. Social costs of the current policy, the pool scheme and ethanol production are estimated and evaluated.

CHAPTER 1

THE WORLD ENERGY BALANCE

1.1 INTRODUCTION

The two major oil crises in 1973/74 and 1978/79 resulted in economic upheaval in both industrialized and developing countries. These events exposed their dependence on fossil energy and in particular crude oil. Although the price of crude oil has decreased in real and nominal terms (U.S. dollars) since the last crisis, prices of petroleum products in South Africa were increased in January 1985 by over 40% because of the rand's unfavourable exchange rate with the U.S. dollar. The reaction of society to this increase was similar to that shown in the 1970's. This chapter will review briefly the demand and supply of energy sources in the world and the effects of petroleum price increases on the economies of countries and on agriculture.

1.2 WORLD PRIMARY ENERGY CONSUMPTION

In the 100 years from 1875 to 1975 the world population more than tripled from 1.2 to 3.97 billion while primary energy consumption increased from 250 million to 7 877 million tonnes of coal equivalent (tce) per annum, a factor of 32 (Grathwohl, pp. 17-19). Increases in energy consumption are determined by various factors, the most important being population growth, economic development, increased mechanization and the pursuit of higher standards of living (Department of Planning and the Environment, 1978, p.10). In 1976, for example, the industrialized areas of North America, Western Europe and Japan accounted for 57% of world primary energy consumption whilst contributing only 18% of the world population (Grathwohl, p.19). In the same year primary energy consumption per capita in North America was 11 395kg of coal equivalent (kgce) and in Africa 397 kgce which was the lowest for all continents. In contrast South Africa's per capita consumption was 2 985 kgce (op. cit., pp. 24-25).

1.2.1 Consumption of energy by various sectors in South Africa

The Department of Planning and the Environment (1977) distinguished between net energy and useful energy. Net energy "refers to the inputs of energy ... to the final consumption sectors". Useful energy "takes the losses of energy at the point of consumption into consideration, and is thus derived from net energy through the application of the necessary efficiency factors" (p.6). Table 1.1 summarizes the proportions of net energy and useful energy in various sectors of the South African economy.

Table 1.1 : Proportion of energy consumption by various sectors in South Africa, 1974 (percentage).

	Proportion of	
Sector	net energy	useful energy
Industrial and Commercial	47	62
Household and Agricultural	16	14
Transport	29	13
Mining	8	11
Total	100	100

Source : Department of Planning and the Environment, 1977, pp.7,19,28,40.

Of the household and agricultural sector, agriculture consumes about 20% of the net energy and 10% of the useful energy. Agriculture, therefore, consumes only about 3% to 4% of the total net energy and about 1.5% of the total useful energy in South Africa. However, most of this consumption consists of light diesel fuels used for tractors and transport. In 1974 agriculture was responsible for about 10% of the net petroleum energy consumption in South Africa and the transport sector 68%. By the year 2000 agriculture's share is expected to fall to 8% while the transport sector will account for 82% (Bruwer, pp.9-10).

According to Bruwer (p.11) agriculture in South Africa uses about one quarter of the total diesel consumption. About 300 000 tractors, 10 000 combines and 200 000 other engines are employed.

1.2.2 Primary energy consumption and gross domestic product (GDP)

A close correlation appears to exist in a country between its energy consumption and its degree of economic activity as measured by its gross national product (GNP) or its GDP. Analysis of the USA, West Germany and South Africa show strong linear relationships (Grathwohl, pp.23,26 ; Department of Planning and the Environment, 1977, pp.89-91). As Grathwohl (p.23) pointed out the above relationship is not a rigid one but can be modified by technological progress, especially by improved energy conservation technologies and more efficient utilization through lower conversion losses.

Loftness (p.6) maintained that the correlation between GNP and the level of energy consumption is somewhat ambiguous, at least at high levels of energy consumption. He cites the example of New Zealand which has half the per capita energy consumption of the United Kingdom but has a higher GNP per capita. There are many countries where the energy consumption/GNP ratio is relatively low but where the standard of living is considered to be high. These differences may be due to the nature of the economy (rural or industrial), social values that emphasize low energy intensive economic activities or the lopsided distribution of income between the rich and the poor. However, Loftness does recognize that the use of energy has raised the average standard of living in countries where such energy has been available, but maintains that the relationship between energy consumption and GNP needs further clarification.

A useful indicator of the productiveness of energy utilization in a particular country is the energy consumption per rand of the GDP or the energy intensity ratio. South Africa consumes a larger quantity of energy per dollar of its GDP than some industrialized countries. For example, in 1974 this ratio was 45% higher than for the USA (Department of Planning and the Environment, 1978, p. 15). The energy intensity ratio is determined by a variety of factors such as the ratio of primary to secondary industries, the ratio of industrial to agricultural activities, the extent and nature of mining activities and the cost of energy (op. cit., p.16). However, this ratio is still regarded as a useful indicator of the productivity of energy in a certain country. In this light South Africa does not compare favourably with the major industrialized countries. This may be due to the fact that in a developing country GDP is underrated as not all services are done through the market and are, therefore, not reflected in the GDP (Nieuwoudt, 1985).

The energy-GDP elasticity coefficient is used to measure the increase in energy consumption which accompanies economic growth. This coefficient is defined as the percentage change in primary consumption divided by the percentage change in GDP over a certain period. Generally, highly industrialized countries have coefficients less than unity, mainly due to relatively more efficient use of technologies in the conversion and use of energy. However, a developed country may have a coefficient greater than unity temporarily due to fundamental changes in its economic activity or energy base. In South Africa the lowest coefficient over the last 20 years was 0.75 for the period 1964 to 1969, and the highest 1.22 for the period 1971 to 1976 (Department of Planning and the Environment, 1978, p.17). For the OECD (Organization of Economic Cooperation and Development) countries the elasticity coefficient for the period 1974 to 1985 is estimated to be 0.8 (Grathwohl, pp. 23,26). A decreasing coefficient over time reflects increased efficiency in the use of energy.

1.3 THE WORLD ENERGY TRADE WITH PARTICULAR REFERENCE TO OIL AND COAL

Of the world's proved recoverable reserves of fossil fuels in 1980 coal constituted the major portion, namely 66.4%. Crude oil only accounted for 12.3%, natural gas 9.4% and oil sands and shales 11.9% (Grathwohl, p.69). It can, therefore, be expected that coal will play an increasingly dominant role in the international energy trade in the future. Estimates of recoverable reserves are subject to constant revision as a result of improved technologies in the extraction and utilization of fossil energy sources, changing real price and cost structures and general economic conditions.

1.3.1 Crude Oil

The major producers of crude oil are the USSR, Saudi Arabia and the USA. In 1980, for example, crude oil production in these countries was 603 million tonnes, 493 million tonnes and 484 million tonnes, respectively. The fourth largest producer was Iraq with 130 million tonnes (Grathwohl, p.31). The major industrialized countries of the world situated in North America, Europe and the Far East (Japan) are net importers of petroleum, the major sources being the Middle East and Africa.

In 1980 the world's proved recoverable reserves of petroleum were estimated at 88 352 million tonnes. With world oil production in that year of 3 066 million tonnes the static lifetime (reserves/production ratio) is about 29 years. However, the lifetime varies widely among countries. For example, the lifetime of proved recoverable reserves in the USA is half that of the USSR, while reserves in Middle East countries have the longest lifetimes (op. cit., p.102). Because of the uneven geographical distribution of oil reserves international trade in crude oil has significant implications for world economic politics. Developing countries are expected to produce about 60% of the world's petroleum in the future and OECD countries less than 20%. Crude oil production is expected to reach its peak between 1985 and 1995 and then decline (op. cit., p.49).

On the positive side, indications are that many new deposits of heavy crude oil will be discovered. Some geochemists believe that heavy crude oil (which is highly viscous and has to be mined or made artificially more liquid to facilitate pumping) exists in practically every sedimentary basin in the world (The Economist, p.63). The use of heavy crude oil is considered more economic than the use of tar sands, shale oil, oil from coal or alcohol from biomass.

In South Africa, the Southern Oil Exploration Corporation (SOEKOR) by 1982 had drilled 73 holes offshore in 18 years at a total cost of R353 million. Onshore drilling, which cost R77 million, has been discarded in favour of the more promising offshore prospects. SOEKOR estimated that for an oil field with recoverable reserves of only 100 million barrels, and estimated capital costs of R600 to R900 million, the payback period would be between 2.0 and 3.1 years with internal rates of return of between 22% and 36% (Financial Mail, 1983, p.36). The capital cost of R6 to R9 per barrel reserve oil compares favourably with the $7 to $11 for the North Sea. Should economic quantities be found it would take about five years for commercial production to be attained.

1.3.2 Coal

Coal forms by far the major portion of total fossil energy reserves and is expected to play an increasingly important role in world energy utilization in the future. The three major producers, China, USA and USSR, accounted for two-thirds of world production in 1979. South Africa's production of 96 million tonnes in 1979 was 3.4% of the world's production in that year (Grathwohl, p.82).

World coal reserves are geographically more evenly distributed than oil reserves. This will have implications for future choice of the primary energy source for many countries, particularly those who had negative experiences during the oil crises. Also, the lifetimes of the proved recoverable reserves of coal are much longer than for crude oil, namely 190 years on average in 1979 (op. cit., pp. 80, 83).

South Africa is fortunate in having large recoverable reserves of coal. However, the quality of South African coal is poor by world standards. For example, only 2% of South Africa's coal compares with "standard coal" overseas (Department of Planning and the Environment, 1977, p.99). This is a disadvantage from an export point of view. Locally, coal accounts for 80% of primary energy needs and imported oil 19% (Financial Mail, 1983, p.5). Of the coal mined 45% is used for electricity generation (ESCOM) and 15% for SASOL and chemicals. Of the world's coal production 60% is used to generate electricity.

Major users of coal in South Africa by the year 2000 will be ESCOM and SASOL, with expected average annual growth rates of 6.6% and 6.9%, respectively, during the period 1981 to 2000. Exports are expected to reach 80 million tonnes by 1995, a growth rate of 7.3% per year. With estimates of recoverable reserves being adjusted regularly, coal exports may reach 100 million tonnes by the end of the century (Financial Mail, 1983, p.15).

Coal will remain South Africa's major source of energy for many decades. Vast reserves will make this country one of the few industrialized countries of the world with a net surplus of energy.

However, the problem involves liquid fuels. According to Dutkiewicz, South Africa will consume 17 billion litres of petroleum products by 1990, and 26 billion litres by the year 2000 (op. cit., p.34). In order to become more self-sufficient in liquid fuels South Africa has embarked on large scale conversion of coal into liquid fuels and has become a world leader in this field. SASOL 1 came into operation in 1955, using a variation of the Fischer-Tropsch process. SASOL 2 started production in October 1980 and SASOL 3 in May 1982 (op. cit., pp.32-33). The SASOL plants together will provide more than 40% of the domestic consumption of liquid fuels. It has been estimated that if South Africa would want to increase its liquid fuel self-sufficiency to 50% by the end of the century it would probably need four more SASOL 2-type plants (op. cit., p. 34). With SASOL 2 originally costing R2.5 billion the capital investments would be substantial. A problem with SASOL is that it tends to worsen the present imbalance between diesel and petrol because of higher petrol yields (Scott, 1983, p.63).

1.3.3 Natural gas

About 20% of world primary energy is derived from natural gas (Financial Mail, 1983, p.5). At present natural gas is not exploited in South Africa. However, recently SOEKOR has proved more than 30 billion m^3 of natural gas off the Mossel Bay coast. Studies are now being conducted to determine the feasibility of converting this reserve into liquid fuels. If proved viable the plant could provide over 10% of South Africa's liquid fuel needs for about 20 years (Financial Mail, 1985e, p. 31). The USSR had the largest proved recoverable reserves of natural gas on January 1, 1979 (30%), followed by Iran (19%) and the USA (7.5%) (Grathwohl, p.118). The predicted lifespan of natural gas is longer than that of crude oil (op. cit., pp. 119-20).

1.3.4 Uranium

With nuclear energy expected to contribute an increasing share of total primary energy consumption in the future, the question of uranium production and reserves becomes important. In 1980 nuclear energy accounted for over 3% of total energy consumption in the West (Financial Mail, 1983, p.25).

South Africa is the third largest producer of uranium (after the USA and Canada) with over 7 000 tonnes in 1982. Virtually all of its production is a by-product of gold mining and, therefore, relatively cheap to produce. Total world uranium production was about 41 000 tonnes in 1980. Reserves of uranium are expected to last at least 100 years (op. cit., p.25).

Over the medium term South Africa will be in a position to export most of its uranium production since inland consumption will be relatively small. Koeberg, for example, will consume 120 tonnes per year (op. cit., p. 28). It has been estimated that only about 2% of the total potential energy content of the country's reserves can be utilized in thermal nuclear power reactors. Fast breeder reactors, which are expected to be used commercially towards the end of the century, can utilize 60% to 70% of the total energy content (Department of Planning and the Environment, 1975, p.114). Use of these reactors will extend the life of a country's uranium reserves.

1.4 EFFECTS OF PETROLEUM PRICE INCREASES

The effects of petroleum price increases on economies and in particular agriculture have been demonstrated by the two oil crises in the 1970's and by research studies undertaken to simulate these effects. These effects are of particular interest to South Africa because of the recent sharp increase in petroleum prices.

1.4.1 Economic effects

It has been estimated that the quadrupling of the oil price in 1973/74 (from $3.011 per barrel on October 1, 1973 to $11,651 per barrel on January 1, 1974 (Department of Planning and the Environment, 1977, p.81)) and the more than doubling of the oil price between the end of 1978 and early 1980 "represented a shock to the OECD economies equivalent to roughly 2 percent of GNP on each occasion" (OECD, p.114). The real price of imported crude oil rose by over 300% between 1972 and the middle of 1980 (op. cit., p.116). However, the final price of oil products in OECD countries did not rise to the same extent because fuel taxes were reduced. In the USA, for example, taxes as a fraction of the final gasoline price fell from 31% to 15% and in Canada from 45% to 32% (op. cit., p.117). The demand response to higher crude oil prices was, therefore, less marked than expected in OECD countries. However, the oil crises led to substantial savings in energy in relation to GNP in these countries. In addition to the reaction of users to higher prices, governments encouraged conservation of energy and research into alternative sources of energy (op. cit., p.119).

It is noteworthy that in South Africa the real price of final oil products increased by 284% between 1972 and 1980 (Agricultural Economic Trends Division, pp. 103, 108). This price increase virtually kept pace with the real crude oil price increase of 300%. This implies that taxes as a proportion of the final price remained virtually constant but increased in absolute terms. The higher taxes were possibly used to finance the SASOL 2 and SASOL 3 projects.

The supply of and demand for oil have been estimated to be relatively price inelastic in the short run. An increase in demand or a decrease in supply will, therefore, substantially increase prices of crude oil (OECD, pp. 119-20). Stoeckel (p. 73) expects the influence of political disruptions to be of a short-term nature only and he sees economic factors to be important determinants of long run oil prices. In the long run demand for crude oil is probably elastic due to substitution possibilities.

Any increases in oil prices have important implications for rates of inflation and income levels (op. cit., p. 70). For example, the 1973/74 oil price increase was a major contributor to the 1974/75 recession in OECD countries, the worst in the post-war period. Inflation increased from single figures to 15% in the first half of 1974, while unemployment rose to record post-war levels. The main effect of the second oil crisis was on inflation and current account balances. Both oil crises resulted in substantial terms of trade deterioration for oil importing countries (OECD, pp. 121-22). In South Africa the recent (January 1985) increase in liquid fuel prices by over 40% raised fears that the inflation rate would increase by about 2% to over 15% per annum. Some estimates put the inflation rate at 20% by the end of 1985 (for example, Financial Mail, 1985a, p. 40; 1985c, p.77). A high inflation rate in South Africa relative to its main trading partners erodes the comparative advantage that the country might have in the production of certain commodities.

Impacts of inflation on the agricultural sector have been well documented (for example, Brandow, Freebairn, Lins and Duncan, Robinson (1979), Ruttan (1979), Tweeten and Quance). Lins and Duncan noted that " the problem of inflation is not so much price increases, but rather the inefficiencies and inequities that result from inflation - induced changes in relative prices" (p.1049). Freebairn argued that in the longer run inflation will have very small, if any, effects on relative prices or real incomes. However, in the short-run, which may be several years, some prices may rise more slowly than others and cause income losses. Brandow maintained that cost-push inflation will be more detrimental to agriculture than demand-pull inflation. The latter type may be advantageous to farmers since product prices may rise faster than input prices leading to increases in real net farm incomes. Energy-stimulated inflation, leading to cost-push inflation (Carter and Youde, p.879), thus has more serious ramifications for agriculture. In general, farmers' terms of trade deteriorate in periods of cost-push inflation.

1.4.2 Effects on agriculture

Numerous research projects were undertaken after the sharp increases in petroleum prices in the 1970's to ascertain the effects of these price increases and the possible rationing of petroleum supplies on agriculture. Dvoskin and Heady reported a great difference in effects between an energy reduction policy and a high energy price policy. For example, a 10% energy reduction to agriculture led to a greater increase in food costs than a doubling of energy prices. This is explained by a low price elasticity of demand. Whittlesey and Lee concluded that a doubling of the petroleum price would increase food costs by about 2%. As regards resource use the greatest effects of changes in energy prices and supplies were on irrigation and commercial nitrogen purchases (Dvoskin and Heady). Penn et al reported that with a reduction in USA crude petroleum imports of one million barrels per day (or 65% of the 1967 level of imports), gross output in agriculture in the short term would decrease by less than 3% (p. 667). For Washington agriculture Lee reported that with a 50% increase in prices of petroleum products and natural gas income reduction would be less than 3%.

Debertin and Pagoulatos concluded that increases in real prices of liquid fuels in the southern states of the USA would lead to increased emphasis on livestock activities that make maximum use of available forages, increased production of high-value labour-intensive crops and increased cost pressure on marginal farms. Hite pointed out that on-farm adjustments to higher liquid fuel prices also depend an adjustments in the agricultural sector generally and in the total economy. Model results by Adams et al indicated that the effects of increased energy costs were to increase the production of field crops and to decrease vegetable production in California. Restrictions on fuel and nitrogen fertilizer had different effects on production when taken in the aggregate from those under the reduction of one input in isolation. However, such effects were partly dependent on the availability of substitute inputs such as land and water. Miranowski reported that the typical Iowa farm is insensitive to moderate increases in energy prices because direct energy costs account for less than 8% of total production costs. However, for more substantial increases in energy prices more significant changes in the activity mix will occurr. Christensen and Heady (1983) found that as petroleum prices rise farmers slowed their upward trend in the usage of energy-intensive inputs such as fertilizer, pesticide and irrigation. With the slightly reduced yields the cumulative effect was a decrease in total crop supply in the USA and a price increase over time (with price inelastic demand).

The effects of rising energy prices on irrigation have been researched by, among others, Kelly, Lacewell et al, Mapp and Dobbins. Methods to reduce energy required to pump water for irrigation have also been investigated (for example, Gilley and Watts, Kizer et al). Generally, the effects of rising energy prices are a reduction in net returns associated with irrigated crops and a shift to dryland production. Bhide et al reported that shadow prices decreased for irrigated land but increased for dryland. Land substitutes for inputs such as fertilizer and water.

The effects of changing energy prices on the use of various tillage systems have been widely researched (for example, Burton and Kline, German et al, Griffith et al, Moriak, Rask and Forster). Griffith et al, for example, recorded substantial savings in diesel fuel under reduced-tillage systems. Burton and Kline concluded that zero-tillage systems require less fuel per unit area but require more energy inputs in the form of nitrogen fertilizer and pesticides. Moriak maintained that in the longer run "the feasibility of shifting to minimum tillage as an energy conservation measure is limited because reduced fuel costs frequently are offset by increased use of herbicides, which depend on fossil fuels, and amplified environmental problems" (p.820).

Carter and Youde maintained that major long-term adjustment problems for agriculture will result not from direct price increases of energy-based inputs such as fuel, fertilizer or chemicals, but indirectly from the impact of energy prices on general price levels and economic growth rates (p.878). Since energy prices affect economic growth rates, inflation and income distribution both domestic and export demands for agricultural commodities are affected.

In conclusion, this section has dealt with some research results on the impacts of increased energy prices and reduced energy supplies on agriculture and the food sector. Increases in direct fuel costs alone appear to have negligible effects on agriculture, except for drastic price increases. However, as fuel price increases effect prices of other inputs, such as fertilizer and herbicides, overall impacts on agriculture are more severe, particularly for irrigation farmers. Farmers will, however, adjust their resource use according to relative prices. Effects of reduced liquid fuel supplies are in general more disruptive than fuel price increases.

1.5 SOME POLICY ASPECTS OF ENERGY

1.5.1 Energy analysis

Sharp rises in petroleum prices have induced some people to regard energy as the important criterion on which policy decisions should be based (for example, Odum, Slesser, Gilliland). Proponents of net energy analysis as a basic tool in policy decision-making have criticized traditional economic analysis as not having achieved precise results and Gilliland has claimed that one of the major advantages of this approach is that the resulting energy evaluation will not change with time or factors that usually affect traditional economic analysis (p. 1056).

Pasour and Bullock, Hill and Erickson and Huettner, among others, have criticized the use of energy analysis in decision-making. Huettner saw this approach as "a marked departure from economic theory" (p. 101) and as an energy theory of value (p. 103). Kilocalories would replace monetary units as the common unit of measurement and as method of valuing inputs and outputs. Huettner argued that such a system would be unworkable. "Markets would not clear; investment, resource allocation, and other decisions would be distorted; and real income would be suboptimized and improperly distributed since prices determined by energy content alone were not designed to accomplish these objectives" (p. 103).

Pasour and Bullock and Hill and Erickson also argued that many energy analyses have overlooked economic principles. For example, Pimental et al have shown that the high agricultural productivity in the USA has been achieved through increasingly large inputs of fossil energy. They maintained that U.S. agriculture is an inefficient user of energy according to energy input-output ratios over time. Perelman (1973) came to the same conclusion and reported,"... the fact remains that agriculture appears to be a net energy drain ... If the world is facing a future with rising energy prices, the highly mechanized technology currently used in the U.S. may be inappropriate" (p.525).

The fact is that producers at both micro and macro levels adjust their input or product mix according to relative prices. In developed countries substitution of commercial fertilizers and fossil fuels for land and labour in agricultural production have been a response to the rate of return per monetary unit invested in each of these resources (Hill and Erickson, p.2). Ruttan (1975), for example, concluded that the data used by Pimental et al indicate, if anything, that U.S. maize farmers are using less energy than the optimum amount (p.560). Should relative prices of energy or other inputs change then producers will adjust their pattern of resource use.

Other critiques of energy analysis worth reading include the views of Connor, Edwards (1976), Langham and McPherson, Peskin, and Ruttan (1975). In general conflict exists among economists, ecologists and engineers regarding energy accounting and economic analysis. Ulph, in a survey and critique of world energy models, argued that many studies, some of which have been influential in energy policy making, have not paid sufficient attention to economic factors and to the needs of the policy maker.

1.5.2 Substitution of inputs for energy

Debertin and Pagoulatos examined the potential for substituting other inputs for liquid fuels in agricultural production. Elasticities of substitution between liquid fuels and other energy sources and between energy and other inputs such as capital and labour will determine the extent to which agriculture and the rest of society are able to adapt to increases in real energy prices. These elasticities provide an indication of the change in energy use as prices change. If the elasticity of substitution approaches infinity substitution between, say, energy and capital should be relatively easy. If the elasticity is zero then regardless of the real price of energy there is no opportunity for trade-offs between energy and non-energy inputs. The effect of energy price increases may be to reduce total agricultural output possibly through the removal of inefficient farms. An alternative impact would be major increases in food prices, assuming a highly inelastic demand for food.

In practice increases in real energy prices affect the combination of energy and non-energy inputs used in production. For example, farmers may purchase more fuel-efficient tractors or spend more time and money to tune engines. Debertin and Pagoulatos expect the elasticity of substitution between energy and non-energy inputs to be greater than zero but much less than one.

Several studies have been conducted in the USA to calculate the elasticity of substitution between capital and energy. For example, Berndt and Christensen as well as Hudson and Jorgenson came to the conclusion that energy is a substitute for labour but a complement to capital in production. Griffin and Gregory estimated the elasticity of substitution between labour and energy to be 1.07 for the USA. (Studies for eight European countries showed slightly lower estimates than for the USA.) In contrast to earlier studies, Griffin and Gregory concluded that capital and energy substitute each other. If these estimates are correct then "they suggest more potential for substitution between capital and energy than had previously been suspected" (Debertin and Pagoulatos, p.49).

According to Debertin and Pagoulatos the major difficulty faced by economists when attempting to ascertain whether energy and capital are gross substitutes or complements is that every capital item is unique (pp.49-50). Webb and Duncan, as reported by Debertin and Pagoulatos (p.50), found that land and labour can be relatively easily substituted for mechanical and chemical energy. Lopez reported that with higher energy prices energy demand from agriculture decreases if land and energy are substitute inputs. His analysis suggested that land rental prices decrease in the long-run as a result of higher energy prices.

Debertin and Pagoulatos studied the relationship between the price of farm tractors and their liquid fuel efficiency. They reasoned that if "capital substitutes for liquid fuel, it should be possible to purchase tractors that are more energy efficient by paying a higher price, _ceteris paribus_" (p.51). However, the multiple regression equation showed a strong negative relationship between tractor price and energy efficiency. Hence, for a given horsepower tractor prices do not necessarily reflect energy efficiency. The point was made that farmers are probably largely unaware of the variation in energy efficiency among tractors with the result that these differences are not reflected in market prices.

1.5.3 General policy aspects

Hill and Erickson maintained that any policy decision that directly affects resource use in agriculture or consumer choices (for example, rationing) will be difficult to administer without serious misallocation or distortions in other sectors of the economy. Connor suggested that results of research on the effects of high energy prices and/or reduced energy supplies have several implications in formulating energy policy affecting agriculture. Some points are :

1) A severe energy reduction policy for agriculture should not be considered since it would have serious impacts on food prices in the domestic market, decrease exports, affect some farmers' incomes, disrupt interregional competition and severely affect irrigation farmers.

2) National energy conservation efforts should not single out agriculture to conserve significant amounts of energy since agriculture uses only a

small proportion (approximately 3%) of total energy.

3) Policy makers should be aware of the difficulties that farmers would face in adjusting to changing energy prices and supplies. Farmers are usually price-takers whereas agribusiness and food processing firms have more control over prices they receive and pass on price increases more easily to other sectors.

4) As regards energy conservation in agriculture the possibility of conserving substantial amounts in the short-run are limited mainly because of equipment and machinery design. Connor maintains that it is therefore necessary to distinguish between short-run and long-run policies with respect to agriculture. He suggests a variety of approaches such as reliance on the market system, taxes and subsidies and the use of government controls such as rationing. Connor prefers the use of the market system since agriculture consumes only a small proportion of total energy and because the market approach would be the easiest and least expensive to administer.

5) It would be difficult to return to a more labour intensive and land based agriculture in the future (as some researchers have indicated) because of the age distribution of technology capital, immobility of labour resources and established tenure systems. Also a large area of land would be needed to replace land substitutes such as fertilizer, irrigation and pesticides.

6) It is unrealistic to go for large reductions in grain-fed livestock for conserving energy. A large proportion of livestock production occurs on grassland and makes use of forages which are inedible by humans. Prices will determine livestock supply.

7) Long-run land use policy can have an important impact on energy use in agriculture. In many areas good agricultural land is being withdrawn because of urbanization and industrialization pressure. If production has to shift to lower quality lands higher energy inputs will be needed to maintain the same level of output.

8) Any policy dealing with energy use in agriculture must consider policies enacted for other purposes at the national level since the latter may have severe effects on energy consumption in agriculture.

9) More attention should be given to research and extension activities in relation to energy in agriculture. More resources will be needed than at present.

1.6 CONCLUSIONS

Effects of increasing petroleum prices on the farmer's environment are complicated since higher oil prices do not only affect the price of fuel but also prices of virtually all other inputs and outputs. In the short-term farmers will try to conserve energy while in the longer term more fuel-efficient technologies will be used in response to higher petroleum prices. For farmers in food exporting countries the domestic inflation rate relative to the rate in competing countries will be of major concern as will be the effect on consumers' real incomes and commodity prices.

As regards inflation few conclusions can be reached as to which farmers benefit or lose from inflation as this depends partly on the combination of inputs used in production and the mix of products sold (Tomek and Robinson, p. 197). In general, farmers' terms of trade deteriorate in periods of cost-push inflation because of the negative effect on real net farm incomes and cash flows.

In general, energy supply reduction to agriculture would lead to higher food prices and more disrupting effects than increases in energy prices. If only direct energy (fuel) costs are considered moderate fuel price increases would have little effect on farm incomes. The effects become more significant as fuel prices increase substantially. Irrigation farmers would be affected severely by high energy prices. If only fuel is considered there would be a trend towards minimum or zero-tillage systems as these require less fuel per unit area than conventional tillage systems. However, regarding all energy inputs the reduction in fuel energy is accompanied by increased use of herbicides, pesticides and nitrogen fertilizer.

Energy minimization cannot be realistically considered as an alternative as the real world does not provide incentives for energy self-sufficiency (Miranowski). The criterion is economic. Some researchers have advocated the use of energy input-output ratios as the criterion in choosing production techniques. This would lead to a labour-intensive, land-extensive agriculture and a movement away from mechanized, irrigated and artificially fertilized agriculture. However, such agriculture would not solve the food crisis in many countries. As Timmer pointed out, "Modern, energy-intensive agriculture is the only hope for many of the world's present population and for most of its yet-to-be-born" (p.219).

Crude oil is a non-renewable resource. According to Stoeckel (p. 73) this makes it different to many other factors in terms of supply and demand. As it becomes more scarce with continuous consumption the price can be expected to increase over time. Factors such as the degree of unity among OPEC members and the rate of return on alternative investments for oil producers will influence the supply of oil. However, price increases by oil producers will be constrained by the existence of alternative technologies such as ethanol, methanol, vegetable oil, oil from coal and oil shale. The existence of these technologies in the long-run means that the demand for oil is likely to be more price responsive.

CHAPTER 2

RENEWABLE ENERGY SOURCES WITH PARTICULAR REFERENCE TO BIOMASS

2.1 INTRODUCTION

Since the 1973/74 oil crisis government and private institutions have studied alternative sources of energy and large sums of money have been spent on research. In Chapter 1 the world energy trade with reference to oil, coal, natural gas (fossil fuels) and uranium was discussed. However, fears have been expressed that these major energy carriers are finite and not renewable. This concern has led many governments and researchers to study energy sources which are inexhaustible. Renewable sources include, among others, solar energy, hydro (water) power, wind energy, wave energy, ocean heat and currents and biomass. Some of these sources will be discussed briefly, with emphasis on biomass. Sugar-cane is of particular interest as it is being used as a source of liquid fuel in countries such as Brazil and Zimbabwe.

2.2 SOME RENEWABLE ENERGY SOURCES

2.2.1 Solar energy

Advantages of the direct use of solar energy are that the sun is an inexhaustible source of energy and its use is accompanied by little environmental pollution. However, two inherent characteristics of solar energy make its large-scale use expensive. Firstly, its non-concentrated nature (that is, a surface of one m^2 receives an amount of energy on a cloudless summer's day equivalent to burning one kg of coal) means that relatively large surfaces are required to collect a reasonable amount of energy. The second disadvantage is that it is available only intermittently so that it is important for the energy to be stored and used when the sun does not shine (Department of Mineral and Energy Affairs, pp.1-2).

Despite the disadvantages of using solar energy considerable research has been done on its use in heating domestic water (solar water heaters are being sold commercially), in space heating and cooling and for the generation of electricity (op cit., pp.3-13). In agriculture solar energy may be used in the drying of crops, heating of greenhouses and livestock buildings and for driving water pumps for irrigation schemes (op cit., pp. 7-8; Bruwer, pp.19-20; Katzman and Matlin; Mc Lean; Shove; Sutherland and Sonka; Vaughan et al).

According to the Department of Mineral and Energy Affairs (p. 38) South Africa could be totally dependent on solar energy and other renewable energy sources to meet any further increase in its electricity needs as early as the second half of the next century. The Department maintained that a favourable climate should now be created for research and development in the use of solar energy.

2.2.2 Hydro power

Hydro power at present contributes only about 1% of South Africa's primary energy requirements (Financial Mail, 1983, p.5). With the poor hydro-electric resources in the country it is estimated that hydro-generated electricity will not contribute more than about 8% of ESCOM's total capacity by the end of the century. All of this will be peak booster capacity. In certain regions of the world hydro-power contributes the following proportions to total electricity-generating capacity : North America 20%, Western Europe 26%, South America 55%, Norway 99% (op cit., p.38).

2.2.3 Wind power

Wind power, like water power, was one of the first energy sources to be used. Wind can be converted relatively easily to mechanical energy; for example, the use of windmills to pump water. Disadvantages are that wind power is a variable source of energy and is difficult to use because of low energy densities. The latter also applies to wave, ocean heat and ocean current energy (Grathwohl, p.238). Studies in West Germany suggested that large-scale utilization of wind energy is only economical in areas with an average annual wind speed of at least four metres per second (4m/s). In certain areas of the USA wind speeds of 13m/s or more for 4 000 to 5 000 hours per year have been measured (op cit., p.238). Many countries have been showing interest in the commercial use of wind energy because of its large potential and the potential volatility of the oil market.

2.2.4 Methane gas

Various research projects have been aimed at determining the feasibility and economics of producing methane gas from livestock manure and farm waste. Miranowski et al concluded that methane production on a typical Iowa family farm was not profitable unless energy prices increased sharply, for example 10-fold. Sanghi and Day reported that the cost of an anaerobic digestor (biogas plant) in rural India exceeded the benefit of the biogas produced. Willis and Christensen found that at 1977 price levels methane generation from poultry manure was not economical. However, they provided estimates of reduced costs of methane production in future when improved technologies are used. They argued that these cost reductions of future users could justify a public subsidy to encourage innovations.

2.2.5 Biomass

Modern agricultural production depends heavily on fossil energy. Increased yields over time have been mainly due to increased use of energy intensive inputs such as commercial fertilizers, herbicides, pesticides and the use of hybrid seeds and machinery (Pimental et al). Production also depends on solar energy conversion. Only plants are able to utilize a substantial portion of available solar energy (Grathwohl, p.245; Pimental, p.4). About 1.7×10^{11} tonnes of biomass are produced per year by all land and water plants on earth. The energy content of this biomass is about 10 times the annual world energy consumption (Grathwohl, p.246). Biomass production per unit area can be increased with use of suitable cultivars, irrigation and fertilization, but at the expense of increased energy intensiveness.

2.2.5.1 Some potential energy crops and net energy ratios

Great interest has been shown by many researchers world-wide in the production of alcohol fuels (ethanol and methanol) from various plant species. According to Sheehan et al a major consideration in the production of any fuel is the overall energy balance. They maintained that ethanol cannot be considered a renewable fuel "unless the energy contained in a unit of ethanol is greater than or equal to the energy expended in producing that unit" (p.6.17). They summarized energy output to input ratios for a number of crops (p.6.15) and certain characteristics of major energy crops (p.6.16). Although a wide disparity exists among researchers in their estimates of energy ratios, sugar-cane is the only crop for which all estimates show a positive energy balance. This is confirmed by Austin et al. In South Africa Thompson (1979, p.234) estimated a net energy ratio (NER) for sugar-cane on rain-fed farms of 2.7, on irrigated farms of 1.9 and 2.5 on all cane farms. These ratios are based on research by Donovan.

According to Sheehan et al (p.6.17) cassava's ability to compete with cane for alcohol production in Australia will depend on efforts to mechanize harvesting procedures. (This may not be a problem for countries with a relative abundance of labour.) They expect that should the harvesting problems be overcome and cassava tops be used in addition to the tubers (in which case the NER would just be positive) cassava could be a strong competitor to sugar-cane for ethanol production. Smythe (p.9.2) maintained that both cassava and sugar-cane could be integrated in a fuel alcohol economy, with cassava being grown on land which is marginal for cane. This is the case in Brazil (Daphne, p.68).

Sugarbeet is not considered a suitable source of ethanol since it has no fibrous residue to provide heat energy required for processing (Thompson, 1979, p.233). It has a NER of less than unity. Lipinsky et al, as reported by Thompson (1979), estimated a NER of 0.56.

As regards sweet sorghum Sheehan et al (p.6.16) estimated a NER of greater than unity. It is a fibrous crop which provides fuel requirements for processing. It apparently requires less rainfall and nutrients than sugar-cane, but it can be harvested only within a relatively short period of time (Thompson, 1979, p.233). Sheehan et al (p.6.17) suggested that marginal caneland could be used for sorghum production. Because of its relatively short harvesting period sorghum must be considered in conjunction with other crops.

Considerable controversy has surrounded the use of maize (and food) as a potential source of ethanol. Maize is used as a direct food and as a feed for cattle. Schnittker Associates maintained that this concern is a somewhat different issue in countries with food deficits than it is in nations with high meat diets or large grain exports (p.i). Robinson (1978, p.2) argued that production of ethanol from maize can result in more food being produced than is destroyed. Proteins and fats are not destroyed by the fermentation process but are recovered in the form of a by-product called Dried Distillers Grains and Solubles (DDGS) which contains about 30% protein. Sweeten et al (p.332) reported that research has been conducted for many years on the animal nutritional value of stillage (effluent) and spent grains from ethanol production. Robinson (1978, p.3) referred to research which showed that an increase in meat production of about 13% was obtained with a ration containing 20% DDGS compared with a ration of maize only. Other uses of distillers' feeds for animals are summarized by Houghton-Alico (pp.58-59). Braden et al investigated the economics of an integrated enterprise producing one million gallons of fuel-grade ethanol with the stillage byproduct fed to livestock and found it to be a risky proposition, with returns varying widely with costs and prices.

On net energy ratios for maize Lipinsky et al, as reported by Thompson (1979, p. 234), calculated a NER of 0.74 when stover was used as fuel in the ethanol process. Sheller and Mohr, as reported by Sheehan et al (p.6.15), estimated a NER of 1.16 when 75% of cornstalks, cobs and husks are used as an energy source. According to Thompson (1979) the advantage of maize is that it can be grown in many parts of South Africa where sugar-cane, sweet sorghum or cassava cannot be grown. It can also be stored for relatively long periods of time. However, collecting and transporting stover may present difficulties. According to Oursbourn et al (p.78) the long-term impact of crop residue removal on soil productivity is still unknown. Pimental (p.4) does not recommend removal of crop residues because of the undesirable environmental impacts of such action on soil erosion, soil structure and the soil carbon ratio. Christensen and Heady (1984) reported that alcohol production from corn in the North Central Zone of the USA would increase the erosive potential of marginal land. However, up to 12 billion gallons of alcohol could be produced without increasing soil loss if soil conservation techniques, such as minimum tillage, were used. Use of corn residue for alcohol production, however, could result in serious soil losses.

Extensive research into the use of vegetable oils as an extender of diesel oil has been conducted in various countries (for example, by Bacon et al, Bruwer et al, De Oliveira et al, Kaufman et al, Meikle, Myburgh et al, Stewart et al, van der Walt and Hugo). In South Africa the Division of Agricultural Engineering obtained satisfactory results with air-cooled, indirect-injection engines running on sunflower oil under a cyclic load (van der Walt and Hugo). In Zimbabwe Meikle reported that an air-cooled, direct-injection engine running on a blend of 50% sunflower oil and 50% diesel fuel gave no problems after 1 000 hours in operation. However, water-cooled, direct-injection engines running on the same fuel blend experienced fuel dilution and nozzle choking problems. Ardington (1979, p.61) estimated the NER for sunflower oil to be greater than one.

Timber has been suggested as a source of ethanol and methanol production. Van Breda (p.1) reported an energy ratio of 7 to 10:1. Other authors consider the NER to be less than one; for example, McCann and Sadler for eucalyptus and Lewis for wood, as reported by Sheehan et al (pp.6.15, 6.17). Van Breda (pp.1-2) listed the advantages of using timber as alcohol source. These are :

1) Timber can be grown on land unsuitable for food production.

2) Timber plantations are relatively free of pests and are less susceptible to hail and drought than other agricultural crops.

3) Trees can be harvested throughout the year thus ensuring a constant supply of material to the processing plant and ensuring efficient use of harvesting and transport equipment.

4) A substantial amount of forest biomass which is usually regarded as

waste (for example, tree tops and branches) would be suitable for alcohol production.

5) Forest biomass has the lowest raw material cost per tonne of alcohol. For example, in 1981 wood cost R172 per tonne of alcohol, maize R360 per tonne and sugar-cane R320 per tonne of alcohol.

However, the amount of surplus timber fluctuates with the level of economic activity. In April 1979, the surplus was estimated at 3.69 million tonnes by the Department of Forestry. In his analysis van Breda estimated three million tonnes of oven-dried material (ODM) of surplus and waste available per year for alcohol production. With potential expansion areas about 15 million tonnes ODM per year could produce about four million tonnes of methanol or three million tonnes of ethanol per year, representing about 25% of current liquid fuel needs in South Africa (op cit., p.3).

The above analysis seems optimistic when measured against more recent estimates of future timber demand in South Africa. Heyl, for example, expects demand for roundwood to increase by about 3.9% per year, while the Department of Environment Affairs expects a general long-term shortfall in supply. Approximately 44 000 hectares will have to be afforested annually to meet the expected demand of 28 million m^3 by the year 2000 (Arenhold, p.32). Alcohol production would therefore have to rely on waste and residue material. The collection, processing and transport of waste materials would present major problems.

In the USA wood supplies only about 1% of total annual energy consumption. Walker and Hicks maintained that a considerable increase is possible through intensified forest management. "Silage" plantations in which trees are closely spread and the young, whole trees are harvested at regular intervals, are being studied. Various types of trees most suitable for energy production in different localities are being studied overseas. According to van Breda (p.4) fast growing species of poplars, eucalyptus and hybrids have so far proved the most successful.

To conclude, this section has dealt with some potentially important crops for alcohol production and their net energy ratios. Sheehan et al maintained that a crop's overall energy balance is a major consideration in fuel production. Many authors agree. However, the danger of placing too much emphasis on net energy ratios (in whatever way these may be calculated) is that sight may be lost of the economics of producing alcohol from biomass. The market will determine which crops are most suitable . Factors involved are ethanol prices, costs of production and alcohol yields of various crops. The weaknesses of using net energy analysis were discussed in section 1.5.1. In fact, Pasour and Bullock reported that "any productive process measured in terms of energy input and energy output will be energy losing" (p.687).

With this as background the following section deals with yields of ethanol from various crops. This will be followed by a review of literature on the costs of producing ethanol.

2.2.5.2 Yields of alcohol from various crops

This section summarizes yields of alcohol per tonne and per hectare for some potentially important crops.

2.2.5.2.1 Sugar-cane

Yields of ethanol from sugar-cane per unit area vary with yield and the quality of sugar-cane. According to McCann and Prince (p.4.24) high quality cane in Queensland, Australia, should yield 87 litres of ethanol per tonne or 7 400 litres per hectare. Stumpf (1978a) reported a yield of 70 litres per tonne in Brazil. In South Africa Thompson (1979) used 70 litres per tonne while Ravnö (1979, p.243) and Ardington (1979, p.5) used 75 litres per tonne in their analyses. On dryland farms in South Africa, therefore, a yield of about 4 000 litres per hectare on 55 tonnes sugar-cane per hectare per annum is commercially possible. On irrigation farms ethanol yields of up to 7 000 litres per hectare per annum are possible (Ardington, 1979, p.6).

A major problem with large-scale ethanol production is effluent or stillage disposal. For every litre of ethanol about 10 to 15 litres of stillage are produced (Ravnö, 1979, pp.242-43). Lipinsky reported that sugar-cane derived stillage has one-half the protein content of maize stillage, about the same vitamin content and about five times the salt content. This "by-product" of sugar-cane juice, therefore, has only about 50% of the value of maize stillage (p.5). Intensive research has been conducted on the disposal and use of stillage. Some of the possible methods include (Kujala <u>et</u> <u>al</u>, Ravnö , 1979, p.243; Thompson, 1979, p.238):

1) Spreading on cane fields if sufficient land is available. Where sugar-cane is irrigated stillage could be disposed through the irrigation system. The minimum dilution requirement would be one part stillage to nine parts water. However, a ratio of 1:50 would be more desirable.

2) Evaporation to produce a concentrated syrup as a binder in livestock feed rations. However, this is an expensive operation.

3) Spray drying to produce, for example, a ethyl concentrate feed component.

4) Incineration to produce heat, and

5) anaerobic fermentation to produce methane gas or single-cell protein.

Satisfactory solutions to stillage disposal have not yet been achieved and Deicke <u>et</u> <u>al</u> (p.7.14) reported that this aspect may place limits on the ethanol programme in Brazil if the government should impose strict pollution controls.

According to Humbert (p.1) doubling sugar-cane yield per hectare through improved cultural practices and varieties selected for "total sugars" production results in an approximate 30% reduction in costs per litre of ethanol. The varieties should be responsive to chemical ripeners. Experiments by Cackett and Rampf showed that certain practices which were ideal for sugar production required modification to optimize productivity of total fermentable solids.

2.2.5.2.2 Cassava

According to Stumpf (1978a) yields of tubers in Brazil are about 15 tonnes per hectare with 25 tonnes expected in the future. Ethanol production is between 2 700 and 4 500 litres per hectare per annum. Bull and Batstone (p.4.17) expect yields of 40 tonnes in Australia while McCann and Prince (p.4.24) used 50 tonnes of tubers in their analysis. With an estimated production of 168 litres of ethanol per tonne of tubers containing 30% fermentable solids the ethanol yield per hectare for a 50 tonne tuber yield would be 8 400 litres. However, McCann and Prince pointed out that since work on cassava yields in Australia was still in its infancy it was difficult to predict what yields would be possible (p.4.23).

In South Africa the Anglo American Corporation in 1979 established a Centre for Cassava Research at Mtunzini in Natal to concentrate on plant breeding and pathology (Daphne, p.66). Yields at present are relatively low. According to Graham yields vary from 20 tonnes at Mkuze to 36 tonnes per hectare per 18 months at Stanger. Harvesting is after 18 to 24 months depending on the time of planting. In the tropics cassava is usually harvested after about 12 months of growth. For successful cassava production the lower limit appears to be an annual mean temperature of 20°C. This restricts production to areas in the eastern part of South Africa above latitude 31°S and below an elevation of 800 metres. Evenson and Keating reported that cassava tolerates light frost, but the mean monthly winter minimum temperature should exceed 13°C. Thompson (1979, p.234) suggested that the South African cane belt would not be ideal for cassava production because mean minimum temperatures in July are seldom above 13°C. Germination would generally be affected adversely from May to August. However, according to Daphne (p.68), planners of the Anglo American Corporation believe that cassava production in Natal is possible and should start on marginal cane-land. As in Brazil, cassava and sugar-cane are seen as complementary rather than competing crops. Bull and Batstone believe that combining production of sugar-cane and cassava could bring down the cost of producing ethanol.

2.2.5.2.3 Sweet sorghum

Yields of six imported varieties of sweet sorghum on trials conducted by the S.A. Sugar Association Experiment Station at Greytown varied from 25 to 63 tonnes per hectare with the sucrose content varying from 3.5% to 7.3%. In the USA yields ranging from 34 to 85 tonnes of unstripped stalk per hectare have been recorded (Thompson, 1979, p.233). However, data on the suitability of sweet sorghum for sugar and ethanol production is still sparse since the development of varieties with a high sugar content is relatively recent. An ethanol yield of about 55 litres per tonne of sweet sorghum is possible (Ardington, 1979, p.4). Sheehan et al(p.6.17) reported that sweet sorghum will generally yield about one-half the ethanol production of sugar-cane per unit area. However, it has the advantage of multiple cropping and could supply sugar factories during the cane off-season.

2.2.5.2.4 Sugar-beet

According to McCann and Prince (p.4.23) the average yield of beet in the best growing areas of Europe is about 45 tonnes per hectare or 6.3 tonnes of sucrose, and in the USA 50 tonnes of beet. For an ethanol yield of 110 litres per tonne of beet containing 20% fermentable solids, a beet yield of 50 tonnes would produce 5 500 litres of ethanol per hectare. In two semi-commercial plantings in the Highland Sourveld and Mistbelt regions of Natal in the late 1970's it was found that a sucrose yield of at least six tonnes per hectare in April could increase to about 10 tonnes per hectare in September (Inman-Bamber, p.36).

Thompson (1979, p.233) reported that the greatest limitation to the use of sugar-beet as a source of ethanol is the fact that it has no fibrous residue which could be used as furnace fuel. For this reason it has not been recommended for future consideration in the USA. Sheehan et al (p.6.17) pointed out that sugar-beet has always been considered economically inferior to sugar-cane.

2.2.5.2.5 Maize

South Africa's average annual maize production over the five years 1977/78 through 1981/82 was 10.4 million tonnes on 4.35 million hectares (Agricultural Economics Trends Division, p.7). This gives a yield of 2.4 tonnes per hectare compared with over six tonnes in the USA. Production in South Africa varies greatly from year to year; for example, in the 1980/81 production year a record 14.7 million tonnes were harvested while in 1982/83 production was below four million tonnes due to drought. Total domestic consumption averaged 6.1 million tonnes over the five years 1977/78 through 1981/82 (op cit., p.8). In a normal season about four million tonnes could be exported.

Yield estimates of ethanol per unit of maize vary. For example, Litterman et al (p.4) used 2.7 gallons per bushel while Reining and Tyner (p.568) used 2.16 gallons per bushel in their analyses. With a yield of about 350 litres ethanol per tonne of maize the ethanol yield per hectare for South Africa would be about 840 litres in a normal season. In the Natal Midlands the yield would be about 1 750 litres per hectare. In the USA the ethanol yield would be over 2000 litres per hectare.

Since arable land is a limiting factor ethanol yield per hectare is important. Since maize has a relatively low yield compared to sugar-cane or cassava it may not be a contender for ethanol production. In fact, Sheehan et al (p.6.17) rejected maize, wheat and eucalyptus as potential sources of ethanol because of their low annual yields per unit area. However, in the USA surplus grain has been converted to ethanol which has been blended with gasoline in a ratio of 10% ethanol to 90% gasoline to produce gasohol. The cost of ethanol has, however, been subsidized by the USA government by 40 cents per gallon of ethanol or 4 cents per gallon of gasohol (Schnittker Associates, p.v).

2.2.5.2.6 Timber

Various uses of timber as an energy source include direct combustion, production of charcoal and producer gas and liquid fuel (ethanol and methanol). According to van Breda (p.9) the most effective way of manufacturing methanol is by gasifying wood chips at an elevated temperature in an oxygen-fed, pressurized gasifier. Ethanol, on the other hand, can be produced from forest biomass by hydrolysis, fermentation and distillation. One tonne of oven dry material (ODM) will yield about 370 litres of methanol or 270 litres of ethanol (op cit., p.10). With yields from good forestry land of 10 tonnes ODM and from marginal land 5 tonnes ODM per hectare per annum (Garbutt and van Breda, p.2) yields of methanol and ethanol, respectively, of 3 700 litres and 2 700 litres per hectare on good land and 1 850 litres and 1 350 litres per hectare on marginal land can be expected.

Yields of ethanol per hectare are low when compared with sugar-cane. Van Breda (p.2), however, maintained that forest biomass has the lowest raw material cost per tonne of ethanol, namely R172 as against R320 for sugar-cane and R360 for maize in 1981.

Table 2.1 provides a summary of estimated alcohol yields of some potentially important crops under South African conditions.

Table 2.1 Estimated yields of alcohol of potential energy crops in South Africa.

Crop	Litres/tonne	Litres/ha/annum
Sugar-cane - dryland	75	4000
- irrigated	75	6000
Cassava	160	2750
Sweet sorghum	55	2500
Maize	350	840
Timber - ethanol	270/ODM*	2000
- methanol	370/ODM*	2800

* ODM = oven-dry material

Sugar-cane yields on average the greatest volume of alcohol per hectare. This is an important criterion where land is a limiting resource and a high volume of alcohol is required. However, the costs of producing alcohol from various sources and how these compare with petroleum prices are important. Litterman et al defined economic feasibility as "the cost of producing the alcohol is less than or equal to the market value of the gasoline it replaces" (p.1). In this sense the next section deals with a literature review of studies aimed at ascertaining the cost of producing alcohol from biomass.

2.2.5.3 Costs of producing alcohol

The view of many researchers is that alcohol production from agricultural biomass is not economic when compared with equivalent petroleum-based fuels (for example, Bull and Batstone, p.4.21; Committee of Inquiry into the Sugar Industry, 1982, pp.17-18; Deicke et al, p.7.10; Mc Cann and Prince, p.4.29; Meekhof et al, p.408; Ravnö, 1979, p.242; Scott, 1983, p.65; Smythe, p.9.4). Sheehan et al (p.5.14) summarized estimates of ethanol production costs by various researchers. For sugar-cane estimates of total production costs (including raw material and processing costs) for 1977/78 ranged from 14.5 Australian cents per litre to 60 cents with the mode at 27.6 cents per litre. For South Africa Ravnö (1979, p.243) calculated a total cost of 35.8 cents per litre in 1979. The Committee of Inquiry into the Sugar Industry (1982, p.17) arrived at a cost of 39.6 cents per litre compared with a landed cost of 93 octane petrol of 27.8 cents per litre. The difference would be equivalent to a reduction in the cane price of about R7.50 per tonne of cane, which was 38% of the cane price.

Ravnö (1979, p.242) has shown that from about the middle 1930's to the end of the 1970's the cost of the raw sugar-cane material element alone was higher than the net petrol price. According to Ravnö's calculation of ethanol production costs the raw material element accounted for 50% of total costs. In some other calculations growing costs accounted from about 60% of total costs (Sheehan et al, p.6.13) to about two-thirds of production costs (Deicke et al, p.7.11). However, molasses, a by-product of sugar production, appears to be a competitive ethanol source. At a production of 250 litres ethanol per tonne of molasses priced at R18.50 per tonne in July 1979 (Committee of Inquiry into the Sugar Industry, 1982, p.43), the raw material element accounted for only 7.4 cents per litre compared with Ravnö's estimate for juice fermentation of 18 cents per litre. However, supply of molasses is limited by the amount of sugar produced. In addition to an important fermentation industry, molasses has also found application in other fields such as in the production of animal feeds and yeast (op cit, p.43).

The summary by Sheehan et al (p.6.14) of various ethanol production cost estimates also shows a wide divergence among researchers for other ethanol sources. For example, for cassava two estimates were presented, one at 17 cents and the other at 40 cents per litre for 1975. For the same year cost estimates for ethanol from maize ranged from 11.9 cents to 29.8 cents per litre. For eucalyptus McCann in 1976 calculated a cost of 31.6 cents per litre with acid hydrolysis and 47.4 cents with enzyme hydrolysis. With wood waste Hokansen calculated an ethanol cost of 25.8 cents per litre at a price of $17.75 per tonne ODM, and 35.2 cents with a price of $35.50 per tonne ODM. According to van Breda (p.11) a R70 million ethanol plant using acid hydrolysis could produce ethanol at about 42 cents per litre at a wood price of R33 per tonne ODM. A methanol plant costing R55 million could produce methanol at 24 cents per litre at the same wood price. Garbutt and van Breda (pp.3-4) presented a number of feasibility studies which indicated that size of plant and the basic wood price play dominant roles in the final alcohol production cost.

It is apparent from the above analysis that estimates of alcohol production costs depend to a large extent on the assumptions made. Bull and Batstone compared ethanol production costs for the Bundaberg area of Australia using sugar-cane, sweet sorghum and cassava. They concluded that cassava had the lowest raw material cost per litre of ethanol and that it was the most promising crop for developing new lands in that area (p.4.17). They suggested utilizing the existing infrastructure and components of sugar mills for processing cassava. This could lead to economies of scale and reduced ethanol production costs. In South Africa the situation may be different as large areas of the Sugar Industry may not be as ideally suited to cassava production thus leading to lower yields and higher production costs per tonne (see section 2.2.5.2.2) . However, it has a greater potential for genetic improvement than sugar-cane.

Whilst it is generally accepted that production costs of ethanol are at present higher than costs of equivalent petroleum based fuels it may be argued that should crude oil prices escalate in real terms over the longer term ethanol could become progressively more attractive as a fuel.

How suitable is alcohol as an automative fuel? This is discussed in the next section.

2.2.5.4 Alcohol as a fuel

Interest in alcohol as a fuel goes back almost to the advent of the internal combustion engine. By 1936 over 800 megalitres of power alcohol (mainly ethanol) per annum was consumed in the world (Buchanan, 1979, p.244). In Natal in the 1950's Union Motor Spirits (a 1:1 ethanol:petrol blend) was popular because of its favourable anti-knock characteristics. The blend was usually mixed with petrol in a 1:3 ratio (op cit, p.244). However, because of the relatively low cost of petroleum, use of alcohol as a fuel decreased. New interest in alcohol was kindled by the 1973/74 oil crisis. Intensive research on methanol and ethanol as automative fuels has been conducted in many countries , gauging from the numerous papers on this subject presented at alcohol fuels technology symposia in California in 1979, in Brazil in 1980 and in New Zealand in 1982. In the USA a 10% ethanol blend "gasohol" has been marketed in the Midwest since early 1979 (Sundberg and Mead, p.277). In Brazil ethanol blends of up to 20% are being used commercially while in Europe research on methanol blends has been conducted (Buchanan, 1979, p.246). In South Africa methanol blends are being tested by the Energy Research Institute at the University of Cape Town (Dutkiewicz, 1980, p.789) and ethanol blends by the Department of Mechanical Engineering, University of Natal. Hansen et al have evaluated ethanol:diesel blends for agricultural tractors at the University of Natal, Pietermaritzburg.

According to Dutkiewicz (1980, pp.782-83) there are a number of possibilities of using alcohol as a transport fuel, namely (petroleum fuel proportions in parenthesis) blending (10%), through dual fuel aspiration (30%), through dual fuel direct injection (90%) and in high compression ratio spark ignition engines (100%). Blends would normally be introduced first as it would cause least disruption to existing distribution systems.

The properties of methanol, ethanol and petrol are summarized by Buchanan (1979, p.249). Ethanol is more flexible than methanol in that it can be used as an extender for both petrol and diesel fuel. Methanol does not blend with diesel fuel (Dutkiewicz, 1980, p.783). With an imbalance in demand between diesel fuel and petrol in South Africa, with a resultant shortage of the former (op cit, p.786; Scott, 1983, pp.63-64), production of ethanol could be an advantage.

As regards the use of alcohol blends in engines Dutkiewicz (1980, p.786) reported that there are no unsurmountable problems with the use of methanol. Problems with blends can be rectified with engine tuning, carburettor adjustments and substitution of methanol corrosive parts with methanol resistant parts. Power, fuel consumption and exhaust gases of methanol-driven engines compare favourably with petrol-driven engines. Nitrogen oxide emission is only one-third that of a petrol engine and the exhaust of methanol contains much less carbon monoxide and unburned hydrocarbons and hence almost no soot particles. Also, methanol contains no sulphur, and because it does not tend to pre-ignite it does not require lead additives. Its exhaust is thus free of lead (Grathwohl, p.297).

Ethanol has essentially the same properties as methanol (op cit, p.298). Performance of ethanol blends with regard to various factors are as follows (Buchanan, 1979, pp. 247-51) :

1) Economy : Up to a 20% blend little loss in fuel economy is experienced. With optimal ethanol settings no significant loss was reported for blends of up to 40%.

2) Anti-knock value : This has been an important reason for the interest in alcohol fuels.

3) Drivability (Starting, vapour lock etc.) : Ethanol blends up to 20% have physical characteristics that are within the range of variation of petrol. Except under extreme conditions performance of blends are expected to be similar to that of petrol.

4) Exhaust emission : Use of a 10% ethanol blend can reduce carbon monoxide emission by up to 75%. Hydrocarbons and oxides of nitrogen are also reduced. Also, the use of unleaded petrol-ethanol blends eliminates lead pollution of the atmosphere which is of increasing concern to industrialized countries.

5) Engine wear : Extensive tests in the USA with gasohol confirmed that no unusual wear occurred. In Brazil similar results were obtained (Pischinger and Pinto, p.5; Stumpf, 1978b, p.2.23). However, corrosion of metals such as aluminium and copper in exhaust systems could result from high ethanol content blends due to some acetic acid formation. Also PVC parts will in time be rendered brittle by ethanol and should be substituted (Pischinger and Pinto, p.6).

Hansen et al reported several major drawbacks of ethanol as a diesel fuel substitute, namely a lower cetane rating, immiscibility with diesel fuel in the presence of water and at lower temperatures, reduced viscosity and reduced calorific value (p.76). They found a reduction in power of 3% to 5% measured at maximum power with blends containing 15% ethanol. However, power output could be restored by uprating maximum fuel delivery (p.77). There was no significant increase in the wear of engine or fuel injection systems with a 15% ethanol blend. Similar results were obtained under on-farm conditions with a 30% ethanol blend (p.78). They concluded that, with sound management, there are no technical drawbacks with the application of ethanol-diesel fuel blends in compression-ignition engines (p.79).

As regards the distribution of alcohol, oil refineries would have the advantage over alcohol producers in that their distribution networks already exist. It would also permit them to formulate the blend base stock to optimize their economy and the physical characteristics of the fuel (Buchanan, 1979, p.251). A good working relationship between oil refineries and alcohol producers is desirable if the greatest advantage of any alcohol blend is to be realized (op cit, p.251). According to the

Australian Petroleum Institute (p.12), apart from certain technical difficulties in blending alcohol and petroleum, the introduction of these blends would necessitate a separate dispensation system on a national basis through service stations. Storage tanks, pipeline systems and tankers would have to be adapted. However, these problems are not insurmountable as experiences in Brazil and the USA (with gasohol) have shown.

In the short-term ethanol should be seen as an extender of petroleum fuel supplies. Blends containing up to 20% ethanol are acceptable for standard spark ignition engines. For diesel fuel, blends of up to 15% ethanol are acceptable provided a blend stabilizing agent is added. Of interest, then, would be the blend cost. Buchanan (1979, p.251) calculated blend costs using various refinery-gate petrol prices, an ethanol cost of 33 cents per litre and blends containing 5%, 10%, 15% and 20% ethanol. With a 10% blend and a cost of petrol of 20 cents per litre, the weighted average factory gate price of the blend is 21.3 cents per litre or 1.3 cents per litre above the base petrol price. According to Buchanan (1979, p.253) the advantages of ethanol blends could effectively reduce the price gap.

In this dissertation sugar-cane as a source of ethanol has been chosen as the subject of study. Reasons for considering sugar-cane in the South African context are discussed in the next section.

2.2.5.5 Sugar-cane as a source of ethanol in South Africa

If ethanol is to make a significant contribution to South Africa's future liquid fuel requirements it must be produced in large quantities and at a cost which will make it at least comparable with competing fuels. Since land is a limiting factor a crop producing the highest optimal yield of ethanol per hectare should be used. Under South African conditions at present sugar-cane would produce the highest yields of ethanol per hectare, namely 4 000 litres under dryland conditions and over 6 000 litres under irrigation (see section 2.2.5.2). The sugar-cane plant is considered to be one of the most efficient users of solar energy in terms of harvestable biomass per unit area per year (Deicke _et al_, p.7.10; Humber, p.6). Alexander, as cited by Deicke _et al_ (p.7.10), reported that net carbon dioxide (CO_2) assimilation rates for sugar-cane are 1.5 to two times the rates common in other plants. However, cassava may become a strong contender if yields of tubers are over 25 tonnes per hectare per annum. As was pointed out earlier it appears to have a greater potential for genetic improvement than sugar-cane. Cassava does, however, require a hydrolysis stage before it can be converted to ethanol (Smythe, p.9.2). In South Africa, as in Brazil, cassava would probably be a supplementary source of ethanol, it being grown mainly on marginal cane-land (see section 2.2.5.2.2). Sugar-cane has the advantage as a perennial which can be grown on relatively steep terrain.

In addition to molasses as a source of ethanol bagasse (residue after extraction of juice from sugar-cane) is another potential source. Research on the conversion of bagasse to ethanol was initiated in South Africa in 1979 (Purchase, p.1). Agricultural residues are generally inexpensive but for most residues the costs of collection become prohibitive, for example, maize stover and forest waste. Bagasse, on the other hand, collects at sugar factories where infrastructure for further processing exists. The S.A. Sugar Industry has, according to Purchase (p.1), a further advantage in that its cane has a higher fibre content (15% to 16%) than in most countries of the world (11% to 12%). Purchase (p.1) maintained that, given economic incentives, the S.A. Sugar Industry could produce a bagasse surplus of about one million tonnes (dry). Hydrolysis of bagasse is at present not economic but there is considerable potential for cost reduction. Developing a process for converting xylose to ethanol is of special interest because of the Sugar Industry's potential for producing low cost xylose (op. cit. p.4). Bagasse is also used as a furnace fuel, thus reducing operational costs of sugar factories, and for the production of paper hardboard, furfurol and so on.

A decided advantage of sugar-cane is that the Sugar Industry is an established one with an infrastructure that could be utilized for the production of ethanol. Also, an extensive knowledge of local problems and opportunities of sugar-cane growing have been accumulated over years of intensive research. In addition, the world surplus of sugar and the resulting low export prices, which may persist for some time because of the shift to alternative sweeteners in major industrialized countries and the price support policies in sugar producing countries, makes ethanol production from sugar in South Africa a consideration.

As the blending and distribution of petroleum-ethanol blends would most probably lie with oil companies (because of their existing distribution networks), the Sugar Industry has the advantage in that its main production areas are relatively close to major oil refineries in Durban.

With some major advantages of sugar-cane as a source of ethanol mentioned above, it is important to briefly summarize views of the growing and milling sections of the S.A. Sugar Industry on the production of ethanol. Since the middle of the 1970's leading authorities of the Sugar Industry have expressed their views, with most seeing a role for the Industry to produce ethanol, with positive action deemed necessary to examine the possibilities and potential. Complaints were also expressed about lack of clarity from the government regarding its long-term fuel policy (Ridgway, 1978/79, p.65). Jones (1978/79) maintained that the Industry has no permanent surplus cane for ethanol production. If export sugar was diverted to ethanol production about 600 million litres could be produced from a normal export production of one million tonnes of sugar per year. However, he maintained that abandoning the export market would be a retrograde step for the Sugar Industry as it would mean losing markets that had been developed over many years and also losing foreign exchange. For millers it would result in underutilization of factory capacity and higher sugar costs to consumers. Jones maintained that extensive studies are necessary to determine the technical ramifications, capital requirements and the viability of such a project. Also, negotiations with oil companies regarding blending and marketing, and with the government over duties and levies would have to be held. Milling companies would require long-term security for such a venture. The logical approach, according to Jones, would be to bring new areas under cane production specifically for ethanol production, without affecting the local and export markets.

Chance maintained that the basic cause of the Industry's financial problem was the persistently low world free market price of sugar (p.57). One of the seven possibilities he mentioned to solve the Industry's problems was that of finding other uses for sugar-cane and sugar. One of these could be ethanol. "We are confident it will not be long before we will be producing ethanol from the whole cane biomass" (op cit, p.57). He mentioned some advantages of using sugar-cane as ethanol source, namely significant savings in fuel imports could be achieved; ethanol production from cane requires less fuel than production from any other crop; operating costs for cane must be lower than for cassava because cane ratoons while cassava has to be replanted after harvesting; bagasse from cane can be used as fuel to run the factory and distillery; cassava requires an additional phase to convert starch to sugar; in a few years it could be possible to convert the entire cane biomass, including fibre, to ethanol. Cane should then be producing more than three times as much ethanol per hectare than cassava. However, Chance maintained that before committing millions of rands to such a venture it was necessary to know government policy on such an issue (op. cit., pp.58-59).

Jones (1979/80) pointed out that the Industry had noted the guidelines published earlier that year by the Minister of Mineral and Energy Affairs in respect of fuel production from renewable sources. The government was prepared to offer certain concessions and incentives to encourage such production in general. However, it was made clear that such ventures would be entirely at the risk of the entrepreneurs concerned. The government had received tentative applications from the Industry for the production of ethanol and had asked the Industry to formulate guidelines and arrangements under which ethanol could be produced. Jones' view, as mentioned before,was that should ethanol be produced then this should come from the development of new areas without affecting the existing Industry and its potential for expansion (p.70).

Ridgway (1980/81) pointed out that it was unfortunate that little progress had been made with ethanol production and that it was impossible to obtain all details of the government's future energy plans. "It has been suggested that given a sufficiently flexible attitude by Government in relation to the relevant taxes, the cost of ethanol production compares reasonably well with the cost of methanol from coal and that the Industry is well set up to produce significant quantities" (p.43). He saw the problems with regards to ethanol production as follows :

1) Substantial capital investments had been made for the manufacture of fuel from coal at various SASOL plants;

2) the imbalance between petrol and diesel was difficult to resolve with the use of ethanol and

3) substantial investments by the major oil companies for refining fuels from crude oil.

Ridgway maintained that there were other complications which were not publicly known. However, he insisted that it was high time for the government to remove continuing uncertainty regarding ethanol's place in the nation's long-term fuel plan (op cit, p.43).

Ardington (1981/82) maintained that the S.A. Cane Growers' Association had for five years advocated a policy of tentative diversification into ethanol production but it had received little encouragement from either the Millers' Association or the government. "Unhappily, there had been no investments in establishing back-end distilleries and so ethanol production does not represent a solution to our problems in the short-term. However, it is important to recognize the extent of the opportunity lost to our Industry as supplying ethanol to the local market now would be twice as renumerative to this Industry as the export of sugar" (p.60).

The Committee of Inquiry into the Sugar Industry (1982) did not recommend production of ethanol as it was, according to their calculations, uneconomic.

2.3 CONCLUSIONS

This chapter discussed some major sources of renewable energy with particular reference to the use of biomass. The problem in the short-term lies with liquid fuel. Any shortages or substantial price increases could have disruptive effects on a nation's economy. This is particularly pertinent to South Africa which relies to a large extent on imported crude oil.

Of the major sources of biomass in agriculture sugar-cane seems the most promising under South African conditions. Sugar-cane yields the greatest volume of alcohol per hectare and since land is limited, this becomes an important criterion in choosing amongst alternative sources. Also, the cane industry is well-established with an infrastructure which could be used for ethanol production, through, for example, back-end distilleries. Research on sugar-cane is also well advanced and experiences in Brazil in producing ethanol from sugar-cane could be a valuable source of information.

However, despite the advantages of sugar-cane as a source of ethanol, production costs of alcohol appear to be above those of petroleum products at present. Various opinions suggest that should petroleum prices increase over the longer term, alcohol production would become progressively more attractive. To be economically feasible the profit per hectare from ethanol production should at least exceed the opportunity cost of the land. This aspect will be investigated in this study. Aspects such as the quantity of ethanol that will be supplied at various ethanol prices under different policy aspects, and effects of ethanol prices on enterprise mixes in various areas will be investigated. Also, the relationship between these prices and the petrol price needs analysis. At what stage would ethanol production become economically viable? Buchanan suggested that the advantages of ethanol blends (such as the anti-knock value, reduced emissions of undesirable components such as lead and sulphur, and possibly improved performance) may offset at least part of increased costs of blends.

Before development of the sugar-cane model is discussed, it is considered important to study the S.A. Sugar Industry in order to gain insight into its structure, performance and problems. This is the topic of the next chapter.

CHAPTER 3

AN OVERVIEW OF THE SOUTH AFRICAN SUGAR INDUSTRY

3.1 INTRODUCTION

An evaluation of alternative alcohol sources from biomass showed that sugar-cane had a number of favourable characteristics. In a South African context sugar-cane is the highest yielder of alcohol per hectare; bagasse (fibre) can be used as a furnace fuel and is a potential source of alcohol, and the Sugar Industry is an established one with an infrastructure that could be utilized for ethanol production. With this in mind it is appropriate to present an overview of the structure and performance of the Industry.

3.2 STRUCTURE OF THE SOUTH AFRICAN SUGAR INDUSTRY

3.2.1 Location and organization

The S.A. Sugar Industry consists of approximately 22 000 individual farmers and 17 sugar mills spread along the Natal coast, the Midlands of Natal and extending into Eastern Transvaal (South African Sugar Association, 1982/83, p.119).

The South African Sugar Association is the principal governing body of the Industry. It comprises two members, namely the S.A. Cane Growers' Association and the S.A. Sugar Millers' Association Ltd. Each is represented in the Association by 18 delegates. "Broadly, the objects of the Association are to promote and regulate the production of sugar-cane and the manufacture of sugar, to present the view of the Sugar Industry to the government, to improve technical knowledge of people engaged in the Sugar Industry, to encourage the consumption of sugar, and to provide the machinery for examining and adjusting major grievances among sections of the Industry" (South African Sugar Association, 1982/83, p.119).

The S.A. Cane Growers' Association was established in 1927 and represents all cane growers except mill owners. The major function of the Association is "to foster the business interests of the cane growers. In essence this means to ensure that the price received for cane is sufficient to meet the cost of production under reasonable standards of efficiency and to provide an adequate margin of profit" (op. cit., p.119). The Association is financed by a levy on each tonne of cane produced by individual members. The S.A. Sugar Millers' Association Ltd. represents the interests of all sugar millers and refiners in South Africa. It was originally established as the Natal Sugar Millers' Association in 1920. "The Association's objectives include the advancement of the Sugar Industry generally and the milling and refining section in particular, the expression of views on legislative measures affecting the Industry, industrial relations and training, scientific and technological research, statistical compilation and analysis and acting as intermediary with State Departments on all matters concerning member companies of the Association" (op. cit., p.120). As a constituent member of the S.A. Sugar Association it determines with the S.A. Cane Growers' Association all matters of industrial policy.

Other organizations of interest are the Sugar Industry Central Board, the Sugar Milling Research Institute and the S.A. Sugar Association Experiment Station. The Sugar Industry Central Board evolved from an agreement between representatives of growers, millers and refiners. It was implemented by the provisions of the Sugar Act No. 28 of 1936. The objectives of the Central Board are "to carry out any existing agreement and to exercise any function assigned to it under any agreement" (op. cit., p.119). The Sugar Milling Research Institute, which was established in 1949, is responsible for research on manufacturing problems of the S.A. Sugar Industry. The S.A. Sugar Association Experiment Station, which was initiated in 1925, is entirely financed by the S.A. Sugar Association. Its responsibility is research on cane-growing.

More detail regarding the above organizations and information on other organizations comprising the Sugar Industry are given by the South African Sugar Association (1982/83, pp.119-32).

3.2.2 Control of production

Production of cane and sugar in South Africa at present is controlled in terms of the Sugar Act of 1978 and the Sugar Industry Agreement of 1979 (Wilkinson, p.21).

Control of sugar-cane production is effected by a quota system and control of registered quota land. Basic quotas have been established on the mean of the grower's best two consecutive yields on his registered land, the so-called "farm mean-peaks". A grower may only supply cane to a mill from his registered quota land which is controlled by the Central Board.

In addition to basic quota, contingency and provisional quotas are also issued by the Central Board. Contingency quotas are issued to growers in times of expansion. Provisional quota involves transfer of quota without transfer of registered land. This quota is then attached to new land which has to be registered with the Central Board. Once a contingency or provisional quota has been issued the grower has four seasons to convert it to a basic quota. Unconverted quota is cancelled. Should a grower wish to withdraw registered land and register new land, he can only do so with approval of the Central Board, which would first determine the cane growing potential of the land involved (op. cit., p.22).

The quota is in effect also a contract between grower and miller. A grower is therefore obliged to supply a certain mill and transfer of quota from one mill to another can only be effected with permission of the mills concerned.

The weaknesses of using quotas for production control are well documented (for example, Commission of Inquiry into the Sugar Industry, 1970, p.29; Groenewald; Nieuwoudt, 1978; Paarlberg). Use of quotas to control production is similar to the Cochrane plan (Wallace, pp.581-83). Social costs are experienced because of higher prices on the domestic market and due to price distortions causing excess production (Beck, p.243).

3.2.3 Division of proceeds

Proceeds of the S.A. Sugar Industry are summarized by the South African Sugar Association (1982/83, p.194). Earnings from sale of white and brown sugar on the domestic market and molasses and export earnings are summed to give the gross proceeds of the industry. Industrial levies, local market selling commission, industrial loan repayments and sums for replenishing the Stabilization Fund are subtracted and industrial loans and withdrawals (if any) of the Stabilization Fund are added to give net divisible proceeds. Any shortfalls are absorbed by the growing and milling sections. This occurred in four of the last 10 seasons and reached nearly R50 million in the 1982/83 season. The net proceeds, after accounting for total refining costs, are then divided between growers and millers according to the division of proceeds formula. The apportionment is in two phases; firstly in proportion to total costs of each section, and secondly, the remaining balance is divided between the two sections according to their profit entitlement (Morrison). Millers are allowed a return on capital of 14% on historical (book) values and growers 7% of asset replacement value.

From the growers' share of proceeds an amount of R4 million is taken for the Equalization Fund, the purpose of which is to assist small cane growers. The cane price of these growers is supplemented by the Fund on a sliding scale which starts at 3 500 tonnes of cane and ends at 13 500 tonnes. Growers producing less than 3 500 tonnes of cane receive a flat rate of 60 cents per tonne. The Fund is fixed at R4 million annually so that over time inflation reduces its effectiveness. The Commission of Inquiry into the Sugar Industry (1970) would have recommended the termination of this Fund (its main weakness being the possible promotion of inefficient or uneconomic farming units) were it not for the fact that it contributed up to 11% of small growers' income (p.49).

3.2.4 Cane transport

Cane transport costs and their recovery have been the subject of much controversy in the Sugar Industry. The van Biljon Commission of Inquiry into the Sugar Industry (1970) recommended that cane growers be responsible for the cost of transporting cane from farm to mill as this would give rise to the most economical modes of transport (p.56). Some growers were being subsidized for cane transport at the time; for example, those falling under Clause 45 of the Sugar Industry agreement, 1943, as amended, which dealt with tramline agreements and subsidization by millers on a voluntary basis. This caused discontent amongst growers. The recommendations of the van Biljon Commission were considered too drastic and unacceptable to the Sugar Industry and the Department of Industries. After various investigations the Cane Transport Scheme of 1973 was introduced. It was modified subsequently (Committee of Inquiry into the Sugar Industry, 1982, pp.27-28). The Committee summarized the main provisions of the Scheme as follows :

"(i) The grower or miller who provides or commissions the cane transport is paid for his services out of industry funds at the standard rates laid down each year for the different modes of transport.

(ii) The responsibility for the total payment so made is apportioned as follows :

(a) The individual cane growers pay the actual cost per ton incurred by them in 1969-70 (after subsidization), but increased by the rate of increase in the sucrose price which occurred from 1977-78 onwards. Furthermore, a commensurate amount is allowed as a grower's cost in the Division of Proceeds Formula, which, in effect, means that the average amount per ton paid by the growing sector as a whole would be refunded to each grower as part of the sucrose price.

(b) The individual millers pay the actual subsidy they paid on cane transport in 1969-70, which is, as in the case of the growers, also increased by an inflationary factor and averaged amongst all millers.

(c) The balance of the standard cost payments is, in effect, treated as a charge to be paid by the industry as a whole."(p.28).

Chadwick and Nieuwoudt pointed out that since millers were not directly liable for transport costs they had little economic incentive to locate mills at optimum sites. There was also little incentive for millers to exchange cane quotas to reduce transport costs (p.24). Chadwick estimated that inefficiencies caused by the Cane Transport Scheme increased costs by R18 million a year, which amounted to about 25% of total transport costs in

1981/82 (p.176). A summary of transport subsidies paid in the six years 1976/77 to 1981/82 is given in Appendix 1.

The Committee of Inquiry into the Sugar Industry (1982) recommended that growers accept full responsibility for transport costs (p.33). As this would have far-reaching repercussions they proposed that a fund be established to compensate "losers", that is, growers and millers who would be worse off. "Gainers" will contribute to this fund over seven years whereas "losers" will be compensated to the extent of the capitalized present value of the annual loss, based on the tonnage in a normal season. Compensation will be in five equal instalments. The Committee's recommendations were accepted by the Sugar Industry and were implemented at the start of the 1984/85 season.

3.3 PERFORMANCE OF THE SOUTH AFRICAN SUGAR INDUSTRY

The performance of the Industry in terms of total cane and sugar production, mean yields per hectare, sugar recovery and exportable surplus for 25 years, is summarized by the South African Sugar Association (1982/83, pp.192-93). Although the area under sugar-cane increased by 63% during the 25 - year period 1958/59 to 1982/83, sugar production and area harvested doubled. Yield of sugar per hectare harvested has remained virtually constant whereas yield per hectare under cane has increased. This implies that cane is being cut at a younger age. A major reason for this was the introduction of irrigation areas such as Pongola and the Eastern Transvaal during the 1960's. Here cane is cut every 12 to 15 months whereas in dryland areas the cutting age is 18 to 24 months. Figure 3.1 reflects trends in cane yields per hectare harvested and per hectare under cane as well as the annual rainfall from 1958/59 to 1982/83.

Note that cane yields per hectare lag rainfall by a year. Since sugar-cane is a perennial crop which under dryland conditions is cut after 18 to 24 months the benefit (harm) of a good (poor) rainfall in one year is mostly realized the following year when cane is harvested.

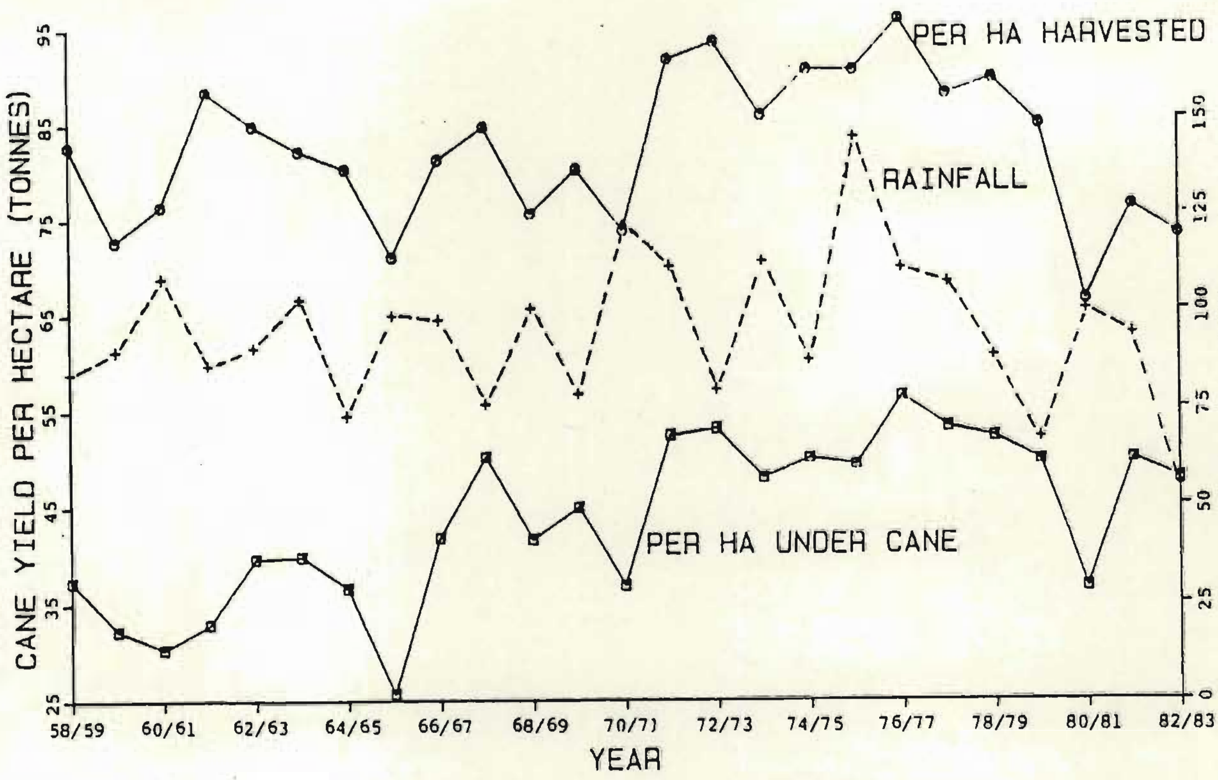

Figure 3.1 Sugar-cane yields per hectare harvested and per hectare under cane, and annual rainfall, South African Sugar Industry, 1958/59 to 1982/83.

It is noteworthy that the cane to sugar ratio has deteriorated over the 25 - year period, namely from a five-year mean of 8.81 (1958/59 to 1962/63) to a mean of 9.06 (1978/79 to 1982/83). However, overall recovery and average extraction improved, reflecting increased efficiency by millers. Both Ardington (1980/81) and Jones (1980/81) recognized the necessity for improving cane quality. Extraneous matter such as tops, trash, roots and soil make up about 10% of cane tonnage supplied to mills. Jones (1982/83) pointed out that potential benefits of reducing extraneous matter would be four-fold, namely

1) increased sugar recovery of about 20 000 tonnes a year;

2) an overall reduction in tonnage hauled of about 750 000 tonnes (extraneous matter reduced by four percentage points);

3) a saving in capital expenditure to millers (a 4% reduction in extraneous matter is equivalent to about 300 tonnes cane per hour worth R40 million in capital expenditure); and

4) a reduction in maintenance costs of several million rand a year. Overall, cane should be "clean, fresh and mature" (op. cit., p.46).

Van der Pol maintained that although the S.A. Sugar Industry's sucrose recovery was amongst the highest in the world, he was not convinced that the Industry was the most cost-effective one as the cane to sugar ratio had not improved significantly over the last decade despite improvements in factory performance (p.47).

Of the 122 sugar producing countries of the world South Africa is the 12th largest producer, accounting for 2% to 3% of total tonnage (Financial Mail, 1981, p.17). The USSR is the world's largest sugar producer followed by Brazil, Cuba, India and France. These five countries account for about 37% of world sugar production.

3.4 MARKETING OF SUGAR

3.4.1 The domestic market

The proportion of total sugar consumption for industrial uses increased steadily from a three - year mean of 20.3%, centred on 1959/60, to a three - year mean 20 years later of 27.2%. It reached a peak of 29.7% in 1981/82. Direct consumption showed a corresponding decrease (South African Sugar Association, 1982/83, p.196). Per capita consumption of sugar has fluctuated from year to year with the trade price and is reflected in Figure 3.2 (prices are on a 1979/80 basis). Total sugar consumption per capita averaged 36.85kg during the five years 1976/77 to 1980/81, whereas direct consumption per capita averaged 26.97kg during the same period (op. cit., p.196).

Peaks (troughs) in consumption correspond to low (high) prices. For example, following price increases of about 46% in the period 1965/66 to 1967/68 per capita sugar consumption dropped to a low level of 32.54kg in 1967/68 from 35.98kg in 1965/66. Two price decreases in the period 1971/72 to 1974/75, in which sugar prices fell by 19%, lead to increases in per capita sugar consumption reaching 40.43kg in the 1975/76 season. From the

1st September 1976, when the price of refined sugar was increased by about 17% to R126 per tonne, there have been regular price increases. The refined sugar price reached R423 per tonne on March 5, 1982, an average increase of 28% per annum. This again led to a decline in per capita sugar consumption. However, the Sugar Industry feels that these price increases were justified since the consumer was subsidized by the Industry to the extent of R195 million during the 1970's (Ardington, 1981/82, p.59).

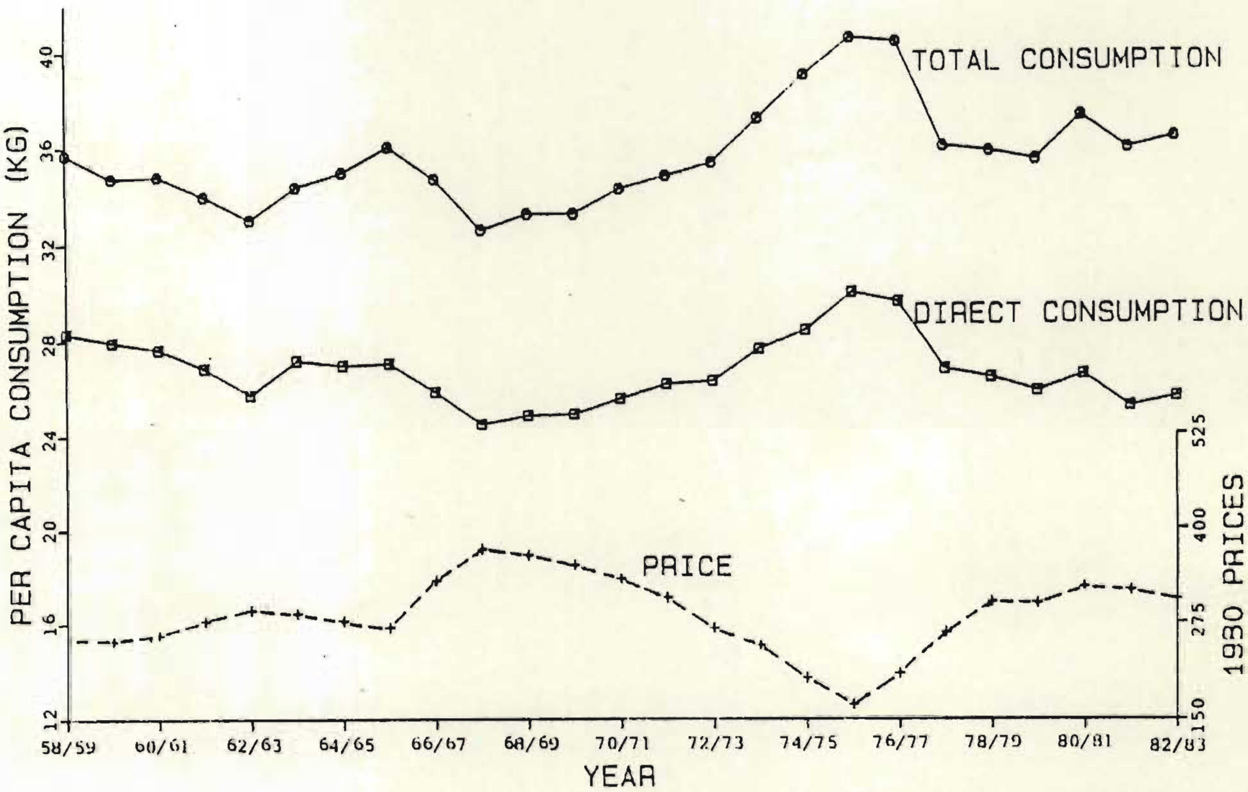

Figure 3.2 **Trends in per capita sugar consumption and wholesale prices of sugar in South Africa, 1958/59 to 1982/83.**

A study of price and per capita consumption trends entails a study of consumer responsiveness to price changes in the commodity. At the wholesale or retail level price elasticity of demand is the measure usually used to gauge responsiveness of consumers to price changes. In addition to statutory control over the industrial selling prices of sugar, maximum wholesale and retail prices for each magisterial district are prescribed in terms of the Price Control Act of 1964 (Committee of Inquiry into the Sugar Industry, 1982, p.37). Of interest to the Sugar Industry, therefore, would be the effects of price changes on sugar consumption. With sugar consumption per capita as dependent variable the following equation was derived for the 20 years 1960/61 to 1979/80 :

(3.1) $\log SUCON = 1.7071 - 0.2475 \log TRPR + 0.1337 \log REALY$

(t = -10.8) (t = 3.8)

$\bar{R}^2 = 0.90$

d = 1.85

df = 17

where SUCON = sugar consumption per capita (kg)

TRPR = real trade price of sugar (R/tonne)

REALY = real disposable income per capita

$\bar{R}^2$ = adjusted coefficient of determination

d = Durbin - Watson statistic

df = degrees of freedom

The price elasticity of demand for sugar is calculated as -0.25, that is, a 1% rise in the price of sugar is estimated to lead to a decrease in consumption of 0.25%. Cubbin (p.385) reported that Schultz's estimates of sugar demand elasticities for the USA varied from -0.27 to -0.39, while Stones' estimate for the UK was -0.44. The income elasticity of demand is estimated as 0.13 from equation (3.1). Stone calculated a coefficient of 0.1 and Houthakker 0.2 (Cubbin, p.385). These estimates were based on time series data for individual countries.

Combining cross-section and time-series data for a number of countries Cubbin (p.382) estimated a price elasticity of demand of -0.504 and an income elasticity of 0.645. From cross-sectional data of 38 countries Cubbin computed price elasticities of -0.414 and -0.344 for 1965 and 1966, respectively. Income elasticities were 0.612 and 0.56, respectively. Cubbin's explanation of the differences with other results is that use of time-series data, regressing the dependent variable on current values of the explanatory variables plus a trend, leads to an estimation of short-term effects of the independent factors. Cross-sectional analysis tends to measure longer-term effects of price changes (p.385).

The estimate of price elasticity of demand for sugar in South Africa is similar to those calculated for other individual countries. Horton reported that most estimates of the price elasticity of demand for sugar in developed countries are around -0.3 "but they are based on data for which there is a fairly high price floor level" (p.195). He suggested that if sugar could be traded at free market prices in developed countries "it is possible that a new layer of industrial demand and demand as livestock feed would develop" resulting in a significant increase in sugar sales (op. cit., p.195). Due to sugar support price policies in many developed countries the development of artificial and natural sweeteners such as high-fructose corn syrup will tend to make demand for sugar more elastic because of substitution possibilities.

High fructose corn syrup (HFCS) is experiencing a high growth rate in demand in the USA since its introduction in 1967 (Carman, p.625). It is a direct substitute for cane or beet sugar in many manufactured commodities. Carman used a logistical trend model to show that both per capita and total sugar consumption will decrease for a number of years as HFCS is adopted. HFCS could eventually account for about 25% of the total USA calorie sweetener market, given present technology and economic factors such as long run production costs for HFCS and sugar, the ratio of HFCS and sugar prices and the government's sweetener price policy. The technical market-share ceiling is approximately 30% (p.627). Carman mentioned available information which indicated that HFCS would have a long run cost advantage over domestically produced sugar in the USA due to production and processing costs and value of byproducts such as corn gluten feed, corn gluten meal and crude corn oil (p.627). However, Carman found that the impact on domestic producers under current government policy would be minimal with costs being borne mainly by sugar-exporting countries as USA imports decrease. Japan, one of South Africa's important sugar buyers, reduced overall sugar imports by 700 000 tonnes in 1981 mainly due to increased use of HFCS (Committee of Inquiry into the Sugar Industry, 1982, p.7).

In South Africa the possibility of producing HFCS has been studied. Contrary to the USA experience it does not appear to be a viable proposition at this stage (Nourse, 1983, p.12). However, it was recently reported that Coca-Cola is importing its first consignment of HFCS for use on a trial basis (Financial Mail, 1985f, p.38). This is in response to a 355% increase in the local sugar price over the last 10 years to R574 per tonne. Niall and Smith also concluded that a HFCS industry in Australia could not yet compete with the sugar industry (p.52). However, competition from substitutes in the export market constitutes a threat to sugar exporting countries. For example, in 1980 HFCS had replaced about 2.5 million tonnes of sugar, over 10% of sugar traded on the world free market. The potential is a 25% replacement (Niall and Smith, p.69).

As regards growth in sugar demand on the domestic market the S.A. Sugar Association expects an average rate of 2.8% per annum up to 1990/91 (Committee of Inquiry into the Sugar Industry, 1982, p.6). The Committee of Inquiry worked on an average growth rate of 3% per annum over the same period (p.15).

3.4.2 The export market

Of the sugar produced in the world about 70% is consumed in the country of origin and about 15% is traded under special or preferential arrangements such as the Lome' Convention and those between the Comecon countries (Nourse, 1983, p.11). The Committee of Inquiry into the Sugar Industry (1982) estimated sales by special arrangement to account for about 25% of total world sugar exports (p.40). Sales on the world free market account for about 15% of the total sugar trade. This market can be seen as a residual one so that surplusses or shortages of sugar lead to wide fluctuations in the spot price (Nourse, 1983, p.11).

International sugar agreements (ISA) have been negotiated from time to time in an attempt to control fluctuations of the world price. South Africa has been a member since the first agreement commenced in 1938 and since that time the world free market sugar trade has been regulated in only 19 years (Committee of Inquiry into the Sugar Industry, 1982, p.40). The last agreement came into force on January 1, 1978 and was extended by two years to the end of 1984. This agreement has been regarded as a failure in that it was unable to keep price fluctuations within the limits set. Most of the time the spot price was below the minimum of the price range, the main reason being surplus production. A large portion of this surplus (about 5 million tonnes) was blamed on the EEC which is not a member of the ISA (Nourse,1983, p.11).

Under the ISA basic quota allocations to exporting countries were based on their performance on the free market over an agreed number of years. By 1981 South Africa had built up a basic quota of 968 000 tonnes raw sugar, or 5.4% of the total for member countries. However, the basic quota could be adjusted upward or downward depending on the world market prices. For example, in 1981 South Africa's "quota-in-effect" was 823 000 tonnes (Committee of Inquiry into the Sugar Industry, 1982, p.41).

Negotiations in May 1984 for a new ISA were not successful and from January 1, 1985 there will be no ISA with economic provisions. The International Sugar Organization (ISO) will, however, be retained in London. Its major function will be the collection and dissemination of information. The objective is to keep people and countries in contact so that a new ISA with economic provisions may be negotiated at some future date (Hardy). The termination of the ISA is not expected to influence South Africa's relationship with its major trading partners.

South Africa's main sugar buyers have been Japan and Canada and more recently South Korea. In 1982/83, for example, Japan purchased 415 073 tonnes (44%), Canada 214 594 tonnes (23%) and South Korea 172 000 tonnes (18%) (South African Sugar Association, 1982/83, p.24). All exports are through Durban harbour where the Sugar Industry has total storage capacity in three silos of 520 000 tonnes. The bulk storage and outloading facilities are of the largest and best equipped in the world (Committee of Inquiry into the Sugar Industry, 1982, p.41).

The Sugar Industry's average export commitment is about 900 000 tonnes (Jones, 1982/83, p.46). This makes the "degree of exposure " to world free market prices about 43% of total production. Australia's is about 71% and Thailand's about 63% (Nourse, 1983, p.12).

Although the depressed state of the world sugar market is regarded as a major cause of the Sugar Industry's problems (op. cit., p.11), leaders of the Industry consider it important to supply export markets in order to retain these outlets and to maintain customer goodwill. Jones (1978/79, p.84) maintained that abandoning the export market would be a retrograde step for the Industry because of loss of markets developed over many years, loss of foreign exchange of about R250 million a year and underutilization of factories. Jones (1979/80, p. 70) further argued that the Industry never had difficulty in disposing of its export sugar because of its high quality and the Industry's reputation as a reliable supplier. Ardington (1981/82, p.53-59) maintained that restricting output in the face of low export prices would not improve the financial position of the Industry as sugar-cane is a long-term crop with a high capital investment and a high proportion of fixed costs in growing and milling. Marginal costs are low and exporting sugar - even at low prices - contributed towards covering the Industry's fixed costs. However, Ardington suggested that a more flexible and dynamic system, similar to the three-pool system in the EEC, be examined and possibly introduced to replace the "single average price" system (op. cit., p.60). This was also recommended by the Committee of Inquiry into the Sugar Industry (1982, p.18). The effects of such a scheme are to be evaluated in section 6.5.1.

3.5 CONCLUSIONS

The South African Sugar Industry has a reputation world-wide as being well-organized and a reliable supplier of high quality sugar. However, one may argue that it is in a state of flux at present following two disastrous droughts at the beginning of the 1980's, low world sugar prices, abolition of transport subsidies and the introduction in the 1985/86 season of a pool scheme. Low world prices, which are regarded a major cause of the

Industry's financial problems, could become a feature of the world market because of the use of alternative sweeteners in major industrialized countries and the sugar support policies in major producing countries. The Sugar Industry is seeking alternative uses of sugar of which ethanol is one. Chapter 4 discusses development of the sugar-cane model with which the economic feasibilty and impacts of an ethanol industry will be evaluated.

CHAPTER 4

DEVELOPING THE SUGAR-CANE MODEL - BASIC CONSIDERATIONS

4.1 INTRODUCTION

In Chapter 3 some characteristics of the S.A. Sugar Industry were discussed and evaluated. This chapter deals with considerations in the development of the sugar-cane model, which include the demarcation of the Sugar Industry into homogeneous resource areas, the potential for cane expansion and the determination of enterprise production costs. Analysis of rents for agricultural land is stressed, and in order to evaluate the effects of alternative policy measures it is necessary to simulate present production patterns, for which purpose reliable data are necessary.

4.2 DEMARCATION OF HOMOGENEOUS RESOURCE AREAS IN THE SOUTH AFRICAN SUGAR INDUSTRY

The opportunity cost of growing sugar-cane differs between areas due to differing cropping patterns. Including potential cane growing regions, the South African sugar-cane region was divided into 22 areas with help from members of the S.A. Cane Growers' Association and the S.A. Sugar Association Experiment Station. White farming areas were divided into 16 homogeneous areas with the first six groups comprising irrigation areas and the remaining 10 the dryland areas. These divisions are summarized in Table 4.1.

In the four-year period 1976/77 through 1979/80 white farmers accounted for about 91% of total cane production in South Africa, blacks for about 4%, Indians about 5% and Mangete growers 0.2% (South African Sugar Association, 1982/83, p.26).

Table 4.1 Stratification of White sugar-cane farming areas into homogeneous resource areas, South African Sugar Industry.

Strata		Region
1	Irrigated	Eastern Transvaal (Onderberg)
2	Irrigated	Pongola
3	Irrigated	Hluhluwe
4	Irrigated	Nkwaleni
5	Irrigated	Glendale
6	Irrigated	Tala Valley
7	Umfolozi Flood Plain	Umfolozi Flats
8	Zululand Coastal high rainfall	Felixton Flats
		Empangeni East
		Emoyeni
9	Zululand Coastal low rainfall	Umfolozi Hills
		Felixton North
		Empangeni West
		Amatikulu
10	Zululand hinterland	Melmoth
		Eshowe
		Entumeni
11	North Coast hinterland	Doornkop
		Melville Inland
		Kearsney
		Chakas Kraal Inland
		Upper Tongaat
12	North Coast lowlands	Darnall
		Gledhow
		Chakas Kraal Umhlali
		Tongaat
		Mount Edgecombe
		Melville
13	South Coast lowlands	Illovo Coast
		Renishaw
		Sezela
		Umzimkulu

Strata		Region
14	South Coast hinterland	Highflats Paddock Harding
15	Midlands South	Illovo-Eston Mid Illovo Richmond Camperdown
16	Midlands North	Noodsberg Union Co-op

Sources : South African Cane Growers' Association (Frean)
South African Sugar Association Experiment Station (Paxton)

For Zulu, KaNgwane, Indian and Mangete farmers demarcation was crude as data concerning production costs were not available for certain areas. Indian and Mangete growers farm in relatively homogeneous areas and were treated as two separate groups. Zulu dryland growers, who numbered about 8 000 in 1979/80, were divided into two groups, those farming south of the Tugela river and those farming north of this river (Zululand). In addition to the above four areas, two irrigation or potential irrigation areas were considered, namely KaNgwane and Makatini Flats. In 1979/80 only 219 hectares of cane were being grown in KaNgwane under irrigation (van Zyl) and none on the Makatini Flats. Both areas, however, have great potential for cane production (Committee of Inquiry into the Sugar Industry, 1982, p.10; Hellmann and Moberly).

With data obtained from the S.A. Cane Growers' Association for the four years 1976/77 through 1979/80 the mean total area under sugar-cane, the mean production of cane and sucrose and mean yields were calculated for each of the homogeneous areas comprising the white farming sector including private growers and miller-cum-planters (MCPs). This information is presented in Appendix 2. Data over four years were taken in order to obtain representative estimates of sugar-cane production and yields in these areas. In the irrigation areas MCPs achieved better yields on average than private growers. For dryland areas private growers achieved better yields in most cases.

For black growers total areas under sugar-cane and total cane and sucrose production for the same four years were obtained from Bates. These data are given in Appendix 3.

Table 4.2 summarizes the information presented in Appendices 2 and 3.

Table 4.2 Hectares under sugar-cane and yields of sugar-cane and sucrose in various areas and sectors of the South African Sugar Industry. Means over four years, 1976/77 through 1979/80.

Area/Sector	Area under cane (ha)	Cane yields (t/ha/an)	Sucrose yield (%)
Eastern Transvaal	18 424	73.0	12.8
Pongola	11 275	72.8	12.7
Hluhluwe	4 315	50.4	13.0
Nkwaleni Valley	4 822	52.8	12.5
Glendale	1 498	49.6	13.3
Tala Valley	707	53.3	12.3
Umfolozi	15 354	50.6	12.7
Zululand high rainfall	28 117	58.3	12.4
Zululand low rainfall	28 367	40.8	12.8
Zululand hinterland	18 403	49.2	13.0
North Coast hinterland	23 048	55.7	12.8
North Coast lowlands	56 942	56.7	12.8
South Coast lowlands	39 792	49.4	12.7
South Coast hinterland	17 111	44.3	13.0
Midlands South	19 870	44.0	12.8
Midlands North	39 244	39.8	12.3
KwaZulu	31 377	32.6	12.9
Indian areas	26 632	35.4	12.6
Mangete	1 558	24.4	13.1
KaNgwane	219	75.0	12.8
Makatini Flats	-	-	-

Source : Appendices 2 and 3.

4.3 EXPANSION POTENTIAL FOR SUGAR-CANE PRODUCTION IN SOUTH AFRICA

After demarcation of the white cane growing sector into 16 homogeneous resource areas the potential for cane expansion in these areas was assessed with the help of extension officers, consultants and members of the S.A. Sugar Association Experiment Station and S.A. Cane Growers' Association. For the Eastern Transvaal de Villiers provided detailed information on present land utilization and the potential for cane expansion in that area. The Committee of Inquiry into the Sugar Industry (1982) also provided some insight into potential cane expansion in certain white farming areas. It should be noted that, in this context, cane expansion potential includes the areas at present under grassland and also under crops such as vegetables, fruit, cotton, dry beans and timber. A detailed analysis of the potential areas and types of crops being grown at present is given in Appendix 4.

Of the white areas the Onderberg area of the Eastern Transvaal and the Pongola/Mkuze areas have the greatest potential for expansion. In the Onderberg region a total of about 86 000 hectares could be irrigated of which over 30 000 hectares are presently under irrigation. The volume of water provided by the Crocodile, Kaap, Komati and Lomati rivers, which feed the area, amounts to 10% of all river water in South Africa (Committee of Inquiry into the Sugar Industry, 1982, p.12). The area not being irrigated is at present under grassland and bush and is used mainly for extensive beef ranching. In the Pongola/Mkuze area up to 30 000 additional hectares could be put under irrigation if water in the Pongola and Mkuze rivers were harnessed (Havenga). At the present time investigations are being conducted by the Department of Environment Affairs into the possibility of diverting water from the Josini dam to the Mkuze Flats (Frean).

The expansion possibilities in certain black areas are vast. In KwaZulu the area under cane in 1979/80 was approximately 38 000 hectares. Milling companies have estimated that a further 90 000 hectares are suitable for cane production within economic transport distances from mills (Committee of Inquiry into the Sugar Industry, 1982, p.9). As regards the Makatini Flats the Lonrho Company has found that a net area of 28 653 hectares would be suitable for cane production (Lonrho). The Lonrho report indicates a high potential for agricultural development in that area as growing conditions are of the best in Southern Africa. Adequate water supplies from the Josini dam, suitable soils and adequate labour resources are available (Committee of Inquiry into the Sugar Industry, 1982, p.10). Cane production experiments indicated that the cane yield potential at Makatini is slightly higher than at Pongola (Hellmann and Moberly). The Lonrho report did point out that special concessions would have to be granted to ensure a viable milling enterprise in the area owing to high average milling costs. Apparantly it was for this reason that the KwaZulu government did not support recommendations made by Lonrho when submitting evidence to the Committee of Inquiry into the Sugar Industry (1982, p.9). It is interesting that shortly after the Lonrho survey was completed in 1977, the South African government had agreed in principle to the establishment of a 160 000 tonne sugar mill as part of the initial development of this area. Lonrho, which strongly recommended the production of sugar and ethanol on the Makatini Flats, was prepared to participate in the project. Lonrho suggested that these developments could also lead to the construction of a sugar terminal at Richards Bay, bearing Swaziland sugar exports in mind.

Considering all of the above factors, cane production on the Makatini Flats appears feasible provided milling operations are economically viable. The latter criterion may imply, amongst other things, that cane throughput be at a high level. A milling company venturing into the area may well demand that a substantial portion of the cane crushed should be MCP cane or that other concessions be granted.

Another black area with a great potential for cane production is KaNgwane. About 23 000 hectares of suitable land are available (Committee of Inquiry into the Sugar Industry, 1982, p.10). Water for irrigation is available from the Komati and Lomati rivers. In 1979/80 219 hectares of cane were cultivated. Despite uncertainty about the political future of this territory it has been included in this study as it is part of the Onderberg area of the Eastern Transvaal and is inextricably linked to the white farming sector in that area. The cane produced in KaNgwane will most probably be crushed by mills situated in the white farming areas, namely at Malelane (the present mill) and at a proposed new mill at Komatipoort.

Indian growers are faced with severe limitations regarding the acquisition of additional agricultural land from white farmers as a result of government legislation (op. cit., p.11). For this reason potential expansion in this sector is not considered in this study. Should the political restraints be eased or removed over time, the expansion potential allowed for in the white sector may account for potential expansion by Indian farmers. This stems from the fact that most Indian growers farm in areas where the potential to expand is limited (for example, the North Coast) and they would therefore have to compete with white growers for land. At present there are about 1 835 Indian growers farming 25 800 hectares, an average of 14 hectares per grower (op. cit., p.11). As regards the Mangete growers an additional 1 000 hectares of potential land are available (op.cit., p.10).

Table 4.3 summarizes the total area under sugar-cane as at 1979/80 and the potential areas for cane production in various regions.

Table 4.3 Areas under sugar-cane in 1979/80 and land available for sugar-cane expansion, South African Sugar Industry.

Region	Hectares under sugar-cane (1979/80)	Potential area for expansion (hectares)
Eastern Transvaal	17 780	68 220
Pongola/Mkuze	11 332	29 750
Hluhluwe	3 966	-
Nkwaleni Valley	4 395	955
Glendale	1 491	-
Tala Valley	686	-
Umfolozi Flats	14 680	-
Zululand high rainfall	28 722	2 000
Zululand low rainfall	26 824	-
Zululand hinterland	19 834	6 400
North Coast hinterland	26 384	300
North Coast lowlands	56 462	200
South Coast lowlands	38 300	3 000
South Coast hinterland	18 385	5 000
Midlands South	19 377	10 000
Midlands North	39 547	6 000
KwaZulu - North of Tugela	15 550	54 800
KwaZulu - South of Tugela	22 375	35 200
Indian	26 578	-
Mangete	1 575	1 000
KaNgwane	219	23 000
Makatini Flats	-	28 650
Total	394 462	274 475

It is obvious from the table that the greatest potential for expansion lies within the irrigable areas and KwaZulu.

4.3.1 Summary of the views of the Committee of Inquiry into the Sugar Industry (1982) on cane expansion

The Committee's findings and recommendations regarding the extent and location of cane expansion are given in their Report on pages 14-24. In essence, the Committee predicted an average growth rate of 3% per annum in local sugar consumption. Sugar exports were pegged at 1.1 million tonnes for various reasons (p.16). Ethanol production was not considered viable at the time. The Committee was of the opinion that certain restrictions should be placed on vertical expansion (pp.22-23) in order to enhance horizontal expansion, particularly in developing areas (p.21). The Committee projected that the potential for additional sugar production would be 489 000 tonnes over 10 years (p.17). Under a policy of general expansion sugar production could increase by more than 800 000 tonnes over 10 years (p.19). The above restrictions were only envisaged for the 10-year period ending 1990/91 (p.23). The Committee recommended that high priority be given to the investigation of a multiple pool system which would allow for greater flexibility when deciding whether to expand or not.

On the siting of a new mill or mills the Committee said,"... if expansion were to be envisaged on a scale which would justify the erection of a new mill in an area, the Eastern Transvaal Lowveld and Makatini would be the logical regions for the establishment of such a mill" (p.21). On the question of whether or not existing mill capacities should be increased or new mills established, the Committee recommended that economic studies be undertaken "to establish the optimum levels of size at which the long term milling and transport costs combined would be at a minimum" (p.19). The costs involved in sub-optimal siting of sugar mills in South Africa were estimated by Chadwick.

4.3.2 Conclusions

The Committee of Inquiry based its recommendations regarding cane expansion on projected supply and demand of sugar over a 10-year period. Ethanol production was not envisaged since it was considered uneconomical at the time. However, the introduction of a multiple pool scheme (which would allow greater flexibility in production) coupled with low world sugar prices and possible increases in the real price of crude oil in the longer term may render ethanol a viable source of fuel. The implications for employment opportunities and development could be significant. In its submission to the Committee the KwaZulu Government recognised the possibility of ethanol production. The Committee noted that "The KwaZulu government has also qualified its decision (of not constructing its own mill in the homeland) by intimating that, as recent developments in the production of ethanol may still make it possible to erect smaller units within the KwaZulu homeland, it wishes to reserve its position with regard to participation in projects requiring cane for ethanol production" (p.9).

In addition, the Lonrho Company strongly recommended the production of ethanol and sugar on the Makatini Flats. In the Eastern Transvaal a feasibility study undertaken on behalf of a farmers' co-operative at Komatipoort by an international firm of sugar consultants indicated that a sugar-cum-ethanol plant would be economically viable and commercially sound (Committee of Inquiry into the Sugar Industry, 1982, p.13). Such a dual purpose plant would have the advantage of flexibility in that it could switch from the production of sugar to ethanol and *vice versa*.

Given the differences of opinion regarding the economics of ethanol production it is considered important that the feasibility of ethanol production be analyzed in order to ascertain break-even prices for ethanol and the impacts of such a project in South Africa.

4.4 DETERMINING CROP PRODUCTION COSTS

4.4.1 Sugar-cane production costs

Costs of producing sugar-cane by white growers were derived from sample data gathered by the S.A. Cane Growers' Association for the years 1976/77 through 1979/80. During these years a total of 1 753 growers submitted data. These growers were allocated to the various homogeneous areas. In calculating the mean production costs for each area all extreme cases, that is, growers with less than 40 hectares and those with more than 480 hectares registered caneland, were eliminated. Since the sample of farmers is not a random one it is hoped that a more representative cost structure for each area will be achieved by eliminating the extreme cases. This procedure is also used by the S.A. Cane Growers' Association as an initial step when determining the cost of cane production on which the cane price will be based. The issue of basing prices on costs of production is a contentious one (see, for example, Belongia; Boehlje and Griffin; Groenewegen and Clayton, 1982 and 1983; Johnson, 1978; Krenz; Luttrell; Pasour, 1980 and 1983; Vaughn).

All individual cost items for the four years were converted to a 1979/80 base with the use of indices supplied by the S.A. Cane Growers' Association and other sources. These figures were summed and divided by four to give the mean result for each item on a 1979/80 basis. The mean figures for each homogeneous area, including production, registered cane area per farm and yields per hectare, are summarized in Appendix 7. Hired transport and loading costs were obtained from the transport section of the S.A. Sugar Association and are applicable to farmers in the sample.

Investments in machinery, equipment and fixed improvements per farm are on a replacement cost less depreciation basis. These were based on a survey of capital investment on cane farms at the end of 1977 by the S.A. Cane Growers' Association. Growers in this survey were divided into the homogeneous resource areas. Regression analysis was then used to determine the relationship between machinery investment and registered cane area (the explanatory variable) and total investment (excluding land) and registered cane area for each region. The choice between a linear or log function was made on the magnitude of the t-values and adjusted R^2. The mean registered cane area per sample farm was then plugged into the relevant equation and the machinery and total investments calculated. With use of relevant indices from the S.A. Cane Growers' Association these investment figures were updated to a 1979/80 basis. The results are given in Appendix 5. Depreciation on machinery and equipment was taken as 20% per annum and as 4% for fixed improvements which were found as the difference between the total and machinery investments. Interest on machinery investment was taken as 6% per annum. The reasons for using 6% are given in Appendix 6.

Interest on fixed improvements was not considered so that gross income less total costs represents the returns to own management, land and fixed improvements. This figure can be compared with land rents in each region. Although rent shows the return to land and fixed improvements it serves as a reliable indicator of the profitability of cane farming. It shows what farmers are prepared to pay for hiring additional caneland.

A comparison of the sample cane yields and the monitored population yields in the homogeneous regions showed that in all cases except one the sample yields were higher, on average by about 9%. This implies that better farmers have submitted data. The greatest differences appear to lie in the drier and cooller areas of the Industry. These areas appear to have the greatest potential for vertical expansion. For irrigation areas the difference was only about 6%.

For black areas cane production costs had to be estimated. This was done in consultation with Frean, Bates and Stead. For Zulu and Indian growers in Natal the cost per tonne of North Coast white farmers was taken and inflated by 10%. Multiplying this figure by the cane yields gave the costs per hectare. The reason for this approach is that black growers' costs per tonne are expected to be higher because of lower yields, even though overhead costs are lower. For Mangete growers the production costs per tonne of white growers in the Zululand high rainfall area (adjacent to the Mangete area) were inflated by 20%, the reasons being low yields and overmechanization. For Zulu growers in Zululand costs per tonne were based on the same area with white farmers' costs increased by 10%. For KaNgwane growers, costs per tonne before labour and fuel were based on Eastern Transvaal growers' costs per tonne since yields are only marginally different. Labour use is assumed to be higher on black farms and the transport costs for KaNgwane growers are higher because of the greater distance to the Malelane mill.

4.4.2 Production costs of other enterprises

Detailed production costs of other enterprises grown in the various demarcated areas are presented in Appendices 8 and 9. Vegetable and subtropical fruit budgets for the Eastern Transvaal were based on budgets published annually by the Division of Agricultural Production Economics and on a survey conducted by Carstens and Viljoen in the Eastern Transvaal in June 1979. Although the Division's annual budgets only consider variable costs, estimates of fixed costs per hectare were made from the survey report. Yields were obtained from various sources, including de Villiers, the Division's budgets, the Citrus and Subtropical Fruit Research Institute in Nelspruit, the Citrus Exchange and Wolstenholme.

For other areas it was difficult to obtain complete cost budgets for individual enterprises. For example, tomato and cotton variable costs for Pongola were derived from the Division's budgets for that area, but fixed costs were estimated from the Eastern Transvaal survey. Production costs of valencia oranges and grapefruit were based on Eastern Transvaal figures. The banana costing for the Natal South Coast was derived from budgets of the Banana Study Group active in that area.

Timber budgets were based on the work of Edwards and Rusk. Information on yields of timber and wattle bark in different areas was also received from members of the Institute of Commercial Forestry Research in Pietermaritzburg. Details of timber production costs are given in Appendix 9.

Data from Mail-in Records of the Division of Agricultural Production Economics were used to obtain beef gross income and variable costs per animal unit (A.U.) for various areas. As with prices of other commodities beef gross income was averaged over five years (1977/78 through 1981/82) taking account of inflation with 1979/80 = 100. Deducting the 1979/80 variable costs gave the gross margin per A.U.. According to Whitehead, his analysis of past Mail-In Records has shown that about 40% of the gross margin per A.U. would be fixed costs for extensive ranching areas such as Pongola/Mkuze and for more intensive areas, such as the Natal Midlands, about 60% of the gross margin could be used as the fixed cost estimate. The gross margin less fixed costs and interest gave rise to a net income per A.U. estimate. The net income per hectare was derived by simply dividing the net income per A.U. by the stocking density of grassland. For traditional areas in the homelands only labour was considered as a cost in beef production.

4.5 RENT OF AGRICULTURAL LAND

4.5.1 Introduction

The renting of agricultural land has occurred virtually since the start of organized land settlements (Barlowe, p.161). The popular meaning of rent is the payments made to owners of property for use of their lands and buildings. Economists often refer to rent as economic rent which Bannock *et al* defined as "the excess of total payments to a factor of production (land, labour or capital) over and above its total transfer earnings" (pp. 139-40) (where transfer earnings are earnings which are just sufficient to keep a factor in its present employment (*op. cit.*, p. 433)). In other words, economic rent is the return to a unique factor in excess of its opportunity cost or the amount it could earn in its next best alternative employment (Bullock *et al*, p. 380; Greenwald, p. 478). Thus, any factor of production with a positive sloping supply captures rent (Nieuwoudt, 1976, p. 195). Bullock *et al* (p. 380) pointed out that, although the concept of economic rent has gained general acceptance among economists, Mishan (1959, 1968, 1969), Shepherd (1970, 1971) and Wessel have shown that the concept is ambiguous and confusing.

In this study the term "rent" will be used to mean the actual payment to the property owner by the tenant. For the renting of caneland, rent includes quota rents since quotas are in operation and have a market value.

The history of land rent and the development of land theory by the Physiocrats (a group of French economists who influenced the thinking of the Classical economists, particularly Adam Smith), the Classical economists (Adam Smith, David Ricardo and John Stuart Hill) and Henry George, who initiated a popular movement in the post-classical era, are discussed by Currie (Ch.5). Other authors such as Barlowe (ch. 6), Buchanan (1929) and Worcester also provide interesting views and discussions on the history and development of rent theory.

4.5.2 Rent of sugar-cane land and production costs

Rent paid for sugar-cane land in South Africa is usually based on a proportion of gross income and varies between 10% and 15% of gross income, excluding transport subsidies and Equalization Fund payments (Frean). In some areas, for example, the Eastern Transvaal and Natal Midlands, the proportion is up to 20%. The use of this system can be debated, but the usual reason given for its use is that the sugar-cane tonnage can be easily monitored and it is a more flexible system than a fixed rent per hectare.

Rents have not been studied in any detail by the S.A. Cane Growers' Association. Renting of sugar-cane land is not practised to any great extent by farmers. In the USA, for example, renting of land is more common than in South Africa as there exists more economic pressure to increase farm sizes due to the high fixed costs of mechanization. In South Africa agriculture is less mechanized and farm sizes have not increased to the same extent as in the USA (Nieuwoudt, 1985). This also applies to sugar-cane farms in South Africa which are relatively labour-intensive.

According to the marginal productivity theory of distribution (which was developed by the neoclassical theorists including J.B.Clark, Wicksteed, Marshall, Walras and others (Jones, 1975, pp.29-30)) factors of production "will each earn an income corresponding to the value of output produced by the last unit of the factor employed" (Bannock et al, p.149). Euler proved this mathematically using a production function with constant returns to scale (Jones, 1975, pp.30-32).

Nieuwoudt (1980, p.395) has suggested that rent data could provide a useful check on production cost data by deducting rent per hectare from gross income per hectare. This procedure should introduce more objectivity in cost calculations since rents paid in a certain area serve as a reliable barometer of the profitability of farming in that area.

The fact that the S.A. Cane Growers' Association uses production costs to determine the cane price has led to speculation that farmers tend to inflate their production costs submitted to the S.A. Cane Growers'

Association by, for example, allocating costs attributable to fruit and vegetable production to sugar-cane. With this in mind it was considered appropriate to check calculated costs with the total income less rent figure. Since calculated production costs as used here do not include risk and returns to management, these are expected to be less than the total income less rent statistic. Estimates of rents per hectare in various areas were derived in consultation with extension officers in these areas and with members of the S.A. Cane Growers' Association. The figures are summarized in Table 4.4. Total income includes the relevant transport subsidy and Equalization Fund payments. Calculated costs include all transport costs, own and hired.

Table 4.4 Comparison of gross income less rent with calculated costs per hectare for sugar-cane, South African Sugar Industry, 1979/80.

Region	Total income (R/ha)*	Estimated rent (R/ha)	Total income less rent (R/ha)	Calculated costs (R/ha)
Eastern Transvaal	1 463	230	1 233	1 303
Pongola	1 482	220	1 262	1 425
Hluhluwe	977	102	875	-**
Nkwaleni Valley	1 013	107	906	1 041
Glendale	871	105	766	-**
Tala Valley	1 302	123	1 179	1 255
Umfolozi Flats	1 056	108	948	957
Zululand high rainfall	1 054	185	869	853
Zululand low rainfall	849	97	752	752
Zululand hinterland	1 037	106	931	921
North Coast hinterland	1 086	140	946	921
North Coast lowlands	1 142	207	935	891
South Coast lowlands	883	97	786	775
South Coast hinterland	978	102	876	871
Midlands South	1 028	103	925	914
Midlands North	758	121	637	612
Indian areas	629	112	517	538
Mangete	453	-	-***	419
KwaZulu - North of Tugela	604	-	-***	495
KwaZulu - South of Tugela	604	-	-***	-
KaNgwane	1 556	-	-***	1 173
Makatini	-	-	-	-

* Total income includes the transport subsidy plus Equalization Fund payments.

** No satisfactory costs could be obtained from these areas.

*** Renting of caneland is not practised in these areas.

From the table it is evident that for irrigation farms calculated costs are greater than the total income less rent figure. For dryland farms the two figures are in most cases similar. The irrigation areas are recognized by economists of the S.A. Cane Growers' Association and extension officers as profitable cane-growing areas. This is borne out by the high price of irrigation land in these areas (see Table 5.7). These prices also include quota values. It is possible that costs submitted by farmers are inflated with costs attributed to vegetables and subtropical fruit which have high cost structures. For the Nkwaleni Valley calculated costs averaged over four years (R1 041 per hectare) are higher than average total income over the same period (R1 013 per hectare). This area is an important citrus-producing area and some of these costs may have been allocated to sugar-cane.

The problem is which costs to include in the model. Ideally the calculated costs should be used and the shadow prices of land in the linear programming print-out should reflect the rents per hectare. However, using these costs for the irrigation areas would not provide a true reflection of the profitability of sugar-cane growing. For the Nkwaleni Valley sugar-cane will not appear in the solution as average costs are greater than average income, except possibly in the case where farmers have risk preference. For dryland areas the calculated costs seem reasonable when compared to the gross income less rent figures for each region.

In summary, there are three possible options, namely :

1) To use the calculated costs in each area;

2) to use the gross income less rent figure for irrigation farms and the calculated costs for dryland farms; and

3) to use the gross income less rent figure for all regions.

The first option, which would normally be the correct procedure (since the shadow prices of land can then be compared with the actual rents paid), would not be suitable for irrigation areas for reasons explained above. Option 2) would be a compromise as it would reflect more truly the profitability situation in irrigation areas. For dryland areas the calculated costs are similar to the gross income less rent figures. The argument against this option is the lack of consistency in the method of costing.

The use of option 3) has the advantage of consistency in the method of costing. However, the shadow prices of land are expected to be lower than actual rents since the model accounts for risk. Another disadvantage of this method is the fact that the quality of cost data is not being tested via a comparison of the shadow prices of land and actual rents.

Considering the pros and cons of the various options it was decided to use option 2) as it appears to be the best compromise under the circumstances. Calculated costs are used for dryland farms and the gross income less rent figure, which seems more acceptable than the calculated costs, for irrigation farms. Cane under irrigation is considered profitable and is reflected in the high price of caneland in these areas. Shadow prices of irrigation land in the model can, therefore, be expected to be lower than actual rents as risk will be considered.

4.5.3 Rent and prices of land

Rent paid for the use of land is a reflection of the profitability of a crop and is capitalized into the value of land (Nieuwoudt, 1980). Krenz reported, "As per Ricardo, farmland is worth what farmers are willing to pay for it, which depends upon what profits can be expected from production" (p.930).

Various research studies have shown that price and income support programmes are capitalized into the price of land, the right to produce and other assets (for example, Belongia, Boehlje and Griffin, Harris, Hedrick, Pasour (1980), Seagraves, Traill). In the case of sugar-cane, prices are based on costs of production while production is restricted with production quotas. Bullock et al reported that a quota has no alternative use and is perfectly inelastic in supply. Quotas "are fully utilized and, hence, acquire economic value as long as the return to the resources required in allotted crops is greater than from alternative enterprises" (p.380). When a land quota is used to restrict output, the annual rent to the quota is capitalized into the value of land. If a quota should be abolished, Bullock et al have demonstrated that "the change in land value (and, hence, wealth) is seldom equal to the capitalized value of the allotment rents" (p.380). Nieuwoudt (1976, pp.194-95) has shown that should production quotas be abolished some of the existing quota rents may be transferred to land rents resulting in higher land prices.

In sugar-cane production in South Africa rent paid by farmers incorporates both land and quota rents. Rent is thus capitalized into the value of land and quotas. According to Hudson sugar-cane quotas had a value of about R70 per tonne of sucrose in 1979/80. However, this varied widely between regions. Relationships between rents and value of land in the S.A. Sugar Industry are discussed in section 5.5.

4.6 CONCLUSIONS

In Chapter 4 basic considerations regarding the development of the sugar-cane model have been discussed. The Sugar Industry was divided into 22 areas, including 16 homogeneous areas for white farmers. This was necessary so that the unique characteristics and costs of each area could be accounted for. Zulu growers were divided into KwaZulu north and south of the Tugela River. Yields in these two Zulu areas were taken to be the same as a summarized account of each area's yields was not available. For Zulu, Indian and Mangete growers the costs of production were based on white growers' costs with adjustments made for lower yields and lower overheads. More research will have to be done in future in black areas if more detail regarding production costs is required for planning models.

The expansion potential for cane growing is vast, particularly in irrigable and black areas. The implications for development in black areas are important and have been recognised by the Committee of Inquiry into the Sugar Industry (1982). The development costs could be substantial.

As regards production costs of enterprises on white farms a substantial amount of time and effort was required to obtain estimates of these costs. The Division of Production Economics publishes a number of budgets every year which are useful for individual farmers. However, for a regional planning model fixed costs per hectare are also required, and this need provided the greatest difficulty as little information is available. Fixed costs differ widely from farm to farm and between farm sizes and this is the Division's main reason for not including them in their budgets. Normally, gross margins are not used in regional planning models as the exclusion of fixed costs would distort social costs and welfare estimates. The solution may be for the Division to also draw up budgets similar to the Economic Research Service (ERS) budgets of the US Department of Agriculture for different areas and farm sizes. The availability of such models would enhance the development of planning models in South Africa. Rent data could be an important check on the correctness of the cost data.

In Chapter 5 the development of the sugar-cane model is continued with consideration of negative sloping demand for crops, substitution between crops, positive sloping supply for labour and risk factors.

CHAPTER 5

DEVELOPING THE SUGAR-CANE MODEL - CONSIDERATION OF DEMAND, SUPPLY AND RISK FACTORS

5.1 INTRODUCTION

In this chapter the sugar-cane model is developed further. The emphasis is on the determination of negative sloping demand functions for various crops, substitution in demand between crops, positive sloping supply functions for labour and variance-covariance risk matrices. Towards the end of the chapter the simulation results of the linear programme are discussed.

5.2 CROP DEMAND FUNCTIONS

5.2.1 Structure of demand

Experiments with the model to test alternative sugar-cane policy measures necessitate a more flexible alternative than the price-taker assumptions often used in linear programming. Use of linear demand curves confronting a region enables product prices to be generated within the model.

The approach adopted in this study was to derive regional demand slopes from national demand slopes. The regional demand functions are "scaled-down" national demand functions (Kutcher, pp.50-59). Let national demand be presented by

$$p = a - bq.$$

Kutcher showed that the slope of the regional demand function (B) can be calculated with the following formula :

$$(5.1) \quad B = \frac{b(1 + \beta\ Q_2/Q_1)}{1 + bS_1\ (\alpha\ - \beta Q_2/Q_1)}$$

where Q_2/Q_1 = ratio of production in the rest of the country relative to production in the cane producing areas (Q_2 + Q_1 = national output).

β = proportion by which a production shift that occurs in the region also applies to other areas.

S_1 = slope of regional supply.

α = ratio of the slopes of supply in the rest of the country relative to the area under study.

Kutcher (p.58) showed that the regional slope coefficient B is insensitive to different α values since S_1 is numerically small. Thus, for the purpose of this study the B coefficient was calculated using only the numerator of equation (5.1). A β value of 0.25 was chosen for all crops since shifts that occur in the sugar-cane areas are expected to have little effect outside the region. A value of $\beta = 0$ implies that a shift occurring in the sugar-cane area does not occur elsewhere. Alternatively, if $\beta = 1$ a shift in the region occurs to the same extent outside this area.

5.2.2 Calculating regional demand slopes

Given the national demand equation $P = a - bq$ the slope (-b) can be calculated with the price flexibility formula :

$$P_F = dP/dq.q/P$$

where dP/dq is the slope of the demand function.
Hence $b = P_F.P/q$.

Most of the price flexibility coefficients were taken from Ortmann who analyzed demand at the farm level for a number of vegetables and subtropical fruit in South Africa. For market tomatoes a price flexibility coefficient of -1.03 was obtained from Waugh (p.34). The same coefficient was used for factory tomatoes as no better coefficient was available. For dry beans and cotton the inverses of their price elasticity coefficients, taken from Shepherd (1963, p.62(a)) and Nieuwoudt et al (1976, p.486), respectively, were used. This is not strictly correct as one is the inverse of the other only when no cross effects exist and R^2 equals unity (Colman and Miah, p.366). However, in view of the crudeness of the estimates of regional demand slopes this approach was considered acceptable.

Base regional production figures were obtained mainly from de Villiers, the Citrus and Subtropical Fruit Research Institute at Nelspruit and Duthoit. Total South African production was obtained from the Agricultural Economic Trends Division, Pretoria.

The ratio Q_2/Q_1 in equation (5.1) for each crop was calculated for the period 1979 through 1981. The mean production per annum of each crop in the region under study for the three years was the only representative figure available at the time of analysis.

As regards the base prices for each enterprise a five-year mean (1977/78 through 1981/82, centred on 1979/80) was used for all enterprises. The CPI was used to either inflate or deflate the prices to a 1979/80 basis. The simple arithmetic mean was calculated. The reasons for using these prices are explained in Appendix 11.

With the above information the regional demand slopes and the constants in the regional demand equations were calculated. Results are summarized in Table 5.1.

Demand for other enterprises considered in the model (for example, citrus, timber and beef) was taken as perfectly elastic. The reasons are that these products are either exported or imported, the price is controlled or because the region's contribution is so small as to have a negligible effect on the producer price.

Table 5.1 Determining slopes of the regional demand functions for vegetables, subtropical fruit, dry beans and cotton, South African Sugar Industry region.

Enterprise	Price flexibility	Production rest SA/ region	Base product price* (R/t)	Base regional production** (tonnes)	Total SA production** (tonnes)	Slope of regional demand (B)	Constant in regional demand equation (a)
Tomatoes-market	-1.03	13.24	205.53	16 500	234 901	$-3.884x10^{-3}$	269.62
Tomatoes-factory	-1.03	7.09	52.64	9 000	72 848	$-2.064x10^{-3}$	71.21
Cucumbers	-0.22	1.84	101.84	7 500	21 282	$-1.537x10^{-3}$	113.37
Green beans	-0.38	6.58	189.55	4 420	33 500	$-5.687x10^{-3}$	214.69
Gem squash	-1.06	2.93	83.34	11 000	43 264	$-3.538x10^{-3}$	122.25
Hubbard squash	-0.31	14.76	92.71	2 700	42 539	$-3.169x10^{-3}$	101.27
Bananas	-0.89	2.42	210.66	32 000	109 385	$-2.751x10^{-3}$	298.69
Pawpaws	-0.31	2.58	149.17	6 400	22 883	$-3.324x10^{-3}$	170.45
Mangos	-0.56	3.07	344.78	2 900	11 812	$-2.889x10^{-2}$	428.56
Litchis	-0.48	3.28	643.23	600	2 568	$-2.188x10^{-1}$	774.52
Guavas	-0.61	4.69	84.37	3 900	22 202	$-5.036x10^{-3}$	104.01
Dry Beans	-4.35	54.56	437.33	1 500	83 333	$-3.342x10^{-1}$	938.65
Cotton	-4.35	8.79	467.43	14 840	145 338	$-4.473x10^{-2}$	1 131.28

* Base prices show five-year means, 1977/79 through 1981/82, centred on 1979/80.

** Production figures show three-year means, 1979 through 1981.

5.2.3 Steps in demand functions

In a competitive market system consumer and producer surplus are maximized. This represents the total area under the demand curve less the total area under the product supply curve. Maximization of this area in the model solution corresponds to market equilibrium.

Assuming a linear demand and no cross price elasticities the demand can be specified as $P = A - BWX$

where P = n x 1 vector of prices
A = n x 1 vector of constants
B = n x n diagonal coefficient matrix
W = n x n diagonal matrix of yields
X = n x 1 vector of total hectares.

The Duloy-Norton aggregate model objective function is

$$(5.2) \quad \text{Max } Z = X'W(A - 0.5\,BWX) - C'X$$

Where the term $X'W(A - 0.5\,BWX)$ is the sum of areas under the product demand functions and $C'X$ is the area under the supply curves or total production costs (C is a vector of cost coefficients). Letting $Y = WX$, then in the single product case the following can be derived (Hazell and Scandizzo, 1974, p.236):

$$(5.3) \quad \int_0^y (a - by)dy = y(a - 0.5by) = wx(a - 0.5bwx).$$

The objective function (5.2) is quadratic and Duloy and Norton (1973) derived a method by which the function can be linearized to any degree of precision by segmenting the demand function into numerous steps. A version of this procedure was used to linearize the objective function.

For the 13 crops to which the negative sloping demand functions apply limits were set to their prices above or below which prices would not fall. It was assumed that prices would not fall by more than one-third of the base price or rise by more than 50% of this price. In fact, due to highly elastic demand curves for most crops the intercepts were below the assumed maximum price levels. With this situation the range of quantities corresponding to the two price limits were divided into 15 equal steps.

The welfare corresponding to each output level was calculated using equation (5.3). The steps are incorporated into the linear programme matrix as follows :

	Crop activity	Selling activity	RHS
Objective function	$-c_i$	w_{i1} ....w_{i15}	
Crop transfer	$-y_i$	q_{i1} ....q_{i15}	≤ 0
Demand constraint		1..........1	≤ 1

where c_i and y_i are the costs and yields of crop i per unit, respectively, and w_{ij} and q_{ij} are the welfare and total product quantities at each step.

5.2.4 Substitution in demand

So far demand for various products has been considered separable, that is, the quantity of product A depends on its price and not on prices of other commodities. Obviously this assumption is not always applicable as cross elasticities exist for many products. Hence the possibility of substitution in demand should be considered. This technique has, to the writer's knowledge, not been used except by Duloy and Norton for the CHAC model in Mexico (1975, p.592).

Of the 13 products with demand functions significant cross effects were only estimated for litchis and Hubbard squash (Ortmann, pp.20-21). For litchi consumption, litchi, mango and pawpaw prices are significant variables with mangos showing a substitution relationship and pawpaws a complementary one. The latter relationship may be due to the seasonal effect in production. According to Wolstenholme most pawpaw production takes place from spring to early summer whereas the litchi season occurs later and coincides with the mango producing period. Because the litchi and pawpaw seasons do not overlap only the relationship between litchis and mangos was considered.

For Hubbard squash consumption the significant gem squash price coefficient is negative, implying a complementary relationship. The complementarity cannot be justified and contradicts other empirical findings. For this reason it is ignored.

Duloy and Norton (1975) were the first to show how substitution in demand could be incorporated into an LP matrix when cross elasticities are known (pp.595-96). Given that significant substitution effects exist between litchis and mangos (E_L = 0.76), an attempt was made to incorporate these into the model using the method suggested by Duloy and Norton.

The objective is to calculate total welfare at various litchi and mango quantities. In order to do this regional litchi demand functions at various mango prices have to be determined. Mango prices have the effect of shifting the litchi demand curve. The slope of the regional litchi demand curve was calculated earlier as -0.21881843. With a cross elasticity of 0.76 the coefficient of the mango price in the regional litchi demand equation was calculated as 0.32254651. (The method of calculation is the same as for the regional demand slopes. The cross flexibility coefficient was estimated as 1.32, the inverse of the cross elasticity.) Because the quantities of litchis and mangos are required for the calculation of total welfare the following regional litchi demand equation was estimated :

(5.4) $Q_{LIT} = a - 4.5700P_{LIT} + 3.10033P_{MAN}$

where Q_{LIT} = estimated quantity of litchis

P_{LIT} = price of litchis

P_{MAN} = price of mangos

Since quantity is now the dependent variable the coefficients were taken as the inverses of the respective coefficients calculated earlier when flexibilities were used. Mango quantities are calculated at various mango prices using the mango demand equation determined earlier.

Using mean (base) prices of litchis and mangos of R643.23 and R344.78 per tonne, respectively, and the mean regional production of litchis of 600 tonnes the constant in equation (5.4) was estimated as 2470.63.

In calculating litchi and mango quantities prices at five different levels were used. In both cases the mean or base prices plus 10% and 20% above and below these prices were considered. The following regional litchi demand equations at various mango prices were derived.

Table 5.2 Regional litchi demand functions at various mango prices.

Level	Mango price (R/t)	Regional litchi demand
1	413.74	$Q_{LIT1} = 3\ 753.36 - 4.57P_{LIT}$
2	379.26	$Q_{LIT2} = 3\ 646.46 - 4.57P_{LIT}$
3	344.78	$Q_{LIT3} = 3\ 539.56 - 4.57P_{LIT}$
4	310.30	$Q_{LIT4} = 3\ 432.66 - 4.57P_{LIT}$
5	275.82	$Q_{LIT5} = 3\ 325.76 - 4.57P_{LIT}$

When the quantities of litchis are computed for each of the five different litchi prices twenty-five litchi quantities are involved. The corresponding welfare values can then be determined. The litchi welfares plus the mango welfares at the above prices give the total welfare for the two crops for the 25 cases.

The example above reflects the tediousness of incorporating substitution in demand into an LP matrix. The number of selling activities can be computed as (number of steps per crop)$^{\text{number of crops}}$. For example, for 15 steps per crop the number of selling activities would be 225 for two products and 3 375 for three products. This tedious process has probably discouraged many economists from using the technique.

5.3 LABOUR SUPPLY

In conventional linear programming exercises the supply of labour is either regarded as perfectly elastic or at the other extreme as perfectly inelastic or fixed. However, it can be expected that on a regional basis farmers would have to pay higher wages to attract more labour. This implies a positive sloping supply curve for labour. This is illustrated in Figure 5.1.

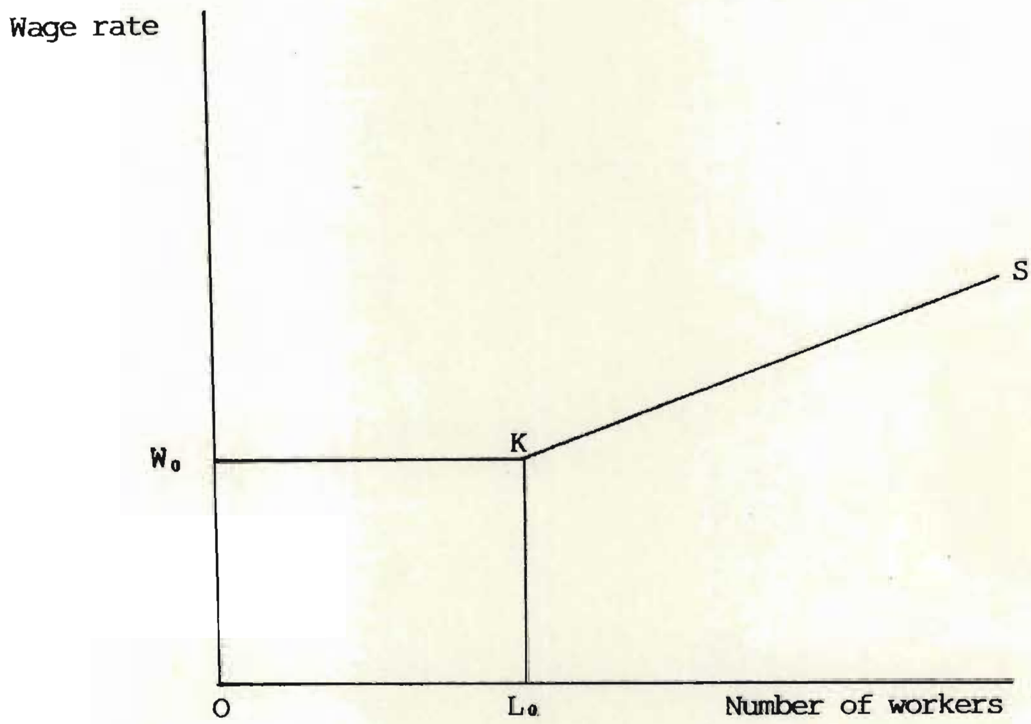

Figure 5.1 Hired labour supply curve.

The annual supply of labour in the above graph is shown by the function W_0KS. W_0 represents the going wage rate at which L_0 number of workers are employed. The supply of labour is assumed to be perfectly elastic up to point L_0. If more labour than L_0 is required higher wages will have to be offered in order to attract labour from other employment sectors.

In this study four major sugar-cane areas were identified. These are the Eastern Transvaal (Lowveld)/KaNgwane region, the Pongola/Makatini Flats area, Zululand and Natal. For each of these areas a labour supply function needs to be determined. To accomplish this, estimates of regional supply elasticities are required.

In South Africa Antrobus (p.103) estimated a supply elasticity with respect to wages for regular black farm workers of 1.96. Attempts by Antrobus to calculate regional supply elasticities were not very successful. However, Latt, using simultaneous equations, calculated supply elasticities ranging from 5.2 to 8.3 for regular black farm workers in Natal.

In the USA Schuh (p.316) estimated the long-run supply elasticity of hired labour as 1.50 at 1957 levels and as 0.78 at the means. Short-run estimates were 0.48 and 0.25, respectively. Tyrchniewicz and Schuh (1966) reported short and long-run supply elasticities of hired labour for nine regions in the USA. Significant elasticities varied from 0.316 to 0.85 in the short-run and from 0.958 to 3.507 in the long-run (p.550). In a subsequent study Tyrchniewicz and Schuh (1969) took account of interdependence among three components of the agricultural labour force in the USA, namely hired labour, unpaid family labour and operator labour. A simultaneous-equations model consisting of six equations was used. Short and long-run supply elasticities, respectively, were calculated as 0.649 and 1.545 for hired labour and 0.681 and 1.513 for unpaid family labour (p.779). No estimates were derived for operator labour.

In his study on needed adjustments in the supply of farm labour Gisser used an interval estimate for labour supply elasticity. The range of coefficients used varied from 1.0 to 3.3 (pp.810-11). Hammonds et al calculated a more elastic supply of labour in Oregon, namely 4.02 for the short-run and 5.15 for the long-run at the means. At the 1970 level the elasticity estimates were 5.46 and 6.0, respectively (p.244). The above results indicate that labour supply is generally more elastic at a regional level.

In South Africa with its relative abundance of labour and high unemployment, particularly in the homelands, one would expect labour supply to be highly elastic at regional level. This is borne out by Latt's study on regular workers in Natal. For casual workers the elasticity is expected to be even higher. Considering the above factors a labour supply elasticity of 10 was chosen for each of the four major regions, giving an estimated supply flexibility of 0.10.

The slope of a regional supply function is derived from the following equations :

$$W = C + DL$$

where W = wage rate per labour day

C = constant

D = slope (= dW/dL)

L = number of workers employed in the region.

The flexibility of labour supply (F_{LS}) is derived as follows :

$$F_{LS} = dW/dL \,.\, L/W = D.L/W$$

Hence the slope $dW/dL = F_{LS}.W/L$.

Thus, if the labour supply flexibility, the base wage rate and the number of workers or labour days employed in the region are known the slope of the regional supply function can be calculated.

Total labour use in each of the four regions was estimated with use of the basic model simulating the production pattern in each region. This was possible as labour use per activity unit (in labour days) had been estimated for each activity considered in the model.

As regards base wage rates it was found in this study that wages differed between enterprises in the same region. This is mainly due to differences in effort required in harvesting crops. For example, cutting sugar-cane requires more effort by a worker than harvesting vegetables. Hence, cane wages tend to be higher. Labour for the various activities generally came from the same source. In calculating slopes of the regional supply functions the weighted average wage, including cash wages and rations, for each region was used. These amounted to R2.05, R1.93, R2.36 and R2.50 per labour day for Eastern Transvaal/KaNgwane, Pongola/Makatini Flats, Zululand and Natal, respectively. Total employment and slopes of supply functions for each region are summarized in Table 5.3.

Table 5.3 Total labour employment and slopes of labour supply functions in four regions of the South African Sugar Industry.

Region	Total labour employment (labour days)	Slopes of regional labour supply functions
EasternTransvaal/KaNgwane	3.736×10^6	5.595×10^{-8}
Pongola/Makatini	1.969×10^6	9.804×10^{-8}
Zululand	11.303×10^6	2.097×10^{-8}
Natal	22.076×10^6	1.132×10^{-8}

An important point regarding employment of more workers in a region is the increase in wage rates with increased demand for workers. This is illustrated in Figure 5.2 below.

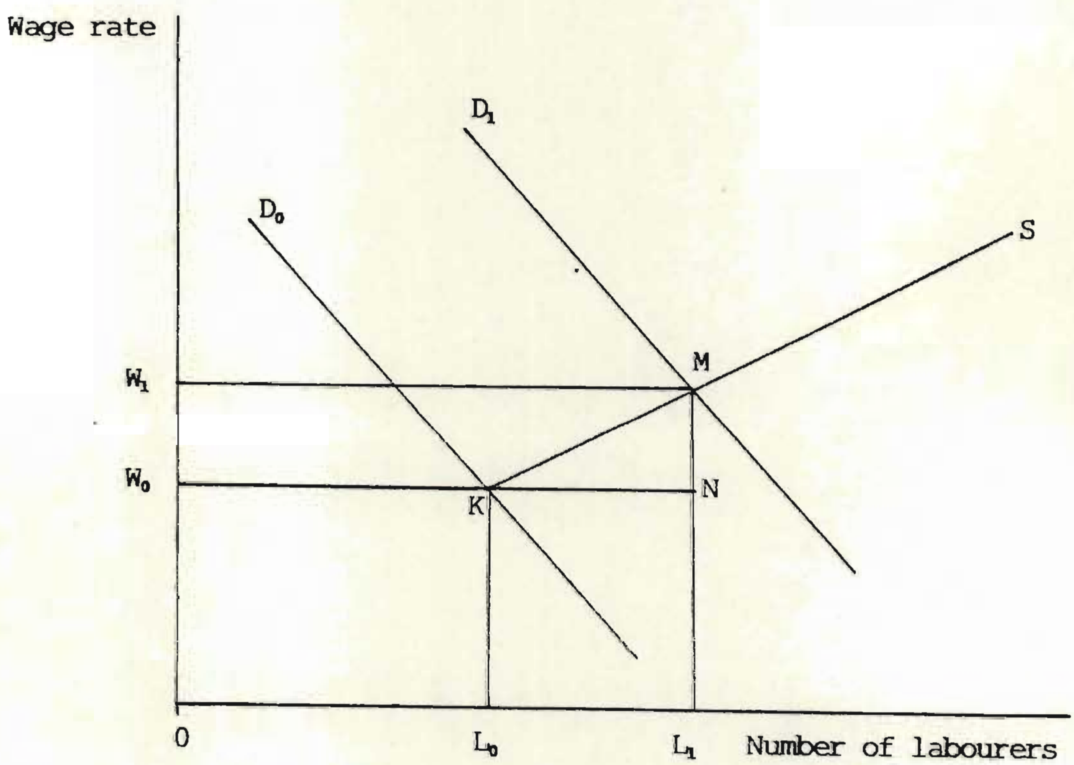

Figure 5.2 An increased demand for labour leads to an increase in the base wage rate.

From Figure 5.2 an increase in demand for labour leads to an increase in the wage rate to W_1. Labour cost increases from area OW_0KL_0 to OW_1ML_1. The fact that base wage rates differ among crops means that the intercept changes. The regional slope is taken to remain the same. The cost of labour at different levels of employment was calculated with aid of a programme developed for this purpose in conjunction with Price.

The positive sloping labour supply function was divided into 15 equal steps. These represent the extra labour that can be hired at various wage rates. The maximum amount of labour that can be hired was estimated for each region based on the possibility of maximum cane expansion. Additional labour that could be hired for each region was 4.5, 6.0, 1.5 and 1.25 times the base employment figures, respectively.

The above information was included in the LP matrix as shown in Table 5.4 (Nieuwoudt, 1984), using a simple example involving two crops :

Table 5.4 LP tableau incorporating step labour supply functions.

Rows	Activities							
	CROP1	CROP2	LAB1	LAB2	LABT1	LABT2	LABHS1....LABHS15	RHS
C	$-C1$	$-C2$			$-W_{01}$	$-W_{02}$	- LC1..... - LC15	
LABTR1	L1		-1					≤ 0
LABTR2		L2		-1				≤ 0
LABRST			1	1			- LH1..... - LH15	$\leq$ BRL
LABR							1..........1	≤ 1
LABTTR1	L1				-1			≤ 0
LABTTR2		L2				-1		≤ 0

LABTR = labour transfer

LABRST = labour restriction

LABR = labour supply constraint

LABTTR = labour total transfer

LABT = labour total

LABHS = labour hire supply (15 steps)

W_0 = base wage rate

LC = labour cost (area under supply curve above W_0 line)

LH = labour hire

BRL = base regional labour (units)

For example, labour activities LAB1 and LABT1 will account for labour employment OL_1 in Figure 5.2 at wage rate W_{01}. In the C-row under the step supply activities area W_0W_1MN (Figure 5.2) is entered. This area is obtained by multiplying OL_1 by the difference in the wage rates ($W_1 - W_0$). The area changes with increasing wages. This extra cost is added to the base cost via the extra labour employed in the LABRST row.

Positive sloping supply schedules have not been widely used in LP models. Nieuwoudt et al (1975) in their economic analysis of alternative peanut programmes in the USA considered labour supply functions for the months May to October, the period of high labour employment on farms in the USA. Hazell (1979) explained a method for incorporating stepped input supply curves in an LP model. However, it appears that he was not aware of the work done by Nieuwoudt et al in 1975.

5.4 INCLUSION OF RISK

Since Freund's classic article in 1956 on the introduction of risk into a programming model, rapid developments have occurred in techniques for incorporating risk into farm planning models, particularly of single-period optimization models (Hazell, 1982). Some examples of research into incorporating risk in farm planning models include work by Camm, Heady and Candler, McFarquhar, Stovall, Hazell (1971), Hazell and Scandizzo (1974), Schurle and Erven, and Scott and Baker. The first four papers considered quadratic programming, as developed by Markowitz, as a useful method for incorporating income uncertainty in farm planning. However, since "available quadratic programming computer codes with the necessary parametric option are of limited dimensions and uncertain performance" (Hazell, 1971, p.56), Hazell (1971) and Hazell and Scandizzo (1974) suggested linearization techniques which enable conventional linear programming to be used. McCarl and Tice maintained that Hazell's approach "works well for risk programming and provides superb computational advantages for large problems" (p.588). Hazell's method has been adopted for this study.

Evidence suggests that farmers behave in a risk-averse manner (Hazell, 1982, p.384; Young, p.1065). Neglect of risk in planning models can lead to considerable overstatements in the size of the risky enterprises. Other consequences may be specialized cropping patterns, biased estimates of the supply elasticities of individual commodities, overestimation of the value of certain resources, such as land and irrigation water, and the incorrect prediction of technology choices (Hazell, 1982, p.384).

In this analysis possible risk-averse behaviour of farmers is allowed for. The extent to which farmers discount expected income therefore needs to be determined. For this purpose the criterion $E - \emptyset \sigma$ is maximized, where E is expected income, $\emptyset$ is a constant and σ the standard deviation of income. A value of $\emptyset = 0$ implies risk-neutrality. The optimum value of $\emptyset$ will be determined where the present regional organizational structure is best simulated.

Risk can be considered as a cost, namely the additional expected return that farmers want as compensation for taking risk (Barry and Fraser, p.288). The inclusion of risk means that the marginal cost (MC) or new supply curve shifts to the left. Under perfect competition equilibrium supplies will thus be reduced.

In this study the risk associated with various enterprises is taken to be reflected in the deviations of gross income per hectare from the trend line. The enterprise price elasticities relate price and yield variabilities to income variability. This measure of risk was also used by Nieuwoudt <u>et al</u> (1975) and Simmons and Pomareda. The mean absolute deviation method was first proposed by Hazell (1971) and later developed by Hazell and Scandizzo (1974).

Risk can now be included in equation (5.2) as a cost factor in the following way (Hazell and Scandizzo, 1974) :

(5.5) $\quad \text{Max } Z = X'W(A - 0.5BWX) - C'X - \emptyset\,(X'\Omega X)$

Where Ω is a variance-covariance matrix of gross incomes per hectare. The term $C'X + \emptyset\ (X'\Omega X)$ is the revised sum of areas under the supply curves, with $(X'\Omega X)$ being the variance.

Use of the mean absolute estimate of variance requires linearization of the function. For purposes of this study the estimate of the standard deviation was used, a procedure followed by Nieuwoudt et al (1975) and Simmons and Pomareda. The standard deviation estimate is calculated as follows :

(5.6) $\quad Est(X'\Omega X)^{1/2} = \sqrt{\Delta}\ /T\ \{\Sigma_t \mid \Sigma_j\ (r_{jt} - \bar{r}_j)X_j \mid\}$

where $\Delta = T\Pi/2(T-1)$, a "correction factor to convert the square of the mean absolute deviation to an estimate of the population variance (assuming the population is normally distributed)" (Simmons and Pomareda, p.473).

T = number of periods considered

$(r_{ji} - \bar{r}_j)$ = deviations of gross income from trend

Π = mathematical constant

Inclusion of risk in an LP matrix using the estimate of the standard deviation version is demonstrated in Appendix 12.

In summary, the programming model for the competitive case, including labour cost (LC), is as follows :

(5.7) $\quad Max\ Z = X'W(A - 0.5BWX) - C'X - LC - \Sigma_{i=1}^{N}\ \emptyset_i (X'\Omega X)^{1/2}$

where N = number of major regions (four in this study).

As was pointed out in section 5.3 four major sugar-cane producing areas were identified is this study, namely Eastern Transvaal/KaNgwane, Pongola/Makatini Flats, Zululand and Natal. A variance-covariance matrix is included for each area to account for risk in production. Six years were considered for risk analysis, namely 1976/77 through 1981/82.

Gross incomes per hectare per annum for sugar-cane in these regions were calculated from data received from the S.A. Cane Growers' Association. For other crops farmers and farming companies provided data on gross incomes and hectares harvested for the six years. Data on valencia oranges and grapefruit for the Eastern Transvaal, Pongola and Nkwaleni were received from the Citrus Exchange (Kruger).

For some subtropical fruits data on hectares harvested rather than total area under the crop were obtained as substantial areas have recently been planted, particularly in the Eastern Transvaal. Inclusion of total area would have rendered gross income per hectare per annum meaningless since the production rotation was not yet in operation. Since the perennial crop budgets are on an established rotation to reflect a crop's profitability, gross income per hectare per annum used for the risk analysis should be on the same basis. An estimate of this figure was obtained by multiplying gross income per hectare harvested by the number of "bearing" years and dividing it by the life period of a tree in years.

For timber, data on total areas felled, the weighted average age of timber felled and gross income were received from farming companies. With this data it was possible to calculate gross income per hectare per annum for eucalyptus, black wattle and pine. The deviations from trend of the above enterprises are summarized in Appendix 13.

As regards beef, gross incomes per animal unit (A.U.) were derived from Mail-In Record business summaries for the same six-year period. Data from the Melmoth study group were used for Pongola/Mkuze and the Eastern Transvaal as conditions there are similar. Gross incomes per A.U. were divided by grassland stocking densities in those areas (namely, five hectares per A.U. for Pongola/Mkuze and 4.5 for the Eastern Transvaal) to obtain gross incomes per hectare for each year. For the Natal Midlands and Natal Coastal hinterland data from the Natal Midlands study group were used. In both regions grassland stocking density is about two hectares per A.U. (du Toit).

In KwaZulu the actual stocking density of grassland is about two hectares per A.U.. The optimum carrying capacity is estimated at 2.62 hectares per A.U.. On the Makatini Flats the stocking density is about 4.3 hectares per A.U. whereas the optimum is five hectares or more (Colvin). Overgrazing in KwaZulu is a serious problem as it leads to degradation of grassland and soil erosion. Many attempts to solve the problem have failed. Doran et al contend that failure to recognise that cattle are held as a store of wealth in traditional societies may worsen the serious overgrazing problem when attempting to implement production-oriented programmes. Since the traditional farmer has no individual title to land cattle are "the most accessible and reliable vehicle for the accumulation of wealth" (p.45). Cattle act as a savings account. Low et al contend that production-oriented development programmes should be accompanied by a change in the land tenure system or effective grazing controls (p.617).

The above situation has implications for beef gross income per hectare. Both income from sales and growth in wealth have to be considered. Since beef gross income per hectare for KwaZulu is not available it was estimated by using total value of sales and slaughterings and total cattle population. These data were obtained from the Agricultural Economic Trends Division in Pretoria. By converting the herd numbers to A.U.s, the gross income per A.U. and per hectare (via the stocking density) were derived. The wealth aspect was included by considering increases in beef prices from year to year. The deviations from trend data for KwaZulu, the Makatini Flats and KaNgwane (five hectares per A.U.) are summarized in Appendix 13. In the next section results of the simulation excercise are discussed.

5.5 COMPARISONS OF MODEL SOLUTIONS WITH ACTUAL CROPPING PATTERNS AND PRICES

Before the model can be used to evaluate alternative sugar policies, results must be compared with actual cropping patterns. This also provides a check on cost data.

Sensitivity of the optimal solution was determined by using different values of Ø. The value of Ø which yields solutions closest to actual cropping patterns will be used to study various policy measures. In essence Ø is used as a fine-tuning device.

In cases where enterprises contribute only a small proportion of national production (for example, beef and timber) or are sold on the world market (for example, citrus) elastic demands were assumed. Upper bounds were placed on the different categories of land such as grassland and timberland. For sugar-cane, registered areas in various regions in 1979/80 were used as upper bounds. Shadow prices per hectare should indicate rent.

In Table 5.5 (p.101) actual crop areas are compared with estimates in two regions with Ø = 0, 0.25, 0.5 and 1.0. Other regions predominantly produce crops with elastic demands (for example, timber) in addition to sugar-cane.

It is of interest to study the effects of increasing Ø values on crop production. Of vegetables produced in the Eastern Transvaal both market and factory tomatoes and Hubbard squash are most sensitive to changing Ø values. Of the subtropical fruits pawpaws, litchis and guavas increase in area with increasing Ø values. Production of dry beans and dryland cotton decrease while area under irrigated cotton increases with rising Ø. Areas under dryland cotton at Pongola are also lower at Ø = 1. Grassland and citrus areas are not affected.

In other regions production is not influenced by increasing Ø values except for Tala Valley and Mangete growers who would not be growing sugar-cane at Ø = 1. Also, at this value, beef on grassland in KaNgwane came in at zero.

In determining producer surplus primal prices were used. The prices were calculated ex post from the demand functions. Primal and dual prices would be equal in the absence of discontinuities; hence, the more steps used to segment a section of the demand curve the smaller the difference between primal and dual prices (Kutcher, pp. 48-49). "The dual price is the shadow price of that segment of the demand curve that is selected in the optimum solution" (Nieuwoudt et al, 1975, p. 16).

Table 5.5 Comparisons of actual cropping patterns with equilibrium solutions at various Ø values in two homogeneous areas, South African Sugar Industry, 1979/80.

Particulars	Actual area (ha)	Model solutions (ha) for Ø=0	Ø=0.25	Ø=0.50	Ø=1.0
1. Eastern Transvaal					
Sugar-cane	17 780	17 780	17 780	17 780	17 780
Tomatoes-market	200	463	138	0	0
Tomatoes-factory	300	375	292	208	42
Cucumbers	350*	296	395	395	325
Green beans	520*	391	522	522	522
Gem squash	350*	343	386	386	386
Hubbard squash	150	140	148	99	0
Seed dry beans	300*	300	300	300	300
Dry beans	1 000**	975	975	923	769
Cotton-irrigated	3 180***	3 067	3 194	3 516	4 006
Cotton-dryland	800	800	800	432	0
Tobacco	200	200	200	200	200
Bananas****	1 000	1 000	1 000	1 000	1 000
Pawpaws	320	315	315	381	381
Mangos	400	400	400	286	235
Litchis	200	200	200	225	275
Guavas	130	135	135	158	158
Valencias	1 290	1 290	1 290	1 290	1 290
Grapefruit	1 700	1 700	1 700	1 700	1 700
Grassland (beef)	56 000	56 000	56 000	56 000	56 000
2. Pongola					
Sugar-cane	11 332	11 332	11 332	11 332	11 332
Tomatoes-market	250	250	250	250	250
Cotton-dryland	4 000	4 000	4 000	4 000	3 462
Valencias	135	135	135	135	135
Grapefruit	365	365	365	365	365
Grassland(beef)	25 000	25 000	25 000	25 000	25 000
Total producer surplus (Rm) (all regions)		73.4	66.4	59.2	45.3

* 30% of this area is double-cropped with cotton.

** 50% of this area is double-cropped with cotton.

*** Excludes double-cropping areas with vegetables and dry beans.

**** Despite efforts to validate income and cost data, bananas were included at unrealistic levels in the model. Bananas were then restricted to the current hectarage.

Of major importance is the effect of increasing Ø on shadow prices of land. These generally show decreases with increasing Ø values. This is also reflected in the decreasing producer surplus from R73.4 million for Ø = 0 to R45.3 million for Ø = 1. The shadow price of land under subtropical fruit, however, increases with higher values of Ø. This can be explained by the inclusion of crops with high negative covariances. Some examples of land shadow prices at Ø = 0 and Ø = 1 are given in Table 5.6.

Table 5.6 Shadow prices for various categories of land in different regions at Ø = 0 and 1.0, South African Sugar Industry, 1979/80.

Region	Land category	Shadow prices of land (R/ha)	
		Ø=0	Ø=1
Eastern Transvaal	Sugar-cane	230	113
	Arable-irrigated	171	137
	Fruit	208	280
	Grassland	7	3
Pongola	Sugar-cane	220	25
	Arable-dryland	54	0
	Grassland	6	4
Nkwaleni	Sugar-cane	127	57
Zululand high rainfall	Sugar-cane	201	131
	Timber	88	80
Zululand low rainfall	Sugar-cane	97	27
Zululand hinterland	Sugar-cane	116	46
	Timber	52	38
	Grassland	10	4
North Coast	Sugar-cane	251	191
South Coast	Sugar-cane	107	47
	Banana-land	94	47
	Timber	50	43
Natal Midlands	Sugar-cane	146	86
	Timber	64	57
	Grassland	11	16

A study of land shadow prices indicates that the most dramatic effect of increasing $\emptyset$ has been to reduce rent of caneland. The effect on timberland has been relatively small.

The question now is, at which $\emptyset$ value is the actual cropping pattern best simulated? One way to determine this is to calculate correlations between actual areas and those under various $\emptyset$ values. The squared simple correlations between actual and simulated areas at $\emptyset$ = 0, 0.25, 0.5 and 1.0 are 0.994, 0.9996, 0.987 and 0.921, respectively. Crop areas which were not affected by the different $\emptyset$ values were excluded in calculating these correlations. Thus the model with $\emptyset$ = 0.25 provides the best explanation of observed areas. Correlations are high because of restrictions on different classes of land and partly because the model simulates well.

A study of shadow prices of land in the model where $\emptyset$ = 0.25 indicates that these compare favourably with actual rents paid by farmers. This is shown in Table 5.7. As rents paid for certain other lands (for example, fruitland and grassland) were not available the ratio of shadow price to land value indicates a realistic value, that is, less than 5%. Land values for sugar-cane were based on five years of data (1977/78 through 1981/82), centred on 1979/80. These data were obtained from the S.A. Cane Growers' Association. Generally, farms covering less than 2% of the total area under sugar-cane are sold annually. The sample of farm sales may not be representative.

Nieuwoudt (1980, p.396) calculated a capitalization rate for land in South African agriculture of 5.4% for 1978/79. Poray (p.35) reported a lower rate of 3.2% for 1982. The arithmetic mean capitalization rate for sugar-cane land (including quotas) based on actual rents is 6.2% and 5.7% based on the shadow prices in Table 5.7. These are higher than for land only since the capitalization rate for quotas is expected to be higher because of greater risk.

Table 5.7 Land rents, shadow prices (for β= 0.25), land values and yields in certain areas of the South African Sugar Industry, 1979/80.

Region	Land category	Shadow prices (R/ha)	Estimated rent (R/ha)	Land values (R/ha)	Shadow price/land value (%)	Rent/land value (%)
Eastern Transvaal	Sugar-cane*	201	230	2 778	7.2	8.3
	Arable-irrigated	125	100	2 500	5.0	4.0
	Fruit	239	n.a.	5 500	4.3	-
	Grassland	6	n.a.	250	2.4	-
Pongola	Sugar-cane*	171	220	4 028	4.2	5.5
	Grassland	6	n.a.	200	3.0	-
Nkwaleni	Sugar-cane*	89	107	1 607	5.5	6.7
Umfolozi	Sugar-cane	81	129	2 803	2.9	4.6
Zululand high rainfall	Sugar-cane	184	185	3 128	5.9	5.9
Zululand low rainfall	Sugar-cane	79	97	1 558	5.1	6.2
Zululand hinterland	Sugar-cane	99	106	1 798	5.5	5.9
North Coast hinterland	Sugar-cane	150	140	1 870	8.0	7.5
North Coast lowlands	Sugar-cane	236	207	2 670	8.8	7.8
South Coast lowlands	Sugar-cane	92	97	2 074	4.4	4.7
Natal Midlands-South	Sugar-cane	99	103	2 096	4.7	4.9
Natal Midlands-North	Sugar-cane	131	121	2 013	6.5	6.0
	Timber	62	30-60	1 500	4.1	3.7

* Shadow prices of caneland in irrigation areas are lower than estimated rent since costs were based on gross income less rent. Inclusion of risk in the model resulted in lower shadow prices.

Estimates of quota rents and quota values per tonne of sucrose in various regions were derived from the model. Quota rents per hectare represent the difference between shadow prices of caneland (including quotas) and shadow prices of land used to grow the next best alternative crop. Quota rents and values in Table 5.8 are given on a per tonne sucrose basis because yields vary widely between regions. The capitalization rate used to obtain quota values is 15%. It is higher than for land because of greater risk.

According to Hudson quota values in 1979/80 were in the region of R70 per tonne of sucrose on average. However, quota values varied widely between regions. The estimates in Table 5.8 appear to be in line.

Table 5.8 Estimated quota rents and quota values in various regions of the South African Sugar Industry, 1979/80.

Region	Quota rents (R/tonne sucrose)	Quota values (R/tonne sucrose)
Eastern Transvaal	12.90*	86
Zululand high rainfall	13.21	88
Zululand hinterland	7.40	49
North Coast hinterland	15.12	101
North Coast lowlands	22.13	148
South Coast lowlands	7.06	47
South Coast hinterland	8.59	57
Midlands South	9.92	66
Midlands North	12.89	86

* This quota rent is derived from actual rents, because the model may have underestimated the shadow price since gross income less rent was used as a measure of profit in the Eastern Transvaal but not in the other (dryland) areas. Capitalization rate = 15%.

Another exercise to test the validity of the model is to compare endogenously generated prices with the actual prices of enterprises with negative sloping demand functions. Table 5.9 summarizes the actual prices and dual prices for $\emptyset$ values of 0, 0.25, 0.5 and 1.0.

Table 5.9 shows that actual prices compare well with the relevant dual prices at $\emptyset = 0.25$. Squared simple correlations between actual and dual prices at $\emptyset = 0$, 0.25, 0.5 and 1.0 are 0.995, 0.999, 0.994 and 0.965, respectively.

A significance test with Pearson's correlation showed that all correlation coefficients were highly significant, at least at the 1% level. On this basis a $\emptyset$ value of 0.25 was used as it simulates the actual cropping patterns best. Before this value is compared with $\emptyset$ values obtained in other studies, results concerning labour employment on farms, fuel use by farmers and contractors are summarized in Table 5.10. These figures were obtained from the simulation model with $\emptyset = 0.25$.

Table 5.9 Actual prices compared with endogenously generated (dual) prices for various crops at various Ø values, 1979/80.

Crop	Actual prices (R/t)	Dual prices (R/t) at			
		Ø=0	Ø=0.25	Ø=0.50	Ø=1.0
Tomatoes-market	205.53	170.71	208.82	227.01	227.01
Tomatoes-factory	52.64	48.61	52.48	57.22	68.89
Cucumbers	101.84	103.78	100.23	99.89	102.00
Green beans	189.55	198.38	191.40	187.48	188.59
Gem squash	83.34	82.04	80.66	80.10	81.34
Hubbard squash	92.71	94.22	94.05	95.32	101.35
Dry beans	437.33	450.73	452.90	472.46	558.91
Cotton	467.43	486.88	464.66	454.30	464.59
Bananas	210.66	213.91	213.91	213.91	213.91
Pawpaws	149.17	147.62	147.62	146.72	145.25
Mangos	344.78	336.30	343.08	347.37	354.63
Litchis	643.23	629.38	629.13	622.87	611.04
Guavas	84.37	82.25	82.12	81.40	80.50

Table 5.10 Labour employment on farms and fuel use by farmers and contractors in four regions of the South African Sugar Industry, 1979/80.

Regions	Labour employment		Fuel use	
	Labour days (10^6 days)	Units	Farmers (10^6 l)	Contractors (10^6 l)
E.Transvaal/KaNgwane	3.736	12 453	5.942	3.685
Pongola/Makatini	1.969	6 562	3.007	0.267
Zululand	11.303	37 677	14.624	6.938
Natal	22.076	73 588	31.541	17.213
TOTAL	39.084	130 280	55.114	28.103

The estimated number of people employed in the area under study seems realistic as 150 000 workers are employed directly by the Sugar Industry (Smeaton, p.236). The latter figure, however, includes factory workers and administrative personnel whereas the estimated employment of 130 280 includes only black workers on farms.

Fuel use on farms and by contractors who transport sugar-cane and timber is interesting as the figures can be compared with the amount of ethanol produced. Since total fuel use is derived from each activity the impacts of higher fuel prices and/or reduced fuel supplies on production can also be ascertained. On farms fuel use consists of both diesel and petrol. Proportions of these two fuels used in different areas are summarized in Appendix 14.

A comparison of the Ø value of 0.25 with values obtained by other researchers is considered important. According to Simmons and Pomareda (p.473) the value of Ø is conceptually an aggregation of individuals' risk-aversion coefficients. Hazell and Scandizzo (1977), who developed an LP model of agricultural production at a subsector level in Mexico, found the best simulation when Ø = 1 (p.208). Nieuwoudt <u>et al</u> (1976) reported a value of Ø = 2 as giving the best solution in simulating peanut production in the USA. Simmons and Pomareda used a value of Ø = 0.5 in their study of vegetable production and exports in Mexico (p.476). For export crops Ø = 0.5 gave the best fit while for other crops higher levels of Ø gave solutions corresponding more closely to actual areas.

Dillon and Scandizzo, using a sampling approach, obtained a mean Ø value of 0.9 for farmers in northeast Brazil. Moscardi and de Janvry calculated a mean Ø value of 1.12 for farmers on the Pueblo Project in Mexico. Brink and McCarl reported a Ø value of 0.23 as giving the minimum mean absolute difference between predicted and actual acreages on Cornbelt farms (pp.261-62). On an individual basis the majority of farmers in the sample had Ø values of zero or less than 0.25. However, there was substantial diversity among individuals with some having Ø values of above 1.25 (p.262). Brink and McCarl concluded that "risk aversion may play a smaller role in Cornbelt crop farming than in many other types of farming" (p.263).

It is debatable whether Ø in fact measures aggregate risk aversion. Hazell (1982, p.386) argued that there are two major problems involved in estimating Ø by using alternative values to find the "best solution". One is that Ø may be biased by model misspecification and data errors. The second is that if farmers have access to insurance facilities their farm planning decisions will not reflect their real risk preferences. The value of Ø is then likely to be underestimated if these risk-sharing possibilities are not included in the model. He concludes that this may have been the reason for the low Ø value attained by Brink and McCarl.

Young reported that this method of estimating risk aversion values has the advantage of providing risk aversion values that can be used directly in decision making models. However, this method "is vulnerable to serious errors of inference. Because it measures risk preferences on the basis of the difference between actual factor use or output supply levels and the levels associated with the (risk-neutral) expected profit maximizing solution, it attributes the entire difference to risk aversion. In actual fact, many other explanations such as inaccurate or incomplete technical and market information, different resource endowments, capital constraints, different objective functions, and different subjective probability assessments could underlie some or all of the residual attributed to risk aversion" (Young, p.1066). However, Sonka (p.1083) maintained that it may be as or more important to model the effects of farmers' multiple objectives as it is to measure risk preferences when attempting to predict future behaviour. Nieuwoudt <u>et al</u> (1976, p.488) placed little significance on the value of Ø. It was used to fine-tune the predictive ability of their model.

In this study Ø was also used as a fine-tuning device and not as a measure of risk aversion. An individual's perception of risk is a state of mind or subjective (Anderson <u>et al</u>, Arrow, Binswanger). The value of Ø as used in this model may be due to other factors, as Hazell (1982) and Young have pointed out.

Studies in developing countries on attitudes towards risk indicate that peasant farmers are generally risk averse (Dillon and Scandizzo; Moscardi and de Janvry; Wiens; Wolgin). Although Young (p.1067) tentatively concluded that peasant farmers appear to be more uniformly risk-averse than farmers in developed countries, nothing can be said about the perception of risk of peasants or of farmers in developed countries. Perception of risk is subjective and circumstances will dictate how individuals will react.

An individual's perception of risk is not expected to change in the short term and may change only marginally in the longer term with experience, age and other factors.

As regards white and black cane growers, therefore, one cannot say that black growers are more risk averse than white growers. Their different circumstances will determine how they will react. Under the same circumstances (for example, in a gambling situation) the black grower may be less risk-averse. "Risk-averse behaviour results when the decision-maker exhibits diminishing marginal utility for increases in expected wealth" (Barry and Fraser, p. 288).

In this study many of the crops grown in the various regions are relatively stable, low-risk crops such as sugar-cane and timber. In the Eastern Transvaal, where a large number of crops are grown, few farmers formally insure their crops against the vagaries of the weather (de Villiers). Farmers are willing to bear risk themselves by diversifying production.

5.6 CONCLUSIONS

This chapter has dealt with inclusion in an LP model negative sloping demand curves, substitution in demand between enterprises, positive sloping supply curves for labour, and risk. Inclusion of these factors in the planning model has aided the simulation of the present cropping pattern and more realistic results can be expected when various policy measures are evaluated.

As regards the simulation procedure a $\emptyset$ value of 0.25 gave the best simulation of actual cropping patterns, land rents and product prices. This value is similar to the one derived by Brink and Mc Carl for Cornbelt farmers. The $\emptyset$ coefficient as used in the model is usually, and erroneously, called a risk aversion coefficient. It is simply a fine-tuning device which may capture the effects of a host of factors such as model constraints, incomplete or inaccurate data, different objective functions and risk. It may be as or more important to capture other effects as it is to capture the effects of risk.

With this in mind, the simulation exercise has been successful. At $\emptyset = 0.25$ high correlations were achieved between actual and simulated areas and prices. This gives confidence in the model on which alternative sugar-cane policies will be based.

CHAPTER 6

AN ECONOMIC EVALUATION OF ALTERNATIVE SUGAR-CANE POLICIES WITH PARTICULAR REFERENCE TO ETHANOL PRODUCTION

6.1 INTRODUCTION

In the previous two chapters a basic sugar-cane model was developed which enabled the 1979/80 areas under sugar-cane and other enterprises to be simulated. In this chapter two policies regarding sugar and ethanol production are to be evaluated. The policies include :

(1) A multiple pool scheme consisting of three pools. The A - pool accounts for domestic market sugar and 50% of normal exports and the B - pool the balance of exports. Ethanol will be produced under the C - pool.

(2) A free market for sugar. A negative sloping demand curve for domestic market sucrose will be incorporated into the model. Producer prices will be established along this demand curve. Ethanol and export demands are considered perfectly elastic.

These two policies and their implications for the Sugar Industry, the mix of enterprises and labour employment are to be evaluated in detail. Social costs of the current policy, the pool scheme and of ethanol production will also be estimated. Before this is done, the enterprises competing with sugar-cane production, the planning horizon and irrigation water tariffs are discussed.

6.2 ENTERPRISES COMPETING WITH SUGAR-CANE

In this study the incentive for development is the prospect of growing sugar-cane for ethanol production. Sugar-cane has to compete with other crops for available resources. Enterprises at present being farmed are obvious contenders. In addition, there may be other crops which could be grown.

Most of the crops being grown in the Eastern Transvaal were also considered for the Pongola, Nkwaleni and Hluhluwe areas as growing conditions are similar. Distances to markets should be considered. As regards labour use, records from the S.A. Cane Growers' Association show that for the four-year period 1976/77 through 1979/80, farmers at Pongola used 14% more labour per tonne of cane produced than their Eastern Transvaal counterparts. Labour costs at Pongola were about 7% lower. Labour use per hectare for vegetables and fruit at Pongola and also at Nkwaleni were taken as 14% higher than for the same enterprises in the Eastern Transvaal.

Double-cropping possibilities in the irrigation areas were considered, with cotton being grown in summer and vegetables, dry beans and wheat in winter. Of the vegetables, green beans, cucumbers and gem squash could be double-cropped with cotton on a one to one basis. For dry beans and wheat only up to 70% of the total area could be double-cropped as time for preparing the lands is limited (de Villiers). Wheat, which was not grown before, will be grown in KaNgwane under irrigation (van Zyl) and was, therefore, also considered for the white areas. In 1983 some farmers in Pongola had grown wheat (Havenga).

For KaNgwane only sugar-cane, cotton (in summer), dry beans and wheat (in winter) were considered as commercial crops. According to van Zyl vegetables and subtropical fruit will be grown only on a small scale, mainly for household use. The same commercial crops were considered for the Makatini Flats.

In dryland areas some potential crops were considered in addition to the present ones being grown. These include cotton in the Zululand low rainfall area, maize, saligna and pines in the Zululand hinterland area, bananas on the North Coast lowlands and pines and maize in the South Coast hinterland, Midlands South and Midlands North areas. Information on these crops was received from various sources including extension officers and the Institute of Commercial Forestry Research in Pietermaritzburg. Cost budgets for these additional enterprises are summarized in Appendices 8 and 9.

In the Natal Midlands the cost of stumping and clearing a timber plantation was about R400 per hectare in 1979/80 (Carter-Brown). This cost varies according to age of plantation and type of tree. Experience has shown that the value of land which has been converted from timber to arable land increases by more than the development costs incurred (Frean). For example, a hectare of land previously under wattle costing R400 to stump and clear would normally increase in value by more than R400. The problem arises what interest charge to apply to this R400 in order to convert it to a flow cost for use in cost budgets. An interest charge of 5% was applied on R400 as reflecting the development cost of land. This equals the current rental rate (rent/land value) of farm land. For clearing of caneland an additional R10 per hectare per annum was used.

In addition to the crops mentioned above a potential enterprise that has stimulated great interest amongst cane growers is beef on pasture as it could complement cane production. Discussions were held with Bartholemew, Bransby, Louw and Mappledorum. A weaner system was selected in which weaners are purchased in autumn at a mass of about 190kg. They are fed cane tops in winter and a mineral lick is provided. During this period body mass is maintained or a slight gain may be registered. Feed costs would be minimal. In spring the weaners are placed on Kikuyu or Coastcross pastures and kept until autumn when they are sold to feedlotters. The average daily gain (ADG)is 0.6kg. The stocking density of pastures and the length of time the animals can spend on pasture depends upon factors such as rainfall and temperature. Table 6.1 summarizes stocking densities, number of days on pasture and nitrogen requirements for different areas.

As regards black farmers a major reason for overstocking and degradation of grassland is the keeping of cattle as a store of wealth (Doran et al). Bransby maintained that if black farmers intend keeping cattle in the future they will have to cultivate pastures because of the poor condition of grassland. Beef on pasture was therefore also considered. Nguni cattle were used as this is the predominant breed in black areas. Mass of weaners was taken as 150kg and the ADG as 0.4kg. In dryland areas a stocking density of five animals per hectare for 240 days was used. For irrigation areas (KaNgwane and Makatini) it is 10 animals per hectare for 270 days.

Fertilization rates are about 60% of that of white farmers in dryland areas and nearly 75% in irrigated areas. Income and cost budgets for beef on pasture are given in Appendix 10.

Table 6.1 Beef on pasture : Stocking densities, number of days on pasture and nitrogen requirements in different regions for a weaner system, ADG = 0.6kg.

Area	Animals per ha	No. of days on pasture	Kg nitrogen per ha
Irrigation areas -1	13	270	400
Irrigation areas -2	12	270	400
Zululand HR and Umfolozi	9	270	350
North Coast lowlands	8	270	300
Zululand LR and North Coast hinterland	7	240	250
South Coast lowlands	6.5	240	250
Zululand hinterland, South Coast hinterland, Midlands South and North	7	200	250

Source : Bartholemew, Bransby and Mappledorum

6.3 PLANNING HORIZON

Introduction of ethanol and other potential enterprises would entail structural changes to the present organization. The Committee of Inquiry into the Sugar Industry (1982) suggested a 10-year development plan for the Industry until 1990/91. In this study a structure in 10 to 20 years time, with 1979/80 as basis, is considered. The model is a static equilibrium one and since price movements in the future are uncertain, price relativities are assumed to remain the same. Technological improvements during this period will obviously occur, resulting in improved production practices and yields of all enterprises. To a large extent increasing yields may be taken up by increasing population, which in South Africa averaged 2.6% per annum over the last 10 years (Agricultural Economic Trends Division, p.1), and/or growing export markets. Increasing population is one factor which may shift demand curves to the right. This can easily be accounted for in the model for enterprises with demand curves by using the method described by Duloy and Norton (1975, pp.589-99).

Development of new sugar-cane varieties which are suited to the present marginal production areas may open up vast new areas for sugar-cane production. However, considering the above factors and in the interest of keeping this study in perspective, the 1979/80 technological base and relative prices were used.

In considering sugar-cane expansion it was assumed that additional mills/distilleries would be constructed in areas where they would be profitable. These areas include the Eastern Transvaal, Pongola/Mkuze, Makatini Flats, at Bedlane (to serve the Nkwaleni Valley and the Zululand hinterland) and at Eston in the Midlands South area. Cost budgets for sugar-cane in the relevant areas include transport costs to these mills/distilleries. The effects of removing transport subsidies on the mode of transport were also taken into account. For example, it was assumed that the use of tramlines at Pongola would cease while on the Umfolozi Flats existing tramlines would be operated more efficiently leading to cost savings. Estimates of transport cost savings were made in consultation with economists of the S.A. Cane Growers' Association.

Upper bounds were placed on production of some crops with elastic demands. These include tobacco and citrus. For tobacco in the Eastern Transvaal the area suitable for planting is limited to about 5 000 hectares (Blignaut).

According to Kruger there is a local and overseas trend towards consumption of navel oranges and easy peelers and a movement away from valencia oranges and Marsh grapefruit. The latter are grown in subtropical climates as at Malelane and Nkwaleni Valley. The desired varieties can only be grown in cooller areas. Grapefruit of the Ruby variety is gaining popularity overseas. It is expected to gradually replace the dominant Marsh variety. The Citrus Exchange is keeping citrus farmers informed about market trends and is trying to convince farmers to plant desired varieties. With this in mind the 1979/80 areas under citrus in various regions (growing mainly valencia oranges and Marsh grapefruit) were taken as the upper limit.

Dry bean seed production is strictly controlled for quality by the Dry Bean Board. Production areas have been linked to the area under dry beans in the proportion which existed in 1979/80.

6.4 IRRIGATION WATER TARIFFS

Development of new irrigation areas requires an assessment of water costs to farmers. According to Abbott the cost of water to farmers depends upon :

(a) the capital cost of the dam,
(b) interest rates (normally Treasury rates are used),
(c) the redemption period (30 years),
(d) the number of hectares which can be irrigated,
(e) operating costs and
(f) use of water by other consumer sectors.

Water rates vary widely among regions depending on the above factors; figures mentioned ranged from R15 per hectare per annum to over R300 per hectare per annum in 1984. The difference depends mainly on the capital cost and the number of hectares that can be irrigated. According to van Niekerk farmers typically pay about 5% of the actual cost at present. Farmers exert considerable pressure to have water costs reduced. However, this may have to change in the longer term with the government's desire that new schemes "be beneficial in the national interest over the long term on a cost/benefit basis..." (Department of Environment Affairs, p.16).

The responsibility of calculating water tariffs lies with the Department of Environment Affairs. According to this Department " the ability of an average farmer on a particular scheme to pay" must be a consideration when water tariffs are calculated (op. cit., p.9). Determining this "ability" and the cost of water as a percentage of total production cost will be the responsibility of the Department of Agriculture (op. cit., pp.9-10).

Before a government water scheme is constructed the Department of Environment Affairs must table a White Paper in Parliament showing the costs and benefits of such a scheme, the division of capital cost between various consumer sectors as well as the ceiling tariff, the proposed tariff and that part of the capital cost that will not be redeemed. "The ceiling tariff for a scheme is the maximum tariff that the farmers concerned will ever have to pay, and consists of the total operating costs plus interest and redemption of 66 2/3% of the capital allocated to agriculture. The ceiling tariff will rise, however, as the operating costs of the scheme increase" (op. cit., pp.12-13). In fact, the government subsidizes a third of the capital cost of a project.

Taking account of the above information and following consultations with Abbott and van Niekerk, it was decided to use a water tariff of R100 per hectare per annum (1979/80 value) for new irrigation areas in the Eastern Transvaal/KaNgwane and Pongola/Makatini Flats regions. This is a subsidized cost. It may be economically justifiable to subsidize water tariffs to some extent because the average cost of supplying water may be falling considerably if more water is used from the same storage dam, which may be a natural monopoly (Hyman, pp.66-68). The effects if farmers in all irrigation areas were to pay 100% of water costs are also to be evaluated.

6.5 RESULTS OF VARIOUS POLICY MEASURES

In the introduction two policy measures to be studied were briefly outlined. In the following sections each of these policies will be discussed in greater detail and the results evaluated.

6.5.1 Multiple pool scheme

6.5.1.1 Introduction

The S.A. Sugar Industry intends introducing a pool scheme in the 1985/86 season. The proposed scheme, which has been outlined by Smeaton (p.236), comprises two pools. The A - pool covers requirements of the domestic market plus about 50% of normal exports in the past. Each grower and miller is allocated a quota and growers receive a premium price for this cane under normal circumstances. A - pool quotas will only be transferable within Mill Group areas. "Some measure of price stabilization will operate within this pool, in that there will be a minimum level of remuneration, below which support loans will be raised, and a maximum level, above which proceeds will be syphoned off and diverted to a reserve fund" (op.cit., p.236). In effect, under normal circumstances the local consumer subsidizes sugar exports because of the relatively low sugar price on the world market.

The B - pool covers the balance of production. This pool is voluntary with no price supports. Growers have to accept whatever proceeds are realized on the export market. This may lead to higher cost producers participating only in the A - pool.

In this study the first policy to be evaluated is based on the above pool scheme. Ethanol production is an additional activity with sucrose (ethanol) prices being varied to trace out a sucrose (ethanol) supply function. Total sucrose production under the A - pool is limited to 1.85 million tonnes. This figure is based on domestic sugar demand of 940 659 tonnes of refined sugar and 142 055 tonnes of brown sugar, the 1979/80 level, and exports of 490 700 tonnes raw sugar which is 50% of mean export production over the four years 1976/77 through 1979/80 (South African Sugar Association, 1982/83, pp.120,125). Conversion rates from sugar to sucrose were obtained from Lamusse. The 1.85 million tonnes of sucrose are equivalent to about 1.6 million tonnes of raw sugar.

The producer price for A - pool cane is a weighted average of proceeds on the domestic and export markets and was calculated as R156,70 per tonne of sucrose for the five years 1977/78 through 1981/82, centred on 1979/80. (The same period was also taken for other crops.) This price was calculated after consulting with Hudson and Nourse (1984). It should be noted that since the domestic sucrose price under the A-pool is higher than under the current policy the consumption of sugar is expected to fall as the price increase filters through to the consumer. Decreased local consumption implies that more sugar will have to be exported if the maximum A - pool tonnage is produced.

For B - pool cane the producers' price is based on the Industry's export proceeds over the same five years. Exports are usually based on the world spot price with other factors such as discounts or premiums modifying the final price between buyer and seller (Hardy). For this reason export proceeds were considered more appropriate than the spot price. Conversion of these proceeds to a per tonne sucrose price for growers for individual years was done by the S.A. Sugar Association (Nourse, 1984). From these prices a five-year mean price, centred on 1979/80, of R124 per tonne of sucrose was calculated. The mean price over seven years (1976/77 through 1982/83) at 1979/80 values was calculated as R122 per tonne. Because of the relatively small difference between the five-year and seven-year means, the former was used to correspond to mean prices of other commodities.

It could be argued that the world sugar market will experience relatively low prices in the longer term because of the increasing prominence of alternative sweeteners in major industrialized countries such as the USA and Japan and sugar price support policies in producer countries. At the same time the rand's exchange rate with other currencies, especially with the U.S. dollar, has weakened and may be a longer - term feature. This will improve the export earnings of the S.A. Sugar Industry. One result may offset the effects of the other to a certain degree. A recent calculation has shown that at an exchange rate of 50 U.S. cents to a rand the growers' sucrose price with present (1984/85) world sugar prices was below R130 per tonne (Hudson). In real terms this price is below the R124 calculated and used in this study. However, even the latter price is not a profitable one, as will be shown later.

For ethanol various producer sucrose prices will be considered in order to derive supply functions for sucrose and ethanol. In this way prices at which various levels of ethanol would be produced can be analyzed with respect to the world price of sugar and the refinery gate petrol price or SASOL fuel prices. Also, the implications of producing various volumes of ethanol on the mix of enterprises and creation of job opportunities for the region can be evaluated. The cost and implications of government support of a relatively high sucrose (ethanol) price will also be considered.

6.5.1.2 Ethanol production

The linear programming matrix for this exercise comprised 1444 columns and 782 rows. A - pool quotas were assumed transferable between regions because of the possibility of ethanol production and, hence, greater flexibility in the marketing of sugar-cane. The response of sucrose production to various sucrose prices at the farm level is reflected in Table 6.2 and in Figure 6.1. Ethanol production is from sugar-cane juice only.

Table 6.2 Sucrose and ethanol production at various sucrose and ethanol prices (1979/80) under a multiple pool scheme, South African Sugar Industry.

Sucrose price (R/tonne)*	Sucrose for ethanol (10^6 tonnes)	Ethanol production (10^6 litres)	Ethanol cost (cents/litre)	Ethanol cost/ pre-tax petrol price
133.40	0	0	n.a.	n.a.
136.30	0.595	345	37.5	2.22
139.20	0.982	569	38.0	2.25
142.10	1.411	819	38.5	2.28
145.00	1.582	917	39.0	2.31
147.90	1.796	1 042	39.5	2.34
150.80	1.899	1 102	40.0	2.37
153.70	2.047	1 188	40.5	2.40
156.60	2.340	1 357	41.0	2.43

* The A - pool mean producers' sucrose price = R156.70 per tonne.

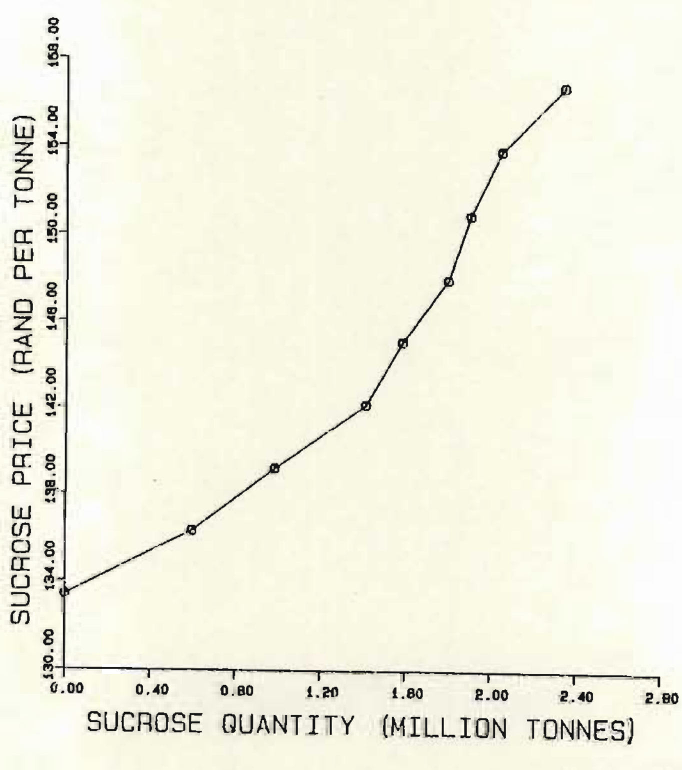

Figure 6.1 Sucrose (for ethanol) supply function under a multiple pool scheme, South African Sugar Industry.

The price elasticities of supply of sucrose and ethanol at the means of quantity and price were calculated as 9.4 and 14.7, respectively. Production of sucrose (ethanol) appears highly responsive to changing sucrose (ethanol) prices. The ethanol supply function lies above the sucrose supply function because of additional manufacturing costs.

The estimate of the sucrose supply elasticity is higher than those of other studies because of the "frictionless" nature of the linear programme. Gemmill, for example, estimated the supply elasticity for sugar-cane in the USA as 1.57 (p. 612). Many of the supply elasticities reported by Askari and Cummings (ch. 8) fall in the range 0.5 to 1.5.

Potential ethanol sources such as molasses and bagasse were not considered in the above analysis. Molasses consumption on the domestic market was 634 700 tonnes in 1979/80 (Committee of Inquiry into the Sugar Industry, 1982, p.43). About 114 400 tonnes are exported on average. This would yield 29 million litres of ethanol. Under the pool scheme molasses production is expected to fall because no B - pool cane will be produced for an unprofitable export market. Model results show that total molasses production is about 529 000 tonnes. If all of this were converted to ethanol for liquid fuel purposes about 132 million litres would be produced. Industrial uses of ethanol are about 100 million litres at present (Buchanan, 1985). Molasses, which is a relatively inexpensive source of feedstock, is not expected to play an important role in ethanol fuel production because production is limited by the amount of sugar produced. Research into ethanol production from bagasse is still in its infancy (Purchase).

According to Dutkiewicz South Africa will consume 17 billion litres of petroleum products by 1990 and 26 billion by the year 2000 (Financial Mail, 1983, p.34). Scott (p.26) reported that forecasts for petrol and diesel demand growth over the next five to 10 years are 4,5% per annum for petrol and 5% per annum for diesel. Since official statistics on petroleum consumption in South Africa are not available, these have to be estimated. Working on the above figures, the estimate for petroleum consumption for 1980 is about 10 billion litres, of which the greatest proportion is petrol and diesel. Assuming a 10:90 ethanol:petrol and ethanol:diesel mix the Sugar Industry would have to supply about one billion litres per annum. To achieve this, farmers would have to receive R147.90 per tonne of sucrose (see Table 6.2) under the multiple pool scheme. This is about 6% below the A - pool sucrose price.

How does the cost of ethanol compare with the refinery-gate or pre-tax petrol price? Research has indicated that the raw material input accounts for 60% to 67% of total ethanol costs (Sheehan et al, p.6.13; Deicke et al, p.7.11). This is confirmed by Ravnö (1984). It is estimated, therefore, that manufacturing costs will be in the region of 14 cents per litre giving a total ethanol cost of 39.5 cents per litre. In another analysis Ravnö (1979, p.243) included a "full return on capital" element for the juice extraction plant and the boiling house equipment. The latter was considered redundant due to diversion of juice to the distillery. Ravnö also did not include farmers' transport costs under the raw material element (as was done in this study) but captured it under juice extraction. This gave a raw material percentage of about 50 out of a total cost of 35.8 cents per litre (p.243). Buchanan (1979) used a total ethanol cost of 33 cents per litre in his analysis (p. 251). The Committee of Inquiry into the Sugar Industry (1982) calculated an ethanol price of 39.6 cents per litre compared with a landed cost of 93-octane petrol of 27.8 cents per litre (p.17).

The mean refinery—gate or pre-tax petrol price over the years 1977/78 through 1981/82 was calculated as 16.9 cents per litre on a 1979/80 basis. (Data for individual years were received from Jacobs.) This corresponds to Buchanan's estimate of 17 cents per litre during the middle of 1979 (p.251). The mean pump price of 93-octane petrol on the coast over the same five years on a 1979/80 basis was calculated as 39.15 cents per litre which is slightly below the total ethanol cost of 39.5 cents per litre. Taxes amounted to 22.25 cents per litre or 57% of the pump price. Ethanol costs, therefore, are 2.34 times the pre-tax petrol price. Adams (p.157) reported that under free market conditions the wholesale price of alcohol in Brazil was about double the price of petroleum.

In February 1985 the refinery-gate petrol price was 56.24 cents per litre and the pump price of 93-octane petrol at the coast 81.4 cents per litre (Jacobs). Taxes as a proportion of the pump price have decreased to 31%. The sharp increase in the pre-tax petrol price since 1979/80 is mainly due to the effects of the depreciating rand against the U.S. dollar on which oil transactions are based. Present estimates of ethanol costs are in the region of 70 cents per litre (Buchanan, 1985). This is below the pump price and about 25% above the refinery-gate petrol price. Events over the five years since 1979/80 appear to have made ethanol production from sugar-cane more favourable relative to petrol from crude oil although the effects of the recent (January 1985) petrol price hike have not yet filtered through the economy.

In South Africa the cost of ethanol should also be compared with the cost of producing petroleum from coal. Attempts to obtain cost estimates were not successful. However, information that was obtained indicated that the SASOL projects were initially financed with "soft" loans from the government. No interest is charged on loans until a SASOL project has attained a certain level of profit. According to Stegmann, as cited by the Financial Mail (1985b, p.78), SASOL is now able (with the weak rand) to compete with crude oil without any government protection or support. "The government has furthermore received back every cent of its investment in SASOL Two, plus interest at commercial rates, and will in due course receive the same for SASOL Three" (op. cit., p.78). Since SASOL fuel prices are linked to the rand equivalent of the international oil price, which is quoted in U.S. dollars, SASOL's earnings have been boosted considerably by the weakening rand (Financial Mail, 1985d, p.94).

According to The Economist (p. 63) production costs for oil from coal were $30 to $40 per barrel in 1979 compared with $75 to $90 per barrel for alcohol from biomass. More recently, Scott (1985) referred to American studies which indicated a cost of $60 to $70 per barrel of petroleum from coal. Estimates for petroleum from crude oil are about $40 per barrel. In the USA, therefore, costs of petroleum from coal are 50% to 70% above petroleum costs based on crude oil. In South Africa petroleum costs based on either crude oil or SASOL would currently (1985) be similar because of the effects of the weak rand. The U.S. dollar has appreciated by 49% against the rand since January, 1984 (Financial Mail, 1985b, p.78). Current estimates of ethanol costs are, therefore, not much higher than the cost of oil from coal, contrary to The Economist's findings. Ethanol from sugar-cane could become a viable alternative compared with liquid fuel costs from new SASOLs because of the unfavourable effect of the depreciating rand on imports of sophisticated machinery and infrastructure for the capital-intensive projects. According to Meekhof et al (p.408) alcohol from grain is competitive with synthetic fuels derived from coal and oil shale in the USA.

Under present circumstances ethanol from sugar-cane would only be produced if it were subsidized by government. Using model (1979/80) results the subsidy amounts to 22.6 cents per litre which is 57% of the total ethanol cost. With a 10:90 ethanol:petrol blend, for example, the subsidy amounts to 2.3 cents per litre for the blend. More recently (1985) the subsidy would have been about 14 cents per litre of ethanol. It could be argued, as Buchanan has done, that advantages of using ethanol in a blend would reduce the cost difference. Some advantages of using ethanol blends include (Buchanan, 1979, p. 253) :

1) The high antiknock value of ethanol could lead to cost savings in the production of blends through reduced use of tetraethyl lead.

2) Reduced emissions could reduce air pollution control costs.

3) Possibly improved fuel consumption.

4) Production of a renewable fuel such as ethanol could justify relief from the Equalization Fund levy which is applicable to petroleum products.

5) decentralization of ethanol production and blending could reduce blend costs through transport savings in areas remote from oil refineries.

The degree of savings would depend on the relative contribution of these advantages. According to Buchanan cost savings from points 1) and 4) alone would be about 1,4 cents per litre on the blend. Contributions by the other factors could make up the difference in cost. Dutkiewicz (1980, p.785) maintained that ethanol production could be cost effective in certain regions, if used at source, and could be cheaper than methanol (from coal) transported over distances of around 600km.

A product price subsidy could either take the form of a fixed payment per unit of output or a deficiency payment in which the government makes up the difference between the guaranteed price and the average market price (Hallett, p. 190). These price supports come at a cost to society. For an ethanol industry in South Africa producing one billion litres per annum subsidies would now amount to about R140 million per annum. However, if the advantages of using ethanol blends are considered social costs may be reduced considerably.

6.5.1.3 Effects of ethanol production

The effects of producing ethanol on enterprise mix and labour employment under a pool scheme in the S.A. Sugar Industry are summarized in Table 6.3. Sugar-cane quotas are assumed transferable between regions.

Before the impacts of ethanol production are considered comparisons will be drawn between resource use under the pool scheme and the current policy. The first important feature of the simulated implications of the pool scheme is that no sugar-cane is produced within the B - pool. On average, it is not profitable to produce sugar-cane at world prices. This implies that the pool scheme, in effect, reverts back to a single-price scheme. (In practice sugar-cane growers may produce some B - pool cane in order to protect their valuable A - pool quotas which they may lose if not performed within a certain period. It can be expected, therefore, that B - pool sugar will comprise about 5% to 10% of total sugar production.) Sucrose production is reduced from 2.42 million tonnes under the current policy to 1.85 million tonnes. This has important implications for resource use in different areas.

Table 6.3 Effects of increasing sucrose (ethanol) production on enterprise mix and labour employment in four major regions of the South African Sugar Industry under a multiple pool scheme with transferable A - pool quotas.

Particulars	Current policy*	Pool scheme*		
Sucrose (for ethanol)price (R/t)	n.a.	133.40	147.90	156.60
Sucrose for ethanol production (10^6t)	n.a.	0	1.80	2.34
Ethanol production (10^6l)	0	0	1 042	1 357
Ethanol costs (c/l)	n.a.	n.a.	39.50	41.00
Ethanol/pre-tax petrol price	n.a.	n.a.	2.34	2.43
Producer surplus (R10^6)	66.4	92.3	109.7	128.0
Producer surplus/ha (R)	99	138	164	192
1. Eastern Transvaal	Enterprise areas (hectares)			
Sugar-cane	17999	20946	83075	93012
Vegetables	1870	-	-	-
Dry Beans	1300	339	324	308
Wheat	-	-	-	-
Cotton	5000	-	-	-
Tobacco	200	5000	-	-
Fruit	5040	3390	2990	3080
Beef on pasture	-	4399	-	-
Grassland	79000	75315	23000	12989
Total hectares**	109389	109389	109389	109389
Labour units	12453	15386	30964	35919

* Prices are on an 1979/80 basis. The producers' sucrose price under the current policy = R143.60 per tonne and under the A - pool R156.70 per tonne. A - pool sucrose production = 1.85 million tonnes.

** The difference between the total area and the sum of the areas for individual enterprises is due to double-cropping of cotton with crops such as vegetables, dry beans and wheat. This also applies to other regions.

Particulars	Current policy	Pool scheme		
Sucrose (for ethanol) price (R/t)		133.40	147.90	156.60
2. Pongola/Makatini	Enterprise areas (hectares)			
Sugar-cane	11332	-	10117	38329
Vegetables	250	2793	1920	847
Dry beans	-	-	-	256
Wheat	-	267	2461	2719
Cotton	4000	2087	4928	4517
Fruit	500	681	1918	1100
Beef on pasture	-	9647	4513	-
Fallow	-	2580	-	-
Grassland	53650	53650	47267	24939
Total hectares	69732	69732	69732	69732
Labour units	6562	5896	10935	19682
3. Zululand				
Sugar-cane	115546	88416	171435	173845
Vegetables	-	198	198	703
Dry beans	-	1129	1077	770
Wheat	-	2627	-	-
Cotton	-	4921	1539	1705
Fruit	955	3886	2609	3118
Maize	-	21234	2410	3118
Timber	7000	5000	-	-
Beef on pasture	-	-	575	-
Grassland	57200	54800	-	-
Total hectares	180701***	178766***	178766	178766
Labour units	37677	34035	52757	53837

*** The difference of 1935 hectares between the totals for Zululand is due to cyclone Damoina which devastated parts of the Umfolozi Flats in 1984 and made them unsuitable for crop production.

Particulars	Current policy	Pool scheme		
Sucrose (for ethanol) price (R/t)		133.40	147.90	156.60
4. Natal	Enterprise areas (hectares)			
Sugar-cane	249585	177301	285214	308599
Fruit	1500	-	-	-
Maize	-	52762	23385	-
Timber	18800	78236	-	-
Beef on pasture	-	986	686	686
Grassland	39400	-	-	-
Total hectares	309285	309285	309285	309285
Labour units	73588	59072	80492	86775
5. Total - all regions				
Sugar-cane	394462	286663	549842	613785
Vegetables	2120	2991	2118	1550
Dry beans	1300	1468	1401	1334
Wheat	-	2895	2461	2719
Cotton	9000	7008	6467	6222
Tobacco	200	5000	-	-
Fruit	7995	7957	7517	7298
Maize	-	73996	25795	-
Timber	25800	83236	-	-
Beef on pasture	-	15032	5774	686
Grassland	229250	177450	70267	37928
Total hectares	669107	667172	667172	667172
Labour units	130279	114389	175148	196213
Fuel use on farms (10^6 l)	55.1	49.7	72.6	81.1
Fuel use by contractors (10^6 l)	28.1	18.1	39.4	48.5

Given the assumption that A - pool quotas are transferable between regions (the Sugar Industry contemplates making quotas transferable only within Mill Group areas) the effects of the pool scheme on crop mix and resource use are considerable. Sugar-cane production in the Eastern Transvaal is estimated to increase by 16% while no cane is grown at Pongola. Cane production in Zululand and Natal decreases by 23% and 17%, respectively. Cane is only farmed in areas of comparative advantage. More specifically, cane is not grown at Pongola, Hluhluwe, Nkwaleni, Zululand hinterland, the South Coast lowlands and hinterland and Midlands South. Areas with increased cane production are the Eastern Transvaal, Mangete and KwaZulu. Vegetable, dry beans, cotton and some fruit production shift from the Eastern Transvaal to Pongola, Hluhluwe and Nkwaleni. Beef on pasture features in the Eastern Transvaal and at Pongola. Tobacco cultivation becomes more prominent in the former area.

Sugar-cane grown in the Zululand hinterland is replaced by maize and 5 000 hectares of timber (pines). Maize also replaces cane in the South Coast hinterland and Midlands South areas whilst timber is grown in the South Coast lowlands (saligna) and Midlands North areas (wattle and pines). The relatively large areas under maize and timber are not expected to influence prices of these products (see discussion on the effects of a free market for sugar in section 6.5.2.4). Overall, the area under sugar-cane is estimated to decrease by 27% under the pool scheme. In regions moving out of cane production, mills may not close down immediately because, being specialized production factors, they earn economic rents (Friedman, pp. 141-47). Millers may, therefore, accept lower profits (rents) and pay farmers higher prices to keep them in production.

Since sugar-cane is produced in areas of comparative advantage with transferable quotas, Pongola farmers, for example, will not lose because they will be able to sell their quotas to Eastern Transvaal farmers. Gainers could compensate losers. Where quotas are transferable between regions the rental rate is the same in all regions as it is determined by the free market (Nieuwoudt <u>et al</u>, 1975, p.34). The shadow price (rent) of A - pool quotas under these circumstances was estimated as R23 per tonne of sucrose. Results of a model in which quotas were not transferable between regions indicated that quota rents on the Umfolozi Flats, the Zululand low rainfall area, KwaZulu south of the Tugela River and Indian and Mangete areas were higher than the free market rental. Quota owners in these regions would lose and quota renters would gain should transferable quotas be instituted. The opposite would apply to regions where quota rents are lower than R23 per tonne of sucrose.

Production of sugar-cane for ethanol is only initiated at a producer price of about R133.40 per tonne of sucrose which exceeds the B - pool price. The effects of increasing ethanol prices on enterprise mix, labour employment and use of fuel on farms and by contractors are summarized in Table 6.3. At a producer price of R147.90 per tonne of sucrose, or about 6% below the A - pool price, it is estimated that about one billion litres of ethanol (10% of South Africa's fuel requirements in 1980) will be supplied (see also Table 6.2 and Figure 6.1). The impacts on resource use are substantial. In the Eastern Transvaal the area under sugar-cane is estimated to increase nearly five-fold compared to the current policy area, with a decrease in production of all other crops. Labour employment in this region increases 2.5 times. In KaNgwane the area under grassland remains intact. This is probably due mainly to the relatively high cost of irrigation water in this region. At Pongola the sugar-cane area is roughly unchanged while production of vegetables, wheat, cotton and pasture for beef production are greater. As a result of intensification, labour employment at Pongola increases by 67%.

With a billion - litre ethanol industry the area under sugar-cane in Zululand increases by 48% compared with the current area, with more diversification into other crops. Beef is not produced off grassland. In Natal the cane area increases by 14% and there is also a shift towards maize production from timber and grassland. In Zululand labour employment increases by 40% and in Natal by 9%. Overall, the sugar-cane area increases by 39% and labour employment by 34% to 175 100 workers compared with the current policy. A strong correlation appears to exist between cane production and total labour employment. This is also the experience in Brazil (Adams, p.159).

As regards labour employment development costs per worker may be an important statistic from a socio-economic point of view. According to Buchanan (1985) a back-end distillery producing 40 million litres a year currently costs about R20 million while an autonomous distillery may cost about 90% of a sugar mill. A 150 000-tonne sugar mill now costs roughly R80 million. With about 13 back-end and four autonomous distilleries producing an average of 60 million litres of ethanol each the development cost is about R700 million. With an additional dam in the Eastern Transvaal and infrastructure (canals and roads) development costs increase to roughly R800 million. Development costs of caneland are now about R1 600 per hectare (Frean). Under the pool scheme an additional 155 400 hectares would have to be developed at a cost of about R250 million. Total development costs of a billion - litre ethanol industry, therefore, are roughly R1 050 million. With additional labour employment on farms of 45 000 and an estimated 2 500 in the distilleries (Buchanan, 1985) total development costs per worker are R22 100. Constructing a new SASOL now costs R5 billion to R6 billion and will employ about 5 000 workers (Scott, 1985). Development costs per worker are, therefore, over one million rand. From a job creation viewpoint ethanol production has a distinct advantage.

The question whether ethanol production would come at the expense of food production is debatable. Under the multiple pool scheme most of the increased area under sugar-cane comes at the expense of timber and grassland. Area under fruit decreases marginally (resulting in higher prices) with the dry bean area increasing. More wheat is produced. As regards grassland, beef produced on this area is negligible in the national context. It could be argued that this area could be used for food production. However, South Africa normally produces a surplus of food and is one of few countries exporting food. Schnittker Associates contend that concern over the use of agricultural resources to produce fuel is a different issue in countries with food deficits than it is in countries exporting food (p.i). Webb (p.536) estimated that production of 10 billion gallons of alcohol per year from corn (about 10% of the USA's gasoline requirements) would increase the wheat export price by between 2% and 6% and would, therefore, not discourage human consumption in developing countries significantly. Corn prices would increase by about 4% for each additional billion gallons of alcohol per year (op. cit., p.534).

In conclusion, the interesting features of the above results are the responsiveness of ethanol production to changing ethanol prices, the changing enterprise mix and the high positive correlation between sugarcane production and labour employment. However, this is only evident at subsidized ethanol prices as ethanol production on its own is not economic compared with fuel from crude oil or fuel from present SASOLs. However, compared with liquid fuel costs from new SASOLs ethanol could be viable and would have a distinct advantage regarding labour employment.

6.5.2 Free market for sugar (human consumption) with price supports for ethanol

6.5.2.1 Introduction

Under a free market for sugar all quotas are abolished and a negative sloping demand curve for sucrose on the domestic market is incorporated into the model. The producer price for domestic sucrose will, therefore, be determined endogenously, that is, by the model. For both the export and ethanol markets perfectly elastic demands are assumed as the Sugar Industry's contribution towards the export and fuel markets are not expected to influence prices in these markets. The export price will again be based on export realizations over a five year period, centred on 1979/80, namely R124 per tonne of sucrose. The possibility of importing sugar is also considered. The cost of importing a tonne of sucrose equivalent, including freight charges of R26 per tonne (Thompson, 1984), is R150 per tonne on a 1979/80 basis.

In this section a free market for sugar refers to sugar for human consumption, hereafter called edible sugar. This is in contrast to sucrose for ethanol production. Under this policy, then, two markets for sucrose are involved - an edible sugar market and an ethanol market. Supply of ethanol will be determined at various (supported) ethanol prices.

A free market for sugar may not be considered practical or desirable by the

Sugar Industry. Major reasons put forward include (Commission of Inquiry into the Sugar Industry, 1970, p.30) :

1) The long production cycle of sugar-cane (up to 10 years) and the high capital investment in cane growing. Risk under a free market would increase because of fluctuating prices.

2) High capital investments in sugar mills, necessitating a constant and reliable throughput of cane if mills are to be economically viable. Reliable cane supplies will not be guaranteed under a free market. (It should be noted here that fixed investments earn rents in good years and lower or no rents in poor years.)

3) Fluctuating prices in a free market and the risks involved may discourage sugar millers from investing in additional milling capacity.

4) Thousands of jobs may be in jeopardy if prices fell to uneconomic levels.

For the above reasons, it is argued, some form of intervention or control is necessary. However, simulating a free market is considered a worthwhile exercise as the effects of control may be quantified.

6.5.2.2 Sucrose demand function

As regards the negative sloping demand function for domestic sucrose the price flexibility of demand is required for its construction. The price elasticity of demand for domestic sugar at the wholesale level was calculated as -0.25 (see section 3.5.1). Although the reciprocal of the elasticity is often taken to represent flexibility, it is only the case where cross effects are zero and R^2 equals unity (Colman and Miah). Waugh (pp. 29-30) prefers to use price flexibilities themselves rather than reciprocals. With this in mind the following regression equation with the real wholesale price of sugar as dependent variable was derived for the period 1960/61 through 1979/80 :

$$(6.1)\ \log SUPR = 6.4405 - 3.5249 \log SUCON + 0.4075 \log REALY$$
$$(t = -10.8) \qquad (t = 2.7)$$

$\bar{R}^2 = 0.87$

$d = 1.65$

$df = 17$

where SUPR = real wholesale price of sugar (R/t)

SUCON = sugar consumption per capita (kg)

REALY = real disposable income (R)

d = Durbin-Watson statistic

df = degrees of freedom

The price flexibility of demand for sugar at the wholesale level is estimated as -3.52 which is less than the reciprocal of the elasticity coefficient.

Since analysis of the free market policy is at the farm level the negative sloping demand function in the model should reflect demand for sucrose at the farm or derived demand level. An estimate of price flexibility for sucrose at the farm level was not available and, although an attempt was made, it could not be calculated as the producer's sucrose price was usually based on production costs and sucrose production was controlled with quotas. The coefficient at the farm level depends on the type of price spread between the wholesale and farm levels. For a constant percentage difference the price flexibilities are the same. For a constant absolute difference prices at the farm level are more flexible (less elastic) than at wholesale or retail level (Tomek and Robinson, pp.59-62). However, because of the crudeness of the estimates involved the price flexibility of sucrose at the farm level was taken as -3.52. The base sucrose quantity was calculated from domestic sugar consumption in 1979/80 (South African Sugar Association, 1982/83, p. 195). As with other crops the sucrose demand function was divided into 15 equal steps. The limits in quantity were calculated from the maximum and minimum prices which were taken, respectively, as 5% higher and 23% lower than the base price of R161.06 per tonne of sucrose. (The price of R161.06 per tonne is the producers' price on the domestic market.) The minimum price is equivalent to the export price of R124 per tonne of sucrose while the maximum price is above the import cost of R150 per tonne of sucrose. Wider limits in prices were initially used for greater flexibility in experimenting with the model, for example, accounting for import levies on imported sugar. However, this was not very successful as the computer had difficulty in finding a solution because the demand steps were too large due to the inelastic demand and the wide range in price limits. Table 6.4 summarizes information regarding the sucrose demand function.

Table 6.4 Domestic sucrose demand function, South African Sugar Industry, 1979/80.

Price flexibility	Base price(R/t)	Base quantity (tonnes)	Slope	Constant
-3.52	161.06	1279820	-4.4298×10^{-4}	727.99

Welfare (W) was calculated in the same way as for other crops with the equation :

$$W = q(a - 0.5bq),$$

where a = intercept, b = slope and q = quantity.

6.5.2.3 Ethanol production

In Table 6.5 and Figure 6.2 the response of sucrose (ethanol) production to various supported sucrose (ethanol) prices is shown. The linear programme matrix comprised 1458 columns and 785 rows.

The supply elasticities of sucrose and ethanol at the means of quantity and price were estimated as 13.3 and 21.1, respectively. The ethanol supply function lies above the sucrose supply function because of additional manufacturing costs. As under the multiple pool scheme sucrose (ethanol) production is highly responsive to changing sucrose (ethanol) prices.

Table 6.5 Sucrose and ethanol production at various sucrose and ethanol prices (1979/80) in a free edible sugar market but with supported ethanol prices, South African Sugar Industry.

Sucrose price (R/tonne)*	Sucrose for ethanol (10^6 tonnes)	Ethanol production (10^6 litres)	Ethanol cost (cents/litre)	Ethanol cost/ pre-tax petrol price
130.50	0	0	n.a.	n.a.
131.95	0.288	167	36.75	2.17
133.40	0.462	268	37.00	2.19
134.85	0.728	422	37.25	2.20
136.30	1.110	644	37.50	2.22
137.75	1.219	707	37.75	2.23
139.20	1.504	873	38.00	2.25
140.65	1.816	1 053	38.25	2.26
142.10	1.941	1 126	38.50	2.28
143.55	2.087	1 210	38.75	2.29
145.00	2.119	1 229	39.00	2.31
147.90	2.333	1 353	39.50	2.34
149.35	2.378	1 379	39.75	2.35

* The free market price for sucrose is R130.46 per tonne.

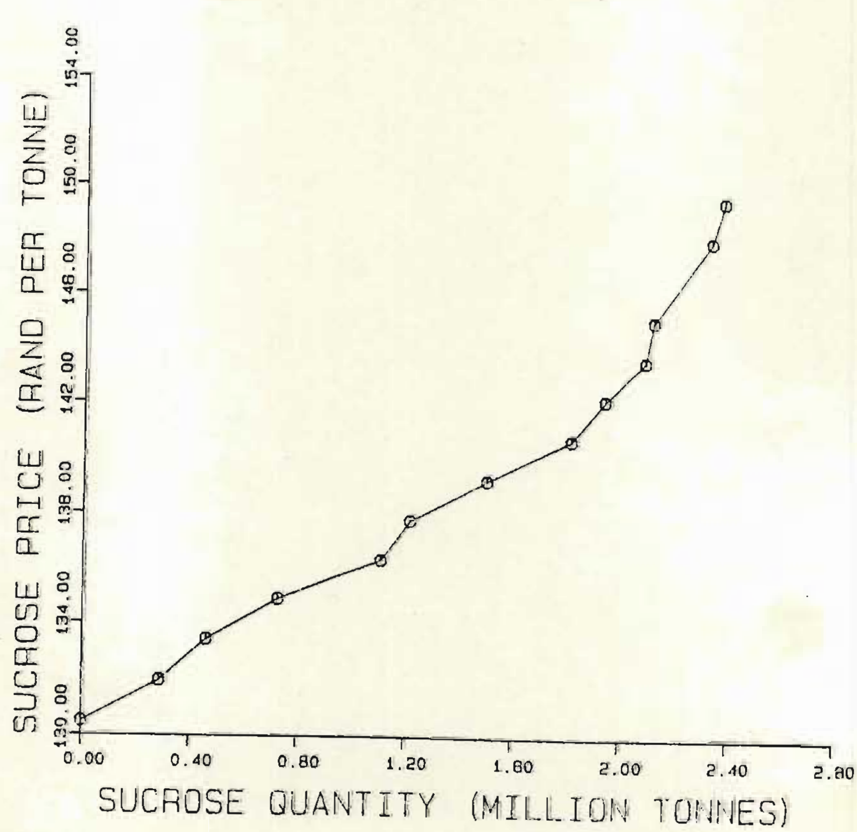

Figure 6.2 Sucrose (for ethanol) supply function in a free edible sugar market but with ethanol price supports.

6.5.2.4 Effects of a free edible sugar market and a supported ethanol industry

The impacts of changing sucrose prices on enterprise mix in different regions are summarized in Table 6.6.

Table 6.6 Effects of increasing sucrose (ethanol) production on enterprise mix and labour employment in four major regions of the South African Sugar Industry under a free market for edible sugar and with ethanol price supports.

Particulars	Current policy	Free market	Price supports for ethanol	
Sucrose price (1979/80)(R/t)	143.60	130.46	140.65	147.90
Total sucrose production (10^6 t)	2.62	1.35	3.14	3.65
Sucrose for ethanol production (10^6 t)	n.a.	0	1.82	2.33
Ethanol production (10^6 t)	n.a.	0	1 053	1 353
Ethanol costs (c/l)	n.a.	n.a.	38.25	39.50
Ethanol/pre-tax petrol price	n.a.	n.a.	2.26	2.34
Raw sugar production (10^6 t)	2.24	1.15	1.14	1.12
Producer surplus (R10^6)	66.4	45.5	72.0	93.5
Producer surplus/ha (R)	99	68	108	140
1. Eastern Transvaal	Enterprise areas (hectares)			
Sugar-cane	17999	18259	75937	83075
Vegetables	1870	130	-	-
Dry Beans	1300	354	339	324
Wheat	-	-	-	-
Cotton	5000	-	-	-
Tobacco	200	5000	1347	-
Fruit	5040	3390	3390	2990
Beef on pasture	-	3256	219	-
Grassland	79000	79000	28157	23000
Total hectares	109389*	109389	109389	109389
Labour units	12453	14358	30053	30964

* The difference between the total area and the sum of the areas for individual enterprises is due to double-cropping of cotton with crops such as vegetables, dry beans and wheat. This also applies to other regions.

Particulars	Current policy	Free market	Price supports for ethanol	
Sucrose price (1979/80)(R/t)	143.60	130.46	140.65	147.90
2. Pongola/Makatini	Enterprise areas (hectares)			
Sugar-cane	11332	-	-	10117
Vegetables	250	2659	2432	1920
Dry beans	-	-	-	-
Wheat	-	271	2603	2461
Cotton	4000	2087	5120	4928
Fruit	500	681	3215	1918
Beef on pasture	-	9781	6431	4513
Fallow	-	2575	286	-
Grassland	53650	53650	53650	47267
Total hectares	69732	69732	69732	69732
Labour units	6562	5833	8215	10935
3. Zululand				
Sugar-cane	115546	55363	112393	171435
Vegetables	-	198	198	198
Dry beans	-	1180	1129	1077
Wheat	-	2576	-	-
Cotton	-	4921	1612	1539
Fruit	955	3886	1253	2609
Maize	-	21234	21234	2410
Timber	7000	5000	5000	-
Beef on pasture	-	20308	3974	575
Fallow	-	12745	-	-
Grassland	57200	54800	33102	-
Total hectares	180701**	178766**	178766	178766
Labour units	37677	24841	37677	52757

** The difference of 1935 hectares between the totals for Zululand is due to cyclone Damoina which devastated parts of the Umfolozi Flats in 1984 and made them unsuitable for crop production.

Particulars	Current policy	Free market	Price supports for ethanol	
Sucrose price (1979/80)(R/t)	143.60	130.46	140.65	147.90
4. Natal	Enterprise areas (hectares)			
Sugar-cane	249585	127880	282214	285214
Fruit	1500	-	-	-
Maize	-	52762	23385	23385
Timber	18800	87147	3000	-
Beef on pasture	-	28748	686	686
Grassland	39400	12748	-	-
Total hectares	309285	309285	309285	309285
Labour units	73588	51138	79651	80492
5. Total - all regions				
Sugar-cane	394462	201501	470544	549842
Vegetables	2120	2986	2629	2118
Dry beans	1300	1534	1468	1401
Wheat	-	2847	2603	2461
Cotton	9000	7008	6732	6467
Tobacco	200	5000	1347	-
Fruit	7995	7957	7858	7517
Maize	-	73996	44619	25795
Timber	25800	92147	8000	-
Beef on pasture	-	62094	11311	5774
Fallow	-	15320	286	-
Grassland	229250	90198	114909	70267
Total hectares	669107*	667172	667172	667172
Labour units	130279	96170	155595	175148
Fuel us on farms (10^6 l)	55.1	46.2	68.8	72.6
Fuel use by contractors (10^6 l)	28.1	13.8	33.8	39.4

In a free market (that is, no price supports) only sugar for the domestic market is produced. This occurs in regions with a comparative advantage in sugar-cane production, namely the Eastern Transvaal, Zululand high and low rainfall areas, the North Coast, Indian and Mangete areas and KwaZulu. The producers' price of sucrose decreases from R143.60 to R130.46 per tonne or by 9.2%, and domestic sucrose demand increases from 1.28 million tonnes to 1.35 million tonnes.

Before the impacts of a supported ethanol industry are discussed it is important to study in greater detail the effects of a free edible sugar market in the four regions relative to the current policy. In Eastern Transvaal/KaNgwane there is a slight increase in sugar-cane area with a decrease in vegetables, dry beans, cotton and fruit production and an increase in tobacco and beef on pasture. As under the pool scheme no sugar-cane is produced at Pongola/Makatini. Of significance in this region is the increased area under vegetables and a fairly substantial area under pasture for beef production. Weaners could be obtained from beef producers on the surrounding grasslands. Alternatively, own breeding herds may be established.

In Zululand the area under sugar-cane is estimated to fall by more than 50% to 55 400 hectares. This is mainly due to the Umfolozi Flats, the hinterland areas and a large portion of the high rainfall area going out of sugar-cane production. It is interesting that the Umfolozi Flats are left fallow even though beef on pasture is an alternative enterprise. Presumably risk was the deciding factor. In the hinterland areas mostly maize and timber (pines) are produced. In the high rainfall region about two-thirds of the total area is put to beef on pasture. The availability of weaners could be a limiting factor. However, breeding herds could evolve.

In Natal a free market for sugar results in an estimated 49% decrease in sugar-cane production from about 250 000 hectares to about 128 000 hectares. The only areas remaining in sugar-cane production are Glendale, the North Coast lowlands, just under 80% of the North Coast hinterland, Indian areas and KwaZulu. The South Coast lowlands (saligna) and Midlands

Midlands South maize, and some beef on pasture is produced on the North Coast hinterland. It is significant that about 22 500 hectares of grassland in KwaZulu are put under pasture.

The effect of a free market on all regions combined is reflected in the last section of Table 6.6. Enterprises that gain from a free market for sugar are maize, timber and beef on pasture. Compared with the enterprise mix under the pool scheme with no ethanol production timber and beef on pasture show the highest increases. Production of maize and timber is not expected to influence prices of these products. For example, the maize area of about 74 000 hectares accounts for less than 2% of the total maize area in the country. Production would be less than 4% in a normal year. The additional timber area of about 66 300 hectares is about 6% of the total area under timber in South Africa (Laurens). Availability of weaners may present problems for beef on pasture in the short term. Many farmers may develop their own breeding herds as a result. Production on this scale is not expected to influence the beef price significantly in South Africa. Area under pasture is about 9% of the total area under consideration. Over one-third of the pasture area is in KwaZulu.

A noteworthy feature of a free market for edible sugar is reduced employment in three of the four regions. In Zululand employment is about 66% and in Natal 69% of employment under the current policy. Overall, employment is down 26%. Only in the Eastern Transvaal/KaNgwane is more labour employed and this is due to a larger area under sugar-cane. What is evident is a strong positive correlation between sugar-cane production and labour employment. This is also the case under the pool scheme.

Under a free market for sugar, quotas are abolished. Since at present quotas are transferable within Mill Group areas and have a market value, abolishment entails a "capital" loss to farmers as quotas then have no value. However, Bullock <u>et al</u> and Nieuwoudt (1976) demonstrated that if quotas are discontinued some of the existing quota rents may be transferred to land rents resulting in higher land prices. With a difference of R13.14 (R26.24) per tonne of sucrose between the producer price under the current policy (pool scheme) and the free market price, in regions where quota rents per tonne of sucrose exceed R13.14 (R26.24) the difference between the actual rent and R13.14 (R26.24) is an addition to land rent. In regions where the quota rent is less farmers lose the value of their quotas.

Production of sugar-cane in a free market occurs in areas of comparative advantage. Mills in high-cost areas may not close down immediately because, being specialized factors, they earn economic rents. As was pointed out under the pool scheme, mills may accept lower profits (rents) and pay farmers higher prices to keep them in production.

The effect of a supported sucrose (ethanol) price on sugar-cane production is highly significant. At a sucrose price of R140.65 per tonne, about 8% above the free market price, it is estimated that over one billion litres of ethanol could be supplied. Area under sugar-cane in Eastern Transvaal/KaNgwane increases more than four-fold. In both Zululand and Natal the cane area more than doubles compared with the free market situation. However, the cane area in Zululand is slightly lower and in Natal 13% higher than the respective current policy areas. At Pongola/Makatini no sugar-cane is produced but production occurs at higher ethanol prices. Compared with the multiple pool scheme one billion litres could be supplied at 1.25 cents per litre less. This is because no sugar is exported. Under the pool scheme areas used for export sugar production are now used to produce ethanol at a lower cost.

Ethanol production is, however, still not economically feasible when compared with the refinery-gate petrol price of 16.9 cents per litre (1979/80). For it to be produced, ethanol has to be subsidized by 21.35 cents per litre, or by over two cents per litre for a 10:90 ethanol:petrol blend. It is noteworthy that the total cost of ethanol of 38.25 cents per litre is less than the pump price of petrol of 39.15 cents per litre. In February 1985 the refinery-gate petrol price was 56.24 cents per litre and the pump price of 93-octane petrol at the coast 81.4 cents per litre (Jacobs). Ethanol production costs were estimated as 70 cents per litre (Buchanan, 1985) which is below the pump price and about 25% above the refinery-gate petrol price. The depreciating rand relative to the U.S.

dollar and the depressed state of the sugar market have made ethanol production more favourable. Compared with new SASOLs, the costs of which would rise substantially with a weak rand, ethanol from sugar-cane may be a viable alternative.

Should a billion - litre ethanol industry be subsidized the enterprise mix in various regions makes an interesting study. In Eastern Transvaal/KaNgwane sugar-cane is the most important enterprise. In fact, all of the 75 937 hectares are in the Eastern Transvaal. In KaNgwane 23 000 hectares are under grassland and 219 hectares under pasture. Some reasons for no sugar-cane in KaNgwane are the cost of irrigation water and the relatively long transport distances to mills/distilleries. Compared with the present organization no vegetables or cotton are produced and areas under dry beans and fruit are reduced. More tobacco is cultivated.

A shift towards production of vegetables, wheat, cotton, fruit and beef on pasture occurs at Pongola/Makatini where no sugar-cane is produced. All of the grassland area is still intact. In Zululand and Natal the predominant crops are sugar-cane and maize. Overall, area under sugar-cane is very sensitive to changing sucrose (ethanol) prices. The enterprise mix for the whole region is given in the last section of Table 6.6.

Comparing the combination of enterprises under the multiple pool scheme and the free market for edible sugar at supported sucrose (ethanol) prices of R147.90 and R140.65, respectively, (which in both cases supply about one billion litres of ethanol) it is noteworthy that under the free market scheme less sugar-cane is produced (470 500 hectares as against 549 800 hectares) and more of other enterprises, in particular maize, timber and beef on pasture. Area under grassland is over 60% higher, that is, 114 900 hectares as against 70 300 hectares. Fewer workers are employed under the free market scheme, namely 155 600 compared with 175 150.

Under a free edible sugar market and supported ethanol production it is estimated that an additional 76 000 hectares will be planted to sugar-cane compared with the current policy. With development costs of R1 600 per hectare in 1985 (Frean) total capital costs amount to about R120 million.

About 12 back-end and five autonomous distilleries producing a total of one billion litres of ethanol will come at a capital cost of roughly R760 million. With an additional dam and infrastructure in the Eastern Transvaal the total development cost is roughly R950 million. With additional employment on farms of 25 000 workers and about 3 000 in the distilleries (Buchanan, 1985) total development costs per worker are about R34 000. Development costs of a new SASOL amount to over one million rand per worker (Scott, 1985).

An important result from the free edible sugar market model is that as the price of ethanol is increased the local price of sugar also increases as more sucrose is diverted into ethanol production. Supply of sucrose for domestic sugar production decreases. Without import protection the local price of sucrose cannot increase to more than R150 per tonne as all sucrose requirements would then be imported.

As regards the food versus ethanol issue, under the above policy more food is in fact produced than under the present organization when one billion litres of ethanol are produced. Areas under vegetables and dry beans increase (resulting in lower prices) with a marginal decrease in fruit production. Wheat, maize and beef on pasture increase and areas under timber and grassland decrease. It could be argued, therefore, that under a free edible sugar market, development of an ethanol industry at the expense of export sugar may be a catalyst in the development of rural areas and increased food production.

6.5.3 Effects of full irrigation water tariffs under a free edible sugar market

In the previous sections it was assumed that irrigation water tariffs in existing irrigation areas do not change. However, in new irrigation areas a water tariff of R100 per hectare per annum was used. This accounted for the statutory 33 1/3 subsidy on initial capital outlay (see section 6.4). However, should the government decide to abolish all subsidies on irrigation water the effects on resource use may be considerable. These potential effects are to be evaluated for a free edible sugar market and supported ethanol prices. Thus, two cases will be analysed, namely where no ethanol is produced and where one billion litres of ethanol are manufactured.

Data from van Niekerk showed that for a new dam which has recently been completed in the Eastern Transvaal farmers will have to pay about R150 per hectare per annum (1979/80 value), depending on the water quota allocation. In the Nkwaleni Valley the full tariff is about R120 per hectare per annum (1979/80 value) with the new Goedertrouw dam. Since no figures for Pongola/Makatini Flats were available R150 per hectare was used. For other irrigation areas water costs are low either because of relatively inexpensive schemes (for example, Tala Valley) or because water is pumped from existing weirs in the river. A figure of R30 per hectare was used for these areas which account for only a small proportion of the total cane area. Table 6.7 summarizes the effects of full irrigation water tariffs relative to subsidized water tariffs.

The effects of full water tariffs on resource use and crop mix are considerable. Under a free market (that is, no ethanol production) the area under sugar-cane in the Eastern Transvaal decreases from about 18 300 hectares where water is subsidized to 600 hectares with no subsidies. Vegetable production increases while areas under fruit and tobacco do not change. No pastures for beef production are cultivated. About 20 000 hectares of presently irrigated land become fallow and labour employment in this region falls by 40%. The shadow price (rent) of irrigated land decreases from about R106 per hectare to R10 per hectare while the grassland shadow price increases from R6.44 to R7.32 per hectare. Irrigation land decreases in value while grassland becomes more valuable.

Table 6.7 Comparison of the effects of full and subsidized water tariffs on enterprise mix and labour employment in four major regions of the South African Sugar Industry under a free market for edible sugar and with ethanol price supports.

Particulars	No ethanol production		Ethanol production (10^9 litres)	
	subsidized water	unsubsidized water	subsidized water	unsubsidized water
Sucrose price(1979/80) (R/t)	130.46	130.46	140.65	143.84
Total sucrose production (10^6 t)	1.35	1.35	3.14	3.15
Sucrose for ethanol production (10^6 t)	0	0	1.82	1.83
Ethanol production (10^6 t)	0	0	1 053	1 062
Ethanol costs (c/l)	n.a.	n.a.	38.25	38.80
Ethanol/pre-tax petrol price	n.a.	n.a.	2.26	2.30
Raw sugar production (10^6 t)	1.15	1.15	1.14	1.13
Producer surplus (R10^6)	45.5	38.9	72.0	68.6
Producer surplus/ha (R)	68	58	108	103
1. Eastern Transvaal	Enterprise areas (hectares)			
Sugar-cane	18259	599	75937	61012
Vegetables	130	959	-	-
Dry Beans	354	354	339	339
Wheat	-	-	-	-
Cotton	-	506	-	-
Tobacco	5000	5000	1347	5000
Fruit	3390	3390	3390	2990
Beef on pasture	3256	-	219	-
Fallow	-	19935	-	219
Grassland	79000	79000	28157	43959
Total hectares	109389	109389	109389	109389
Labour units	14358	8609	30053	24186

Particulars	No ethanol production		Ethanol production (10^9 litres)	
	subsidized water	unsubsidized water	subsidized water	unsubsidized water
Sucrose price (R/t)	130.46	130.46	140.65	143.84
2. Pongola/Makatini	Enterprise areas (hectares)			
Sugar-cane	-	-	-	1603
Vegetables	2659	1460	2432	2119
Dry beans	-	-	-	1875
Wheat	271	1438	2603	2556
Cotton	2087	3358	5120	6006
Fruit	681	658	3215	1457
Beef on pasture	9781	-	6431	-
Fallow	2575	11910	286	6002
Grassland	53650	53650	53650	53650
Total hectares*	69732	69732	69732	69732
Labour units	5833	3241	8215	6562
3. Zululand				
Sugar-cane	55363	74661	112393	143216
Vegetables	198	294	198	198
Dry beans	1180	1180	1129	254
Wheat	2576	742	-	-
Cotton	4921	2745	1612	363
Fruit	3886	3809	1253	3048
Maize	21234	21234	21234	21234
Timber	5000	5000	5000	5000
Beef on pasture	20308	13755	3974	1512
Fallow	12745	2467	-	4195
Grassland	54800	54800	33102	-
Total hectares*	178766	178766	178766	178766
Labour units	24841	30874	37677	45574

* The difference between the total area and the sum of areas for individual enterprises is due to double-cropping of cotton with crops such as vegetables and dry beans. This also applies to other regions.

Particulars	No ethanol production		Ethanol production (10^9 litres)	
	subsidized water	unsubsidized water	subsidized water	unsubsidized water
Sucrose price (R/t)	130.46	130.46	140.65	143.84
4. Natal	Enterprise areas (hectares)			
Sugar-cane	127880	133490	282214	285214
Fruit	-	-	-	-
Maize	52762	52762	23385	23385
Timber	87147	87147	3000	-
Beef on pasture	28748	34881	686	686
Grassland	12748	1005	-	-
Total hectares	309285	309285	309285	309285
Labour units	51138	53602	79651	80492
5. Total - all regions				
Sugar-cane	201501	208750	470544	491046
Vegetables	2986	2712	2629	2317
Dry beans	1534	1534	1468	1468
Wheat	2847	2180	2603	2556
Cotton	7008	6610	6732	6369
Tobacco	5000	5000	1347	5000
Fruit	7957	7858	7858	7496
Maize	73996	73996	44619	44619
Timber	92147	92147	8000	5000
Beef on pasture	62094	48636	11311	2198
Fallow	15320	34312	286	10416
Grassland	190198	178455	114909	97609
Total hectares	667172	667172	667172	667172
Labour units	96170	96325	155595	156813
Fuel use on farms (10^6 l)	46.2	41.7	68.8	65.5
Fuel use by contractors (10^6 l)	13.8	12.3	33.8	33.3

In the Pongola/Makatini area there is a trend away from vegetables and beef on pasture to wheat and cotton production. The area of fallow land increases nearly five-fold and labour employment falls by 44%. Also in this region the shadow price of irrigated land shows a considerable drop while that of grassland increases.

As expected, sugar-cane production shifts to dryland areas in Zululand and Natal. In the former area sugar-cane production increases by 35% and in Natal by 4%. The area of fallow land in Zululand decreases markedly because sugar-cane is now grown on the Umfolozi Flats. Some land lies fallow in the Nkwaleni Valley due to the high cost of irrigation. Production of wheat and cotton shifts from Zululand to Pongola. The area under pasture falls by about one-third.

In Natal the other noteworthy change is the increase in area under pasture by 21%. The increase in pasture area occurs mainly in KwaZulu. Shadow prices (rents) of arable land in Zululand, Natal and in black areas (dryland) increase slightly.

Overall there is an increase in cane area due to the shift of production to lower-yielding areas. It is noteworthy that total raw sugar production does not change so that the equilibrium price remains at R130.46 per tonne of sucrose. However, total producer surplus falls by about 15% to R39 million. Land prices in irrigation areas fall but increase in dryland areas because of the greater demand for land.

As regards ethanol production under full water costs, if one billion litres are produced the cost of producing ethanol increases by 0.55 cent per litre compared with the case where water is subsidized. Raw sugar production is similar. In the Eastern Transvaal sugar-cane production decreases by 20% while more tobacco and extensive beef are produced. In the Pongola area more dry beans and cotton but less fruit are produced. No pastures are cultivated while the area of fallow land increases. Shadow prices of irrigated land in the Eastern Transvaal show a decrease of R100 per hectare to R26 per hectare and at Pongola a decrease from R100 to R17 per hectare. Subsidized ethanol production increases the value of land.

Sugar-cane production shifts mainly to Zululand which also shows increased fruit production but decreased dry beans, cotton and beef production on pastures. It is significant that a large part of the Nkwaleni Valley is fallow. In Natal the timber area is replaced with sugar-cane. In both Zululand and Natal shadow prices of arable land show an increase. For example, in the Zululand high rainfall area the shadow price of caneland increases from R148 to R161 per hectare and on the North Coast lowlands from R229 to R255 per hectare. Arable land in black areas (dryland) also shows an increase in shadow prices with increased water costs in irrigation areas.

In both the Eastern Transvaal/KaNgwane and Pongola/Makatini areas labour employment falls by 20%, while it increases in Zululand by 21% and in Natal only marginally. Overall, labour employment increases only slightly. Producer surplus falls by 5% to R68.6 million. Compared with no ethanol production producer surplus is about R30 million higher. Subsidized ethanol production offsets the effects of no subsidies on water tariffs to a certain degree.

The implications of full water tariffs for the irrigation areas are considerable. Producers would shift to high return crops (some of which have not been considered here) or leave land fallow if they perceive risk to be too high. Land values tend to fall in irrigation areas (as is evident by the decreasing shadow prices) and increase in the dryland areas of Zululand and Natal. The effect of subsidized ethanol production is to increase land values.

6.5.4 Social costs of alternative policies

6.5.4.1 Introduction

In this section social costs of the current policy, the multiple pool scheme and of ethanol production will be estimated. Social cost, in Marshallian welfare analysis, can be defined as "the loss in consumers' and producers' surplus caused by departures from the competitive equilibrium" (Beck, p.242). Consumers' surplus, a concept popularized by Marshall, is defined as the area under the demand curve above the price line. Producers' surplus has traditionally been measured as the area above the product supply curve and below the price line (op. cit., p.242; Currie et al, p.755; Johnson, 1965, pp. 243-44). It is assumed that the total area under the demand curve to the left of a given quantity is a measure of total utility or welfare for a commodity and that the area under the product supply curve reflects the opportunity cost of resources used to produce that quantity of product. Since the concepts of producers' surplus and economic rent relate to the same phenomenon (Currie et al, p.754), Mishan (1968) argued in favour of the more general concept of economic rent (p.1279). However, Currie et al (pp. 758-59) found disagreement among economists over the appropriate definition and measurement of economic rent.

In this study model results are used to estimate social costs of the current policy, the proposed pool scheme and of ethanol production .

6.5.4.2 The current sugar policy (up to the 1984/85 season)

Sucrose production is controlled with quotas under this policy. Although a quota is allocated to a certain area of land which is registered, this land can be deregistered and the sucrose quota transferred to another piece of land with the consent of the Sugar Industry Central Board. If the transfer is to irrigated land, for example, the sucrose quota will be the same and the registered area will be less because of higher yields (Frean). In effect, quotas allotted to farmers are production quotas.

Under the current policy the producers' sucrose price on a 1979/80 basis was estimated as R143.60 per tonne, including transport subsidies and Equalization Fund payments. This is a weighted average of the domestic market price, which was estimated as R161.06 per tonne, and the export price of R124 per tonne. Under a quota scheme producers are better off since output reduction along an inelastic demand curve leads to increases in farm income. Consumers are worse off (consumer surplus decreases) because of high domestic prices and reduced consumption. This is reflected in Figure 6.3. Both demand and supply are at the farm level.

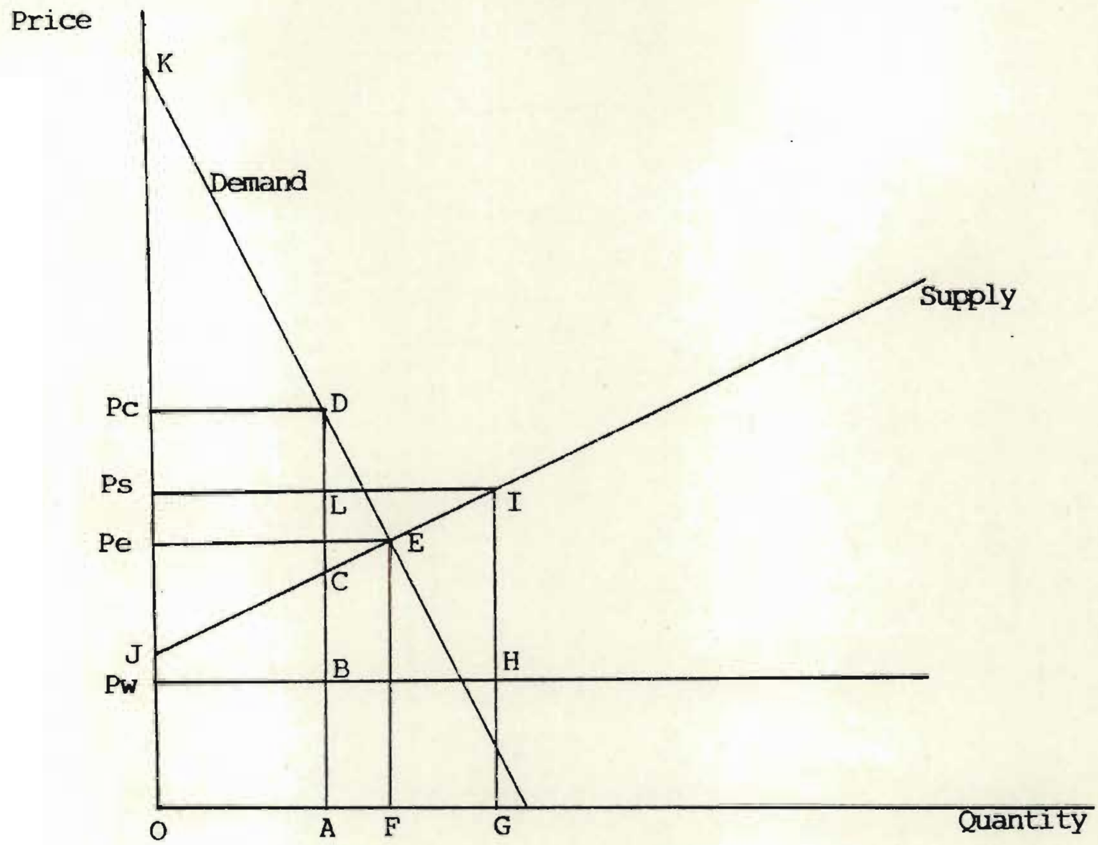

Figure 6.3 Estimating social costs under the current (single-price) sugar policy.

Sucrose production for the local market is limited to OA with the price at Pc. Loss in consumer utility is represented by area ADEF while resources to the value of ACEF are freed for use in other sectors. The net social loss, ignoring the export market, is represented by area CDE.

Another source of social costs is excess production. Sugar is produced for the export market for which the sucrose price was calculated as R124 per tonne which is about 14% below the producers' price and 5% below the domestic equilibrium price. The opportunity cost of the extra resources required amounts to area ACIG while income from exports totals area ABHG. Social cost due to excess production amounts to BCIH. Total social cost is represented by CDE + BCIH.

How can the simulation model be used to estimate total social costs of the current sugar policy? The objective function of the free market model, which maximizes consumer plus producer surplus, measures area JKE in Figure 6.3. The objective function for the current policy model measures area

JPsI which is the producer surplus. (The difference between the objective function of the current policy of R74.2 million and the producer surplus of R66.4 million is due to consumer surplus of crops with demand functions and is also accounted for in the free market model.) Calling area BLIH the subsidy on exports it can be shown that the objective function value of the free market model (JKE) less the objective function value of the current policy model (JPsI) plus the export subsidy (BLIH) less the consumer surplus of the current policy (PcKD) minus area PsPcDL equals the total social cost of the current policy (Nieuwoudt, 1985). That is, social cost (SC) = JKE - (JPsI - BLIH) - (PcKD + PsPcDL). This is identical to area CDE + BCIH indicated earlier.

It was estimated earlier (section 6.5.2.2) that domestic sugar consumption is equivalent to 1.28 million tonnes of sucrose at a price of R161.06 per tonne. Total sucrose production of the current policy model was 2.62 million tonnes. The difference of 1.34 million tonnes of sucrose is assumed to be exported. This is higher than normal export production (equivalent to about 1.14 tonnes sucrose) due to the higher average yields of the farm sample used in this study. However, social costs will be given as percentages of total sucrose value and income transfers and these are expected to be reasonable estimates of the true proportions. The consumer surplus of the policy can be easily calculated by deducting the total value of local sales (OPcDA) from total welfare (OKDA) which is derived from the sucrose demand function in section 6.5.2.2. This surplus amounts to R362.75 million while area PsPcDL equals R22.35 million. The objective function values of the free market and the current policies are R458.53 million and R74.23 million, respectively. The export subsidy amounts to R26.26 million. This subsidy should be similar to area PsPcDL. The difference is due to the higher than normal exports generated by the model which is also reflected in the objective function value. Part of the subsidy is captured by producers, namely area CLI in Figure 6.3.

With the above data the total social cost of the current policy (SCCP) is calculated as :

$$SCCP = R\{458.53 - (74.23 - 26.26) - (362.75 + 22.35)\} \text{ million}$$
$$= R25.46 \text{ million.}$$

The total producers' value of sucrose amounts to R376.23 million and total income transfer (area PePsIE) is estimated as R26.08 million. Social costs as proportion of total sucrose value and total income transfers are 6.8% and 97.6%, respectively.

These estimates of social costs are high compared with results of other studies. For example, Wallace's social cost estimates of quotas in USA agriculture, ignoring the export market, were less than 1% of total production value. McKenzie in his study of the Milk Scheme in South Africa obtained similar results (p. 56). For industrial milk he found that social costs stem largely from loss on exports (p.60). In this study the supply of sucrose was estimated to be highly elastic (9.4 for the pool scheme) and this is reflected in the relatively high social cost because of the high proportion of export sugar. Use of Wallace's formula (p.582) indicates that social cost due to consumption foregone (area CDE) amounts to 0.7% of sucrose expenditure.

Social costs when measured in terms of total production value are usually small. However, as Gardner has pointed out, if the objective of the policy is to transfer income from consumers to producers then social costs in terms of these transfers are significant. In fact, for the current policy social cost is similar to the income transfer to producers.

6.5.4.3 The pool scheme

The pool scheme was explained in section 6.5.1. Results show that no B - pool cane will be produced because of the unprofitable world sugar price. With only A - pool cane being produced the scheme will effectively revert back to a single - price scheme. However, the A - pool price will be higher and total production lower compared with the current policy. The

A - pool producers' price of R156.70 per tonne is a weighted average of the domestic sucrose price, which was estimated as R172.40 per tonne, and the export price of R124 per tonne. Domestic sucrose consumption is estimated to fall to about 1.25 million tonnes. The social cost analysis is similar to that of the current policy.

As with the current policy two sources of social cost can be identified, namely 1) a loss in consumer surplus due to a higher price and a lower quantity compared with the free market, and 2) price distortions causing excess production. In Figure 6.3 total social cost is represented by CDE + BCIH. This can be estimated from model results as follows : Objective function value of the free market (JKE) less the objective function value of the pool scheme (JPsI) plus the export subsidy (BLIH) less the consumer surplus of the pool scheme (PcKD) and area PsPcDL . In summary, the data to be used for a pool scheme with transferable quotas are as follows:

Objective function value	
- free market	= R458.53 million
- pool scheme	= R103.32 million
Consumer surplus	
- pool scheme	= R348.41 million
Area PsPcDL	= R19.62 million
Export subsidy	= R19.62 million
Total sucrose production	= 1.85 million tonnes
Domestic sucrose consumption	= 1.25 million tonnes
Sucrose exports	= 0.60 million tonnes
Domestic sucrose price	= R172.40 per tonne
Producers' sucrose price	= R156.70 per tonne
Free market sucrose price	= R130.46 per tonne
B - pool sucrose price	= R124.00 per tonne.

With the above data total social cost of the pool scheme (SCPS) is estimated as follows : SCPS = R{458.53 - (103.32 - 19.62) - (348.41 + 19.62)} million = R6.80 million. With a total production value of R289.90 million and a total income transfer to producers of R41.98 million the proportions of social cost to these two measures are 2.3% and 16.2%, respectively. For a pool scheme with quotas not transferable between regions social costs were estimated as R13.66 million. Social costs in terms of total sucrose value and income transfers are 4.7% and 32.5%, respectively.

The lower proportions of social costs compared with the current policy can be attributed mainly to the lower export tonnage under the A - pool. However, social cost due to consumption foregone (area CDE) is higher, namely 1.3% of sucrose expenditure. For a pool scheme social costs are lower if quotas are transferable between regions because sugar-cane production moves to areas with a comparative advantage in cane production. Nieuwoudt <u>et al</u> (1976, p.492) also reported that social costs decreased when allotments in peanut production in the USA were made transferable.

6.5.4.4 Effects of ethanol production on social costs

The effects of ethanol production on social costs are to be evaluated in this section for both the pool scheme and a free market for edible sugar. Ethanol prices are supported.

6.5.4.4.1 <u>Pool scheme</u>

For the pool scheme it was estimated that farmers have to receive R147.90 per tonne of sucrose (1979/80) if one billion litres of ethanol are to be produced (see section 6.5.1.2). This price is below the A - pool producers' price of R156.70 per tonne and above the free market price of R130.46 per tonne. Total sucrose production amounts to 3.65 million tonnes of which 1.85 million tonnes are for the A - pool.

Two markets are involved, namely a market for sugar (A - pool) and a market for ethanol (C - pool). The social cost analysis for the A - pool is similar to the one described in section 6.5.4.3 and shown in Figure 6.3. For the ethanol market estimation of social costs is shown in Figure 6.4. Since ethanol is aimed at the fuel market the pre-tax petrol price, either based on crude oil or SASOL, is used as base. Prices are in cents per litre which include the manufacturing cost of ethanol of 14 cents per litre. The support price (Ps) is 39.5 cents while Pe is estimated as 37.0 cents per litre (sucrose for ethanol production only commences after this price (see Table 6.2)). The petrol price (Pp) is taken as 16.9 cents which is based on crude oil. This is the extreme case and is used for illustration purposes since the SASOL price, which was higher than that based on crude oil around 1979/80, is not known.

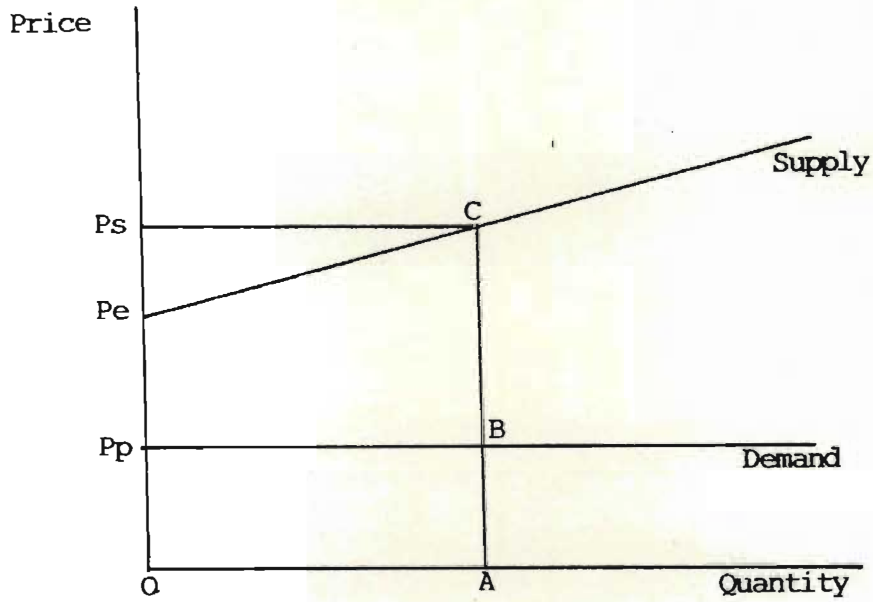

Figure 6.4 Estimating social costs in an ethanol market.

Total ethanol production (OA) amounts to 1041.7 million litres (based on 1.80 million tonnes sucrose) and the total subsidy (area PpPsCB) to R235.42 million. Resources to the value of OPeCA are used for ethanol production while producers gain PePsC. Income from fuel sales amount to OPpBA. Social cost in the ethanol market, therefore, is represented by area PpPeCB and totals R222.40 million. Total expenditure on fuel (area OPpBA) amounts to R176.05 million. Social cost in the ethanol market as a proportion of fuel expenditure is estimated as 126%. This social cost is additional to the social costs of the A - pool (see section 6.5.4.3).

The above analysis was based on the price relationship between ethanol and petrol around 1979/80 and did not consider SASOL costs which were higher than petrol from crude oil. Recent events have decreased the price difference between ethanol and petrol substantially, that is, to about 25%. Working on this price difference social cost in the ethanol market in terms of total fuel expenditure is estimated as 21%. This may have been the situation in relation to SASOL around 1979/80. With new SASOLs there may be no difference in costs between its products and ethanol. This is because of the depreciating rand and its effects on importation costs of sophisticated machinery for SASOL's capital intensive projects which give rise to the bulk of costs of SASOL's products. For ethanol the bulk of costs arise from raw materials (sugar-cane) the production of which is less vulnerable to a weak rand because South Africa produces most of the inputs required for cane production. Under these circumstances social costs due to ethanol production may be negligible.

6.5.4.4.2 Free market for edible sugar but with ethanol price supports

In a free sugar market no sugar is exported. The domestic equilibrium sucrose price was estimated as R130.46 per tonne and sucrose consumption as 1.35 million tonnes. Should ethanol production be considered then the sucrose price will have to be subsidized. Two markets for sucrose are, therefore, involved - one for sugar and one for ethanol. An increasing sucrose (for ethanol) price will lead to an increasing sugar price as more sucrose is diverted to ethanol production. Consumers in the sugar market are, therefore, worse off because of the higher price. Higher local sugar prices and excess sucrose production are again the sources of social costs. The two sucrose markets are shown in Figure 6.5

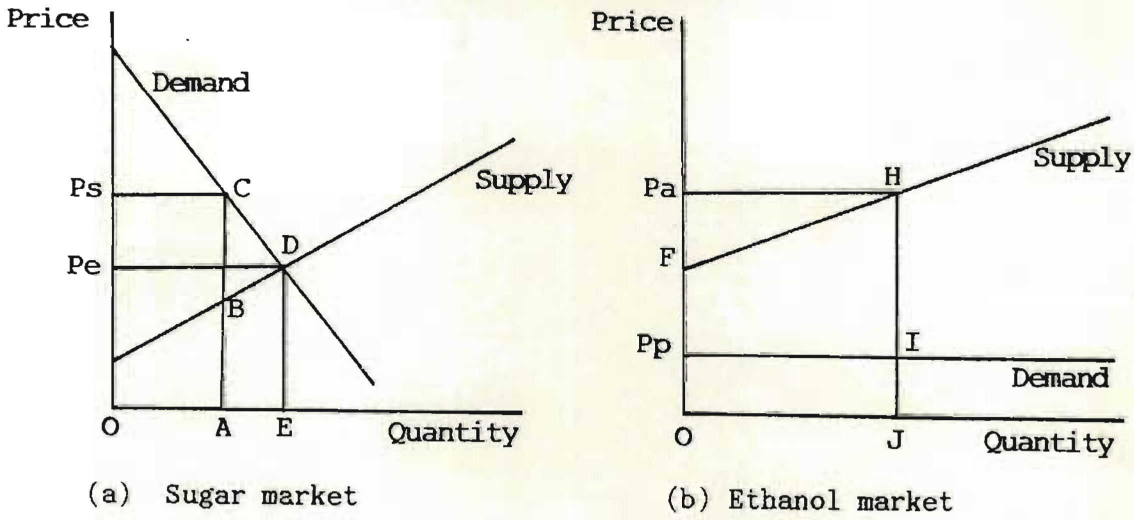

Figure 6.5 Estimating social costs if the edible sugar market is free but the price of ethanol is supported.

For production of just over one billion litres of ethanol the farmers' support price would have to be R140.65 per tonne of sucrose or about 8% higher than the equilibrium price (Pe) of R130.46 per tonne. Sucrose for sugar production decreases from 1.35 million tonnes (OE) to 1.33 million tonnes (OA). For ethanol 1.82 million tonnes of sucrose are produced from which 1053.1 million litres of ethanol are produced (OJ). The price of ethanol (Pa) is 38.25 cents per litre and the price of petrol (Pp) 16.9 cents per litre. The price of fuel in a South African context could be taken as costs based on SASOL's fuel. However, since this is not known the refinery - gate petrol price, which is the extreme case, is taken. Around 1979/80 this was without doubt lower than SASOL's petrol costs. The total ethanol subsidy is area PpPaHI which amounts to R224.84 million.

The social cost of a supported ethanol industry arises out of two causes, namely 1) due to a higher edible sugar price (social cost = area BCD), and 2) due to excess production of sucrose for ethanol production. Total resources used for ethanol production amount to area OFHJ while the value of fuel sales equals OPpIJ. Social cost due to ethanol production is area PpFHI.

In the sugar market social cost expressed in terms of total sucrose expenditure is negligible (0.08%). Social cost in the ethanol market is estimated as R215.62 million or 121% of total fuel expenditure (R177.97 million). With a 25% difference between ethanol and petrol prices social cost as proportion of total fuel expenditure is estimated as 22%. Compared with petrol costs of new SASOLs social costs due to ethanol production may be negligible.

6.5.4.5 Conclusions

The preceding analysis indicates that the pool scheme proposed by the Sugar Industry will come at a lower cost to society than the current policy because of lower export production. However, social cost due to consumption foregone will be higher for the pool scheme because of higher domestic prices. Social costs are lower when quotas are transferable between regions.

Recently world sugar prices have decreased relative to local sugar prices, even after accounting for the low exchange rate of the rand. Under these circumstances social costs will be even higher than those estimated above if similar quantities of sugar are exported. Sugar imports will be cheaper than locally produced sugar under the pool scheme.

Ethanol production will add to social costs if the refinery-gate petrol price or prices of present SASOL's products are used as base. However, if fuel prices of new SASOLs are used ethanol production from sugar-cane may not add to social costs. Social costs due to ethanol production may decrease if the advantages of ethanol are considered.

Implicit in using producers' and consumers' surplus to measure social costs is the assumption of static supply and demand curves and constant elasticities. Shifts in these curves may lead to different estimates of social costs. To a limited extent this has been accounted for in the above analysis as model results were used to estimate social costs. However, substitution in demand between crops was considered for only two crops. A more realistic estimation procedure would entail more sophisticated models where the implications of market interference are simulated more closely. However, such models become very complex, for example, the National Interregional Agricultural Projection (NIRAP) system which is a simulation model of the U.S. Agricultural sector (Webb, 1981, p.533). For all practical purposes the above analysis is regarded as useful because it has given some insight into the relative social costs between various schemes.

6.5.5 <u>Summary of results</u>

This section summarizes the main results obtained in this study.

Area under sugar-cane under the pool scheme, assuming transferable quotas between regions, is 27% below the area for the current policy. Under a free sugar market cane area falls by 49% compared with the current policy and by 30% relative to the pool scheme. With ethanol production of one billion litres (which would have accounted for about 10% of South Africa's liquid fuel requirements in 1980) cane areas under the pool scheme and the free edible sugar market increase by 39% and 19%, respectively, compared with the current area. With full water tariffs cane areas overall are higher because cane production shifts to dryland areas with lower yields per hectare. Land shadow prices (rents) in dryland areas increase because of greater demand for arable land.

Table 6.8 Summary of main results, current policy versus a pool scheme versus a free edible sugar market, South African Sugar Industry.

Particulars	Current policy (simulated)	Pool scheme* No ethanol	Pool scheme* With ethanol (10^9 litres)	Free edible sugar market No ethanol	Free edible sugar market With ethanol (10^9 litres)	Free edible sugar market - full water tariffs No ethanol	Free edible sugar market - full water tariffs With ethanol (10^9 litres)
Cane area (ha)	394462	286663	549842	201501	470544	208750	491046
Sucrose production (10^6t)	2.62	1.85	3.65	1.35	3.14	1.35	3.15
Sucrose supply elasticity	-	-	9.4	-	13.3	-	-
Sugar production (10^6t)	2.24	1.59	1.59	1.15	1.14	1.15	1.13
Ethanol production (10^6l)	-	-	1042	-	1053	-	1062
Ethanol supply elasticity	-	-	14.7	-	21.1	-	-
Ethanol costs (c/l)	-	-	39.50	-	38.25	-	38.80
Ethanol/pre-tax petrol price	-	-	2.34	-	2.26	-	2.30
Labour employment	130279	114389	175148	96170	155595	95306	156813
Fuel use on farms (10^6l)	55.1	49.7	72.6	46.2	68.8	41.8	65.5
Social cost:sugar market -% of sucrose value	6.8	2.3	2.3	0	0.08	0	0.13
Social cost:ethanol market -% of fuel expenditure	-	-	126**	0	121**	0	126**
Producer surplus (R10^6)	66.4	92.3	109.7	45.5	72.0	40.0	68.6
Producer surplus /ha (R)	99	138	164	68	108	60	103

* A - pool quotas transferable between regions.

** These estimates of social costs are based on prices of petrol from crude oil around 1979/80. More recently (1985) social costs in the ethanol market as proportion of fuel expenditure were estimated as 21% for the pool scheme, 22% under a free edible sugar market and 23% with full water tariffs. These estimates of social costs do not consider the benefits of using ethanol.

Total sucrose production reflects the area under sugar-cane for various policies. Under a free edible sugar market, sugar demand decreases with supported ethanol prices. Price elasticities of sucrose supply (for ethanol production) were estimated as 9.4 for the pool scheme and 13.3 under a free edible sugar market. For ethanol, price elasticities of supply were estimated as 14.7 and 21.1, respectively. Ethanol costs were about 2.3 times the refinery-gate or pre-tax petrol price around 1979/80 and appear to have been above SASOL petrol costs. Recently (1985) ethanol costs were estimated to be about 25% above the pre-tax petrol price. Ethanol may be a viable alternative when compared with costs of fuel from new SASOLs because of the effects of a weak rand on import costs.

There is strong positive correlation between sugar-cane production and labour employment. For example, under the pool scheme with ethanol production labour employment is estimated to increase by 34% and the cane area by 39% relative to current policy employment. Under the free edible sugar market and supported ethanol production cane area and labour employment both increase by 19% relative to current policy figures. Within each scheme, comparing no ethanol with ethanol production, increases in cane area and labour employment are 92% and 53%, respectively, for the pool scheme and 234% and 62%, respectively, under a free edible sugar market. Fuel use on farms also increases with increased sugar-cane production but the proportional increase is less than for labour employment. Development costs per worker for an ethanol industry under the pool scheme and a free edible sugar market are R21 100 and R34 000, respectively. For new SASOLs it is over one million rand.

Under a free sugar market the sum of producer and consumer surplus is maximized, that is, there are no social costs. Social costs as proportion of total sucrose value and income transfers are estimated to be higher for the current policy than for the pool scheme. This is because of the higher proportion of sugar sold on the unprofitable world market. Under the pool scheme no sugar is produced under the B - pool, the price of which is based on the world market. Ethanol production increases social costs. This would, however, depend on the relationship between ethanol and SASOL costs. The advantages of using ethanol, with were not considered in the estimation of social costs, may reduce these costs considerably.

DISCUSSION AND CONCLUSIONS

Ethanol production from sugar-cane juice is only feasible at present if subsidized by government. Compared with the refinery-gate petrol price (based on crude oil) ethanol costs were estimated to be over twice as high around 1979/80. Adams reported that ethanol costs in Brazil before subsidization were twice that of petrol (p.156). However, ethanol costs in this study were found to be similar to the pump price of petrol. Recent (1985) estimates of ethanol costs in South Africa are in the region of 70 cents per litre based on cane juice (Buchanan, 1985). The February 1985 refinery-gate petrol price was 56.24 cents per litre and the pump price at the coast 81.4 cents per litre for 93-octane petrol (Jacobs). Ethanol costs have become more favourable relative to petroleum costs mainly due to the depreciation of the rand against major currencies and the depressed sugar market. Since 1979/80 the refinery-gate petrol price has increased by about 20% per year on average and the producers' sucrose price by 10% per annum. The pump price of petrol, however, has only increased by about 8% per year. Taxes as a proportion of the pump price have been halved to 31%.

In South Africa it may be more appropriate to compare ethanol costs with costs of liquid fuels manufactured by SASOL. Various attempts were made to obtain cost estimates of SASOL's products. However, these attempts were not successful. American studies indicate that the cost of producing liquid fuel from coal is about 50% to 70% higher than that of fuel derived from crude oil. In South Africa the situation is different since the depreciation of the rand against the U.S. dollar has favoured SASOL. However, the government has supported SASOL with interest-free or "soft" loans in the past. Although the weak rand has favoured existing SASOL plants it will count against the construction of new SASOL plants because of the importation of sophisticated machinery and infrastructure. Construction of a new SASOL plant may cost about R5 billion to R6 billion at present (Scott, 1985).

As discussed above the weak rand (and its effect on the crude oil price) has not only favoured existing SASOLs but also ethanol from sugar-cane.

Under present circumstances it appears that ethanol costs may still be higher than costs of SASOL products. However, since existing SASOLs do not supply all of South Africa's liquid fuel needs, and assuming that fuel security is a top priority, an ethanol industry may well be viable when compared with the costs of constructing new SASOLs. SASOL has a disadvantage in its capital intensive nature and a weak rand may make construction costs prohibitive. The major portion of liquid fuel costs stem from capital costs. Coal has been relatively inexpensive; for example, in 1983 SASOL's average cost of coal, drawn from its own collieries, was R10 per tonne (Financial Mail, 1983, p. 34). Although South Africa's coal reserves are vast, coal is not renewable and increased domestic and export demand may place upward pressure on coal prices in the longer term.

Ethanol costs, in contrast to SASOL's, depend mainly on the raw material element which accounts for up to 70% of total costs. Sugar-cane production costs may not be as vulnerable to a weak rand as SASOL's construction costs because many of the inputs required for cane production are manufactured locally. Ethanol costs may be reduced through the development of improved sugar-cane varieties providing higher yields of "total sugars"; use of different field practices such as closer spacing of rows with resulting higher sugar yields; economies of scale in ethanol manufacture by fermenting sugars from other crops such as sweet sorghum or cassava in the cane off-season. More research would be required in these fields.

Ethanol costs may also be reduced by the fermentation of molasses. Molasses production is, however, limited by the amount of sugar produced. Under the pool scheme about 529 000 tonnes of molasses are produced and under the free sugar market about 367 000 tonnes. Assuming that all molasses is fermented for liquid fuel purposes about 132 million litres and 92 million litres of ethanol, respectively, would be produced under the two schemes (at present about 100 million litres of ethanol are produced for industrial uses). In 1979/80 the raw material element cost of ethanol from molasses was about 30% that of cane juice. Recent figures show a similar ratio. Although use of molasses will reduce the weighted average cost of ethanol its contribution will be limited.

A decided advantage of ethanol production from sugar-cane over SASOL from a socio-economic point of view is increased labour employment and the development of rural areas, particularly those with surplus labour. An ethanol industry producing one billion litres per annum under a pool scheme would employ an additional 45 000 workers on farms compared with current employment in the Sugar Industry. Under a free edible sugar market and a similar supported ethanol industry an additional 25 000 workers would be employed. Capital (development) costs per worker (including distilleries) were estimated to be in the region of R21 000 for the pool scheme and R34 000 for the free edible sugar market scheme (1985 figures). For a new SASOL project, development costs are in the region of one million rand per worker. In areas of surplus labour ethanol may be more competitive because of lower labour costs.

Which policy would be the most suitable for ethanol production? The free edible sugar market scheme has the advantage in that ethanol is produced at a lower cost than under the pool scheme because no sugar is exported to an unprofitable world market. Domestic sugar prices would move with ethanol prices. Most sugar mills could switch completely or partially from sugar to ethanol production. Under the pool scheme about half a million tonnes of sugar are exported annually at a loss which has to be subsidized by the local consumer. The Sugar Industry considers supplying export markets as important in order to retain markets and customer goodwill. Economics dictates otherwise. Ethanol costs would also be higher under a pool scheme. However, labour employment is higher which is an important consideration from a socio-economic viewpoint. Millers would prefer the pool scheme because of the greater proportion of sugar production and a greater increase in total cane production than under a free edible sugar market.

The food versus ethanol issue is not regarded as very contentious in the context of this study as South Africa is normally a net exporter of food. The effects of ethanol production under the multiple pool scheme on food production were negligible. Under a free market for edible sugar it was found that development of a price - supported ethanol industry at the expense of export sugar may be a catalyst in the development of rural areas and increased food production.

Whether of not the South African government should support an ethanol industry is a policy issue. SASOL I, II and III will not meet the domestic demand for liquid fuel. In fact, estimates put the supply at over 40% of local requirements. This means that South Africa is still dependent on the world oil trade since no economic quantities of crude oil have been found locally. From an economic point of view all petroleum products should be imported from countries which have a comparative advantage in the production of these commodities. The SASOL projects were developed with the view of improving the country's fuel security position. The capital costs of new SASOLs are likely to be exhorbitant with a relatively weak rand. With higher oil prices and a depressed sugar market ethanol production may become more viable. The creation of job opportunities, the development of rural areas, the saving of foreign exchange (particularly in view of the weak rand) and improved fuel security may be some reasons for the development of an ethanol industry, should a policy of self-sufficiency be followed.

With these views, the limitations of the study and suggestions for further research are presented below:

1) Production costs. Considerable time and effort was spent in obtaining enterprise production cost estimates. The major problem involved estimation of fixed costs per hectare which are not readily available. The Division of Production Economics of the Department of Agriculture may be the best organization for this task as it is already involved in annual cost surveys of some major crops such as maize and wheat. Cost budgets, similar to the USDA ERS (Economic Research Service) budgets, for different crops in different areas and for different farm sizes may well enhance the development of regional planning models in South Africa. Rent data could provide a useful check on cost data. This would also imply more research into renting of land in different regions. Also, more research is required into enterprise production costs on black, Indian and Mangete farms in different areas.

2) Economics of farm size. Different sugar-cane farm sizes were not considered in this study mainly because the volume of data would have increased the size of the model substantially. Also, little information regarding the fixed costs per hectare for different-sized farms for other crops was available. Optimum sizes of sugar-cane farms may be attained in a separate study involving more cases per size category than was available in this study. Alternatively, the model could be extended to ascertain the effects of optimum farm sizes on the viability of ethanol production.

3) Substitution between labour and machinery. At a regional level labour wages tend to increase with labour demand. Increased labour costs relative to machinery costs would encourage farmers to consider more mechanization. This aspect was not considered in this study. Use of capital (machinery) was considered the same even though labour wages increased with more development. For more realism in the model the relationship between labour and machinery use in different regions should be known. This would require a separate study.

Should crude oil prices increase relative to labour costs, mechanized technologies will become less competitive. Ethanol may become more competitive for the use of resources leading to increased demand for labour. The tradeoff between labour and capital at various energy prices also needs a more detailed study. The results will vary by region depending on relative availability of labour, farm size, topography and crop mix (Adams, pp.166-67).

4) Other ethanol crops. More research is needed in South Africa into the production of ethanol from other crops, such as cassava and sweet sorghum, which could complement sugar-cane. The use of existing facilities in the Sugar Industry by these crops, for example in the cane offseason, may reduce the costs of ethanol. An integrated production system should be studied. Also, research regarding the use of improved production methods and the development of new varieties geared towards "total sugars" production should be encouraged. Externalities associated with ethanol production, such as pollution from stillage (effluent) and possibly soil loss from more intensified cropping, should be important research areas.

5) Optimum size and siting of ethanol plants. There are basically three types of ethanol plants which could be utilized, namely back-end distilleries attached to sugar mills, autonomous distilleries and smaller distilleries operated by individual farmers or a group of farmers. Research is needed into the economic viability of each and their economies of size. There may be place for each type of plant. Distilleries may be attached to some or all existing sugar-mills and distilleries on their own may be the most feasible in new production areas or in existing cane areas more remote from mills. Costs of ethanol production on farms are likely to vary widely between individual farms and will depend on factors such as location, plant feedstock and the farmer's management skill (Wonder and Simpson, p.165). In fact, Hertzmark et al maintained that farmers generally do not have the time nor technical expertise to run an alcohol plant all the time (p.970). Lockeretz reported that planning and evaluation of an on-farm ethanol system is complex and requires a whole-farm model to optimize various objective functions under capital, labour and other constraints. A farmer should consider how such a venture will fit in with the rest of the farm's operation (p.183). More research is thus required in this field.

Since agricultural biomass is bulky, high transportation costs will limit the economic supply areas of ethanol plants. Research should be undertaken to establish the optimum size of ethanol plants for different areas at which long term ethanol production and raw material transport costs combined are at a minimum.

SUMMARY

In January 1985 the price of liquid fuels in South Africa was increased by over 40% despite the depressed oil market. This increase was due to the unfavourable exchange rate of the rand against the U.S. dollar on which oil transactions are based. At the same time sugar prices on the world market are depressed because of excess supply caused by support price policies in producing countries and a swing towards alternative sweeteners in major industrialized countries. For these reasons ethanol from sugar-cane may become a viable source of liquid fuel particularly when compared with fuel from coal in South Africa.

The major objective of this dissertation is to determine the economic feasibility of producing ethanol from sugar-cane in South Africa. The implications of producing ethanol under different sugar policies on resource use and crop mix are investigated. Social costs of various policies and the effects of ethanol production on social costs are also evaluated.

Coal accounts for about 80% of primary energy needs in South Africa and crude oil, which is imported, about 19%. South Africa does not produce any crude oil and has, therefore, embarked on fuel from coal projects (SASOL) to improve its fuel security position. The three SASOL plants together supply more than 40% of domestic liquid fuel use at present.

The fact that fossil fuels (crude oil, coal, natural gas) are regarded as finite has led many governments and researchers to study energy sources which are renewable. These include, among others, solar, water, wind and wave energy, methane gas and biomass. Only plants are able to utilize a substantial portion of available solar energy and many researchers and organizations have shown interest in the production of alcohol from agricultural biomass. Ethanol:petroleum blends containing up to 20% ethanol are acceptable for standard spark ignition engines. Diesel blends of up to 15% ethanol are acceptable provided a blend stabilizing agent is added.

Many authors maintain that a crop's overall energy balance (as measured by the energy output to input or net energy ratio (NER)) is a major consideration in fuel production. Of various crops considered (sugar-cane, cassava, sugar-beet, sweet sorghum, maize and timber) sugar-cane is the only crop that consistently has a NER greater than unity. However, the danger of placing too much emphasis on net energy ratios is that the economics of alcohol production may be neglected. The market will determine which crops are most suitable. Ethanol prices, yields and production costs are important.

In a South African context sugar-cane has the highest yield of ethanol per hectare, namely 4 000 litres on average on dryland farms and up to 7 000 litres on irrigation farms. Yields could be increased and costs reduced with use of improved cultural practices and varieties selected for "total sugars" production. A major problem with large-scale ethanol production is stillage (effluent) disposal. More research is needed for satisfactory solutions to stillage disposal.

Estimated yields of alcohol per hectare of other potential energy crops in South Africa include cassava, 2 750 litres; sweet sorghum, 2 500 litres; maize, 840 litres; timber 2 000 litres ethanol or 2 800 litres methanol. Of these crops cassava appears to have the best potential as it could be produced on marginal caneland. As in Brazil, cassava and sugar-cane could be complementary energy crops, leading to reduced ethanol production costs per litre. Timber has certain advantages over field crops. However, it has been estimated that there is a long-term shortage of timber in South Africa so that alcohol production would have to rely on waste and residue material. The collection, processing and transport of these materials would present major problems.

General consensus among researchers is that alcohol production from agricultural biomass is not economic when compared to equivalent petroleum-based fuels. However, estimates of production costs vary widely. For sugar-cane the raw material element generally accounts for 60% to 67% of total costs. Molasses, a byproduct of sugar production, is a competitive ethanol source. However, supply of molasses is limited by the amount of sugar produced. Estimates of production costs of ethanol from sugar-cane juice in South Africa have not accounted for the volume of ethanol required for, say, an overall 10:90 ethanol:petrol blend. The raw material cost was simply taken as the ruling producers' price. Advantages of using an ethanol blend, such as its antiknock value and reduced emission of polluting materials, may reduce the cost difference with petroleum.

For ethanol to make a significant contribution to South Africa's liquid fuel requirements it must be produced in large quantities and at a cost which will make it at least comparable with competing fuels. Since cropping land is a limiting factor a crop producing the highest optimal yield of ethanol per hectare would have an advantage. In South Africa sugar-cane, which is considered to be one of the most efficient users of solar energy, provides the highest yields. Sugar-cane also has the advantage in that it is a perennial which can be grown on relatively steep terrains. Its high fibre content is a positive feature in that bagasse (residue after the extraction of juice) can be used as furnace fuel (thus reducing operational costs of sugar factories) and for the production of paper, cardboard etc. Surplus bagasse could be converted into ethanol; however, research in this field is still in its infancy.

A decided advantage of sugar-cane is that the existing infrastructure could be used for ethanol manufacture. The Industry's main production areas are relatively close to major oil refineries in Durban which would most probably do the blending and distribution of blends. Also an extensive knowledge of local problems and opportunities of sugar-cane growing have been accumulated over many years of research. Brazil's experience with ethanol production could be a valuable source of information.

It appears, therefore, that sugar-cane is a leading source of biomass for ethanol production in South Africa. It could extend the activities of the Sugar Industry which at present employs 150 000 people of which 22 000 are individual cane farmers. Seventeen sugar mills are involved. The Industry is governed by the S.A. Sugar Association which comprises the S.A. Cane Growers' Association and the S.A. Sugar Millers' Association Ltd. Production of sugar-cane is controlled with production quotas and registered quota land. Quotas are only transferable within Mill Group areas.

South Africa is the 12th largest sugar producer in the world, but accounts for only 2% to 3% of total tonnage. Only about 15% of world sugar production is traded on the world free market. This market is a residual one so that surplusses or shortages lead to wide price fluctuations. International sugar agreements have been negotiated from time to time in an attempt to control these price fluctuations. Generally, these agreements have not been successful. South Africa, on average, exports just under one million tonnes of raw sugar annually.

With the above background information the sugar-cane model was developed. In order to evaluate alternative policy measures it was necessary to simulate existing cropping patterns in various areas of the Industry.

The Sugar Industry, including potential cane areas, was divided into 22 resource regions of which 16 are in white farming areas and are relatively homogeneous. Indian and Mangete (Coloured) growers were divided into two areas. For black growers four areas were demarcated, namely, KwaZulu north and KwaZulu south of the Tugela River, the Makatini Flats and KaNgwane. Data on crop areas and yields were obtained from the S.A. Cane Growers' Association, extension officers in various regions and consultants. The areas with greatest potential for sugar-cane expansion include the Eastern Transvaal lowveld, KaNgwane, Pongola/Mkuze, KwaZulu dryland areas and the Makatini Flats.

Production costs for sugar-cane in white areas were based on data of over 1 700 farmers over the four years 1976/77 through 1979/80 and were received from the S.A. Cane Growers' Association. Production costs of vegetables, subtropical fruit and beef were based on budgets, surveys and record systems of the Department of Agriculture. Timber budgets were based on work by the S.A. Timber Growers' Association and the Forest Owners' Association. For black cane growers production costs were based on those of white farmers, taking cognizance of differences in farming structures.

Producers' sucrose prices are usually based on production costs. Rent data could provide a useful check on production costs by deducting rent from gross income per hectare. A comparison of calculated costs with gross income less rent for various regions revealed that the former was generally lower on dryland farms and greater on irrigation farms. One would expect calculated costs to be lower because they have not accounted for risk nor the opportunity cost of own management. The irrigation areas are generally regarded as profitable sugar-cane areas. This is also reflected in the high price of land. One explanation for the high calculated costs is that farmers may have allocated costs attributable to vegetables and fruit production to sugar-cane. With this situation, and after considering various options, it was decided to use calculated costs for dryland farms and gross income less rent for irrigation production.

For the simulation model linear programming was used. Experiments with the model to evaluate alternative sugar-cane policies require a more flexible alternative than fixed prices. For this reason negative sloping linear demand curves confronting the region were built into the model for 13 crops. This enabled product prices to be generated within the model. Regional demand slopes were derived from national demand slopes. Prices were assumed not to increase more than 50% or decrease by more than one-third of the base price. The range of quantities corresponding to these prices was divided into 15 equal steps.

Since cross elasticities were evident between litchis and mangos, substitution in demand for these products was also considered. Five steps were taken for each crop giving rise to 25 activities. The tedious nature of this technique has probably discouraged many economists from using it.

As regards the supply of labour one can expect that on a regional basis farmers have to pay higher wages to attract more labour. This implies a positive sloping supply curve. Various studies have shown that labour supply in South Africa is highly elastic; for example, a recent study of regular labour supply in Natal resulted in supply elasticity estimates varying from 5.6 to 8.3. For casual labour this may be even higher. A supply elasticity of 10 was used for the four major regions used, namely

Eastern Transvaal/KaNgwane, Pongola/Makatini Flats, Zululand and Natal. For each of these regions labour supply functions were derived which enabled increasing labour costs to be calculated within the model. The positive -sloping supply curve was divided into 15 equal steps.

Evidence suggests that farmers are risk-averse. Neglect of risk in farm planning models may lead to unacceptable farm plans in that the size of risky enterprises may be overstated. Risk can be considered as a cost or the additional expected return that farmers want as compensation for taking risk. The inclusion of risk means that the marginal cost or new supply curve will shift to the left.

Risk associated with various enterprises was taken to be reflected in the deviation of gross income per hectare from trend. Data on gross incomes were obtained mainly from farmers and farming companies. The inclusion of risk was based on the mean absolute deviation method developed by Hazell and Hazell and Scandizzo. A variance-covariance matrix was included for each of the four major regions.

Different values of the "risk aversion coefficient" Ø were used to "tune-in" on the actual cropping pattern. A value of Ø = 0.25 was found to simulate the actual cropping patterns and prices best. With this value of Ø , shadow prices of land compared favourably with actual rents as did dual prices with actual prices of crops. Generally, the simulation exercise was successful.

Little significance is placed on the Ø value selected. It is simply a fine-tuning device which captures a number of factors such as data errors, model constraints and risk. It is incorrectly called a risk-aversion coefficient. An individual's perception of risk is subjective and is not expected to change in the short-term and may change only marginally in the long-term with age and experience.

A Ø value of 0.25 was used in evaluating alternative sugar-cane policies. Two policies regarding sugar and ethanol production were evaluated: A multiple pool scheme consisting of three pools and a free market for edible (human consumption) sugar. In the pool scheme the A - pool accounts for the domestic market for sugar and 50% of normal exports while the B - pool accounts for remaining exports. Ethanol production forms the C - pool. Although the Sugar Industry intends making A - pool quotas transferable only within Mill Group areas, it was assumed in this study that quotas are transferable between regions because of the possibility of ethanol production and, hence, greater flexibility in the marketing of sugar-cane.

Sugar-cane has to compete with other crops for available resources. In addition to the present enterprises being farmed other enterprises in which farmers have shown interest, such as beef on pasture and maize, were also considered. The 1979/80 technology base and relative prices were used. A water tariff of R100 per hectare per annum was applied to new irrigation areas. A subsidized water tariff may be economically justified if more water is used from the dam.

Under the multiple pool scheme the producers' price under the A - pool was calculated as R156.70 per tonne of sucrose. This is a weighted average of the domestic sucrose price, which was estimated as R172.40 per tonne, and the export price of R124 per tonne which is a five-year mean, centred on 1979/80. Total sucrose production under the A - pool was limited to 1.85 million tonnes of which 1.25 million tonnes, it was estimated, would be consumed on the domestic market. The price of sucrose (for ethanol) was varied to trace out a sucrose supply function. The supply elasticities of sucrose and ethanol at the means of quantity and price were estimated as 9.4 and 14.7, respectively. Sucrose (ethanol) production is highly responsive to changing sucrose (ethanol)prices. The estimate of the sucrose supply elasticity is relatively high because of the "frictionless" nature of the linear programme.

It was estimated that in 1980 petroleum consumption in South Africa was about 10 billion litres. Assuming a 10:90 ethanol:petroleum mix the Sugar Industry would have to supply about one billion litres of ethanol per annum. To achieve this farmers have to receive R147.90 per tonne of sucrose which is about 6% below the A - pool price. With a manufacturing cost of 14 cents per litre the total ethanol cost is estimated as 39.5

cents per litre which is similar to the petrol pump price of 39.15 cents per litre. The ethanol cost is about 2.3 times the refinery-gate or pre-tax petrol price of 16.9 cents per litre. Advantages of using ethanol:petroleum blends may reduce the cost difference. In February 1985 the refinery-gate petrol price was 56.24 cents per litre and the cost of ethanol was estimated at 70 cents per litre. The increasing fuel price and the depressed sugar market have made ethanol a more viable proposition. It may compare favourably with fuel costs from new SASOLs, the costs of which may become exhorbitant with a weak rand.

At a producers' price of R147.90 per tonne of sucrose for ethanol production the total area under sugar-cane was estimated to increase by about 39% and labour employment by about 34% to 175 000 compared with the current situation. A strong positive correlation is evident between sugar-cane production and labour employment. The sugar-cane area increases nearly five times in the Eastern Transvaal/KaNgwane, remains similar at Pongola/Makatini, increases 48% in Zululand and about 14% in Natal compared with actual (1979/80) areas. Major enterprises that are replaced are grassland and timber. Development costs per worker are estimated as R21 000 compared with over one million rand for a new SASOL plant.

In the event of no ethanol production and with transferability of A - pool quotas, sugar-cane is only produced in areas of comparative advantage. Production shifts from Pongola, Hluhluwe, Nkwaleni, Zululand hinterland, South Coast lowlands and hinterland and Midlands South to the Eastern Transvaal and KwaZulu. At Pongola, for example, vegetables, cotton, fruit, wheat and beef on pasture are produced. Maize becomes an important enterprise in the Zululand hinterland area, the South Coast hinterland and Midlands South. No B - pool cane is produced due to an unprofitable export price.

Since quotas are assumed transferable between regions the rental rate will be the same in all regions as it will be determined by the free market. This rental rate was estimated as R23 per tonne of sucrose. Results of a model in which quotas were not transferable between regions (but within Mill Group areas) indicated that quota rents on the Umfolozi Flats, the

Zululand low rainfall area, KwaZulu South of the Tugela River and Indian and Mangete areas were higher than the free market rental. Quota owners in these regions would lose and quota renters would gain should transferable quotas between regions be instituted. The opposite applies to regions where quota rents are lower than R23 per tonne of sucrose.

Under the policy of a free edible sugar market all quotas are abolished and a negative sloping demand curve for sucrose on the domestic market is introduced. The producer price of sucrose is, therefore, determined by the model. Importing of sucrose is also considered with the cost, including freight charges of R26 per tonne, at R150 per tonne. Simulating a free market enables the effects of control to be quantified.

For the construction of the sucrose demand curve the price flexibility of demand at the wholesale level, estimated as -3.52, was used. The base price was taken as R161.06 per tonne of sucrose (which is the estimated domestic sucrose price under the current policy) and the base quantity 1.28 million tonnes of sucrose. The slope of the sucrose demand function was calculated as -4.4298×10^{-4} and the intercept as 727.99.

A result of the free market model is that only sugar for the domestic market is produced. Sugar-cane is produced in areas of comparative advantage, namely the Eastern Transvaal, Glendale, Zululand high and low rainfall areas, the North Coast, Indian and Mangete areas and KwaZulu. The sucrose price decreases from R161.06 to R130.46 per tonne and domestic sucrose demand increases from 1.28 million tonnes to 1.35 million tonnes.

Areas under sugar-cane, tobacco and beef on pasture in the Eastern Transvaal increase with a decrease in production of vegetables, dry beans, cotton and fruit which shift mainly to Pongola, Hluhluwe and Nkwaleni. No sugar-cane is produced at Pongola/Makatini, but there is increased vegetable production and a fairly substantial area under pasture for beef production at Pongola.

In Zululand, area under sugar-cane was estimated to fall by more than 50% to 55 400 hectares. Maize, timber and beef on pasture are the major enterprises replacing sugar-cane. In Natal a similar pattern is evident, with the area under sugar-cane falling by 49% to 128 000 hectares. Maize, timber and beef on pasture are again the main enterprises replacing cane. Overall, labour employment falls by about 26% compared with present employment patterns.

For ethanol to be produced it would have to be subsidized. Sucrose and ethanol production were estimated to be highly responsive to different prices with supply elasticities of 13.3 and 21.1, respectively, at the means of quantity and price. For a billion - litre ethanol industry farmers would have to receive R140.65 per tonne of sucrose or 8% more than the free market price. Under these circumstances the area under sugar-cane in Eastern Transvaal/KaNgwane was estimated to increase more than four-fold and in Zululand and Natal more than twice. However, at Pongola/Makatini no sugar-cane is produced. Ethanol is supplied at 1.25 cents per litre or 3% less than under a pool scheme. Areas previously used to produce export sugar are now used to produce ethanol at a lower cost. Overall, both area under cane and labour employment are 19% higher than under the current policy. Development costs per worker are estimated as R34 000 compared with over one million rand for a new SASOL plant.

As the ethanol price increases the domestic sugar price also increases as more sucrose is diverted to ethanol production. However, the sucrose price cannot increase to more than R150 per tonne without import protection as all sucrose requirements for domestic sugar and ethanol production would then be imported.

At present quotas are transferable within Mill Group areas and have a market value. Abolition of quotas involves a capital loss to farmers. However, this loss is not equivalent to the quota value as some of the existing quota rents may be transferred to land rents resulting in higher land prices. The more inelastic the land supply the more land rents increase to offset the loss in quota rents when quotas are discontinued.

The effects of full irrigation water tariffs on resource use and crop mix are considerable. For example, in the Eastern Transvaal sugar-cane production was estimated to fall from 18 300 hectares (when water is subsidized) to 600 hectares. Large tracts of land in irrigation areas become fallow while labour employment falls by over 40%. Sugar-cane production shifts to dryland areas in Zululand and Natal where land prices and labour employment increase. Total sugar production under the free market does not change but producer surplus decreases overall by about 15% with full water costs. Subsidized ethanol production offsets some of the effects of unsubsidized water tariffs.

Social costs of the current policy are estimated to be greater than for the pool scheme because of a greater volume of exports. These costs are small in relation to total sucrose production value, namely, 6.8% and 2.3%, respectively, but are significant as a proportion of income transfers from consumers to producers (98% and 16.2%, respectively). For a pool scheme with quotas not transferable between regions social costs in terms of total sucrose value and income transfers were estimated as 4.7% and 32.5%, respectively. Social costs are lower with transferable quotas because sugar-cane production moves to areas with a comparative advantage in cane production.

Under the pool scheme social cost in the ethanol market as a proportion of fuel expenditure was estimated as 126%. This analysis was based on the relationship between ethanol and petrol prices (based on crude oil) around 1979/80. With more recent (1985) cost differences of about 25% social cost was estimated as 21% of fuel expenditure. With a free edible sugar market but with ethanol price supports social cost in the ethanol market as a proportion of fuel expenditure in the above two periods was estimated as 121% and 22%, respectively. Compared with petrol costs of new SASOLs social costs due to ethanol production may be negligible.

Whether or not the South African government should support an ethanol industry is a policy issue. The advantages of an ethanol industry in South Africa are the creation of job opportunities, the development of rural areas, the saving of foreign exchange (particularly in view of the weak rand) and improved fuel security. Such an industry may compare favourably with a new SASOL venture. Additional areas of study include the development of improved crop production cost estimates, effects of economies of farm size on ethanol feasibility, substitution between labour and machinery, use of other ethanol crops supplementing sugar-cane and the optimum size and siting of ethanol plants.

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APPENDIX 1

TOTAL CANE TRANSPORT SUBSIDY, SOUTH AFRICAN SUGAR INDUSTRY, 1976/77 THROUGH 1981/82

Season	Total transport subsidy ($R10^6$)	Total cane production (10^6 t)	Total sucrose production (10^6 t)	Subsidy/ tonne cane (R)	Subsidy/ tonne sucrose (R)
1976/77	27.316	19.221	2.389	1.42	11.43
1977/78	31.719	19.009	2.441	1.67	13.00
1978/79	35.679	18.932	2.393	1.88	14.91
1979/80	43.401	18.412	2.386	2.36	18.19
1980/81	35.509	14.062	1.876	2.53	18.93
1981/82	50.276	19.532	2.383	2.57	21.10

Source : South African Cane Growers' Association

APPENDIX 2

SUGAR-CANE AREAS, PRODUCTION AND YIELDS IN VARIOUS HOMOGENEOUS AREAS OF THE SOUTH AFRICAN SUGAR INDUSTRY

Mean areas under sugar-cane and mean cane and sucrose production per annum of private white growers and miller-cum-planters (MCP) in the South African Sugar Industry over four years, 1976/77 through 1979/80, according to homogeneous areas. (Figures in parenthesis after private indicate the number of private white growers.)

Particulars	Registered area (hectares)	Cane production (tonnes)	Sucrose production (tonnes)
1. Eastern Transvaal			
Private (121)	14 300	1 037 574	134 294
MCP	4 124	308 504	38 287
Total	18 424	1 346 078	172 581
Mean yields(t/ha)		73.05	9.37
			(12.82%)
2. Pongola			
Private (190)	10 894	787 702	99 924
MCP	381	33 590	4 315
Total	11 275	821 292	104 239
Mean yields(t/ha)		72.84	9.25
			(12.69%)
3. Hluhluwe			
Private (20)	4 315	217 401	28 220
(No MCP)			
Mean yields(t/ha)		50.38	6.54
			(12.98%)
4. Nkwaleni Valley			
Private (37)	4 822	254 512	31 744
(No MCP)			
Mean yields(t/ha)		52.77	6.58
			(12.47%)

Particulars	Registered area (hectares)	Cane production (tonnes)	Sucrose production (tonnes)
5. Glendale			
Private (4)	140	7 048	932
MCP	1 358	67 170	8 965
Total	1 498	74 218	9 898
Mean yields(t/ha)		49.55	6.61
			(13.33%)
6. Tala Valley			
Private (5)	707	37 694	4 619
(No MCP)			
Mean yields(t/ha)		53.31	6.53
			(12.25%)
7. Umfolozi Flats			
Private (113)	15 214	769 519	97 503
MCP	140	7 380	871
Total	15 354	776 899	98 373
Mean yields(t/ha)		50.60	6.41
			(12.66%)
8. Zululand high rainfall			
Private (131)	25 374	1 473 017	182 917
MCP	2 743	165 200	20 384
Total	28 117	1 638 217	203 301
Mean yields(t/ha)		58.26	7.23
			(12.41%)
9. Zululand low rainfall			
Private (146)	28 367	1 157 593	148 588
(No MCP)			
Mean yields(t/ha)		40.80	5.24
			(12.83%)

Particulars	Registered area (hectares)	Cane production (tonnes)	Sucrose production (tonnes)
10. Zululand			
Private (111)	17 466	863 782	112 426
MCP	937	41 750	5 723
Total	18 403	905 532	118 148
Mean yields(t/ha)		49.20	6.42
			(13.04%)
11. North Coast hinterland			
Private (121)	21 785	1 235 435	158 034
MCP	1 263	48 883	6 066
Total	23 048	1 284 317	164 101
Mean yields(t/ha)		55.72	7.12
			(12.77%)
12. North Coast lowlands			
Private (154)	23 690	1 492 519	189 541
MCP	33 252	1 734 621	223 450
Total	56 942	3 227 140	412 991
Mean yields(t/ha)		56.67	7.25
			(12.79%)
13. South Coast lowlands			
Private (198)	26 493	1 237 229	157 755
MCP	13 299	727 188	92 272
Total	39 792	1 964 417	250 027
Mean yields(t/ha)		49.36	6.28
			(12.72%)
14. South Coast hinterland			
Private (99)	16 101	719 576	93 095
MCP	1 010	37 947	5 053
Total	17 111	757 523	98 149
Mean yields(t/ha)		44.27	5.74
			(12.95%)

Particulars	Registered area (hectares)	Cane production (tonnes)	Sucrose production (tonnes)
15. Midlands South			
Private (111)	17 555	766 231	98 357
MCP	2 315	109 226	14 019
Total	19 870	875 457	112 376
Mean yields(t/ha)		44.05	5.66
			(12.83%)
16. Midlands North			
Private (244)	36 005	1 456 625	179 603
MCP	3 239	106 544	13 037
Total	39 244	1 563 169	192 640
Mean yields(t/ha)		39.83	4.91
			(12.32%)

Source : Calculated from data received from the South African Cane Growers'Association.

APPENDIX 3

AREAS UNDER SUGAR-CANE AND PRODUCTION OF CANE AND SUCROSE BY ZULU, MANGETE AND INDIAN GROWERS, 1976/77 THROUGH 1979/80

Season	Area (ha)	Cane (t)	Sucrose (t)
		Zulu	
1976/77	24 074	561 536	70 417
1977/78	29 345	637 741	82 715
1978/79	34 164	866 703	111 025
1979/80	37 924	921 541	120 077
Mean/an.	31 377	746 880	96 058
Mean yields (t/ha)		23.80*	3.06*
			(12.86%)
		Mangete	
1976/77	1 609	43 083	5 566
1977/78	1 464	32 202	4 251
1978/79	1 582	45 724	6 025
1979/80	1 575	31 085	4 061
Mean/an.	1 558	38 024	4 976
Mean yields (t/ha)		24.41	3.19
			(13.09%)
		Indian	
1976/77	26 996	999 826	124 224
1977/78	26 483	919 416	116 311
1978/79	26 472	1 010 214	126 887
1979/80	26 577	844 518	107 988
Mean/an.	26 632	943 494	118 852
Mean yields (t/ha)		35.43	4.46
			(12.60%)

Source : Bates

* According to Bates, to calculate the actual yields achieved by Zulu growers, area under cane should be lagged two seasons because of the rapid increase in cane area over time. On this basis the cane yield for Zulu growers was calculated as 32.62 tonnes per hectare or 4.195 tonnes of sucrose. This yield was also used for Mangete growers under expansion.

APPENDIX 4

HECTARES UNDER VARIOUS ENTERPRISES IN 22 HOMOGENEOUS REGIONS OF THE SOUTH AFRICAN SUGAR INDUSTRY, 1979/80

Region	Enterprise	Hectares	
1. Eastern Transvaal	Sugar-cane	17 780	
	Tomatoes-market	200	
	Tomatoes-factory	300	
	Cucumbers	350*	
	Green beans	520*	
	Gem squash	350*	
	Hubbard squash	150	
	Seed dry beans	300*	
	Dry beans	1 000**	
	Cotton-irrigated	3 180***	
	Cotton-dryland	800	
	Tobacco	200	
	Bananas	1 000	
	Pawpaws	320	
	Mangos	400****	
	Litchis	200****	
	Guavas	130	
	Valencias	1 290	
	Grapefruit	1 700	
	Grassland (beef)	56 000	86 170
2. Pongola	Sugar-cane	11 332	
	Tomatoes-market	250	
	Cotton-dryland	4 000	
	Valencias	135	
	Grapefruit	365	
	Grassland (beef)	25 000	41 082
3. Hluhluwe	Sugar-cane	3 966	3 966

Region	Enterprise	Hectares	
4. Nkwaleni	Sugar-cane	4 395	
	Valencias	285	
	Grapefruit	670	5 350
5. Glendale	Sugar-cane	1 491	1 491
6. Tala Valley	Sugar-cane	686	686
7. Umfolozi Flats	Sugar-cane	14 680	14 680
8. Zululand high rainfall	Sugar-cane	28 722	
	Eucalyptus(saligna)	2 000	30 722
9. Zululand low rainfall	Sugar-cane	26 824	26 824
10. Zululand hinterland	Sugar-cane	19 834	
	Wattle	5 000	
	Grassland	1 400	26 234
11. North Coast hinterland	Sugar-cane	26 384	
	Eucalyptus(saligna)	300	26 684
12. North Coast lowlands	Sugar-cane	56 462	
	Eucalyptus(saligna)	200	56 662
13. South Coast lowlands	Sugar-cane	38 300	
	Bananas	1 500	
	Eucalyptus(saligna)	1 500	41 300

Region	Enterprise	Hectares	
14. South Coast hinterland	Sugar-cane	18 385	
	Wattle	500	
	Eucalyptus(saligna)	1 500	
	Grassland	3 000	23 385
15. Natal Midlands South	Sugar-cane	19 377	
	Wattle	2 000	
	Eucalyptus(saligna)	8 000	29 377
16. Natal Midlands North	Sugar-cane	39 547	
	Wattle	3 000	
	Eucalyptus(saligna)	1 800	
	Grassland	1 200	45 547
17. KwaZulu North	Sugar-cane	15 550	
	Grassland	54 800	70 350
18. KwaZulu South	Sugar-cane	22 375	
	Grassland	35 200	57 575
19. Indian areas	Sugar-cane	26 578	26 578
20. Mangete areas	Sugar-cane	1 575	
	Grassland	1 000	2 575
21. KaNgwane	Sugar-cane	219	
	Grassland	23 000	23 219
22. Makatini Flats	Grassland	28 650	28 650

* 30% of these areas are double-cropped with cotton.

** 50% of this area is double-cropped with cotton.

*** Excludes double-cropped area.

**** Actual areas under mangos and litchis are 600 and 400 hectares, respectively. A relatively large area is under young trees. Due to the use of negative sloping demand functions total production was considered more important. Mean yields in a normal rotation were used.

APPENDIX 5

ESTIMATING INVESTMENT ON SUGAR-CANE FARMS IN VARIOUS HOMOGENEOUS REGIONS OF THE SOUTH AFRICAN SUGAR INDUSTRY

The equations below were derived from a survey conducted by the South African Cane Growers' Association at the end of 1977. The investment figures exclude the values of land, cane roots and the crop. Movable investments (MI) include machinery and equipment. Fixed investments include buildings and sheds. Total investment (TI) comprises the sum of movable and fixed investments. The relevant area under sugar-cane (A) is plugged into the equation to arrive at the MI or TI which are in terms of 1977 values. Indices received from the South African Cane Growers' Association are used to arrive at 1979 values. Depreciation is calculated at 20% for movable investments and at 4% for fixed improvements.

Region : Eastern Transvaal

Equations : $\log MI = -0.0815 + 0.9043 \log A$ $\quad \bar{R}^2 = 0.58$

$(t = 4.7)$ $\quad df = 14$

$\log TI = 0.4997 + 0.8042 \log A$ $\quad \bar{R}^2 = 0.52$

$(t = 4.1)$ $\quad df = 14$

where MI = movable investment ; TI = total investment ;
A = area under cane ; df = degrees of freedom
(these apply to all equations in this appendix)

Area under cane = 133.52 hectares

Corrected Investment :

Item	End 1977 (R)	Raising factor	End 1979 (R)	Depreciation (R)
Movable investment	69 284	1.3048	90 402	18 080
Fixed investment	92 548	1.3109	121 321	4 853
Total investment	161 832		211 723	

Region : Pongola

Equations : $MI = 14.0444 + 0.4594\ A$ $\quad \bar{R}^2 = 0.72$
(t = 5.6) $\quad df = 11$

$TI = 24.9753 + 1.2913\ A$ $\quad \bar{R}^2 = 0.82$
(t = 7.4) $\quad df = 11$

Area under cane = 61.50 hectares

Corrected Investment :

Item	End 1977 (R)	Raising factor	End 1979 (R)	Depreciation (R)
Movable investment	42 298	1.2684	53 650	10 730
Fixed investment	62 092	1.3109	81 397	3 256
Total investment	104 390		135 047	

Region : Nkwaleni Valley

Equations : $\log MI = -0.2347 + 0.9076 \log A$ $\quad \bar{R}^2 = 0.75$
(t = 4.7) $\quad df = 6$

TI = n.a. $\quad \bar{R}^2 = 0.00$

Area under cane = 127.48 hectares

Corrected Investment :

Item	End 1977 (R)	Raising factor	End 1979 (R)	Depreciation (R)
Movable investment	47 446	1.2715	60 328	12 066
Fixed investment	55 048	1.3109	72 162	2 886
Total investment	102 494		132 490	

Region : Zululand high rainfall

Equations : $MI = 0.7052 + 0.2160\ A^*$ $\quad \bar{R}^2 = 0.54$
$(t = 5.0)$ $\quad df = 19$

$TI = 52.7889 + 0.3640\ A^*$ $\quad \bar{R}^2 = 0.37$
$(t = 3.6)$ $\quad df = 19$

Area under cane = 207.54 hectares

Corrected Investment :

Item	End 1977 (R)	Raising factor	End 1979 (R)	Depreciation (R)
Movable investment	45 534	1.2311	56 057	11 211
Fixed investment	82 799	1.3109	108 542	4 342
Total investment	128 333		164 599	

* These equations were also used for the Umfolozi Flats

Region : Zululand low rainfall

Equations : $MI = 17.9786 + 0.1168\ A$ $\quad \bar{R}^2 = 0.09$
$(t = 2.1)$ $\quad df = 32$

$TI = 71.7203 + 0.2436\ A$ $\quad \bar{R}^2 = 0.04$
$(t = 1.5)$ $\quad df = 32$

Area under cane = 192.54 hectares

Corrected Investment :

Item	End 1977 (R)	Raising factor	End 1979 (R)	Depreciation (R)
Movable investment	40 467	1.2389	50 135	10 027
Fixed investment	78 156	1.3109	102 455	4 098
Total investment	118 623		152 590	

Region : Zululand hinterland

Equations : $\log MI = -0.4457 + 0.9066 \log A$ $\quad \bar{R}^2 = 0.72$

$(t = 7.1) \quad df = 18$

$\log TI = -0.0606 + 0.9323 \log A$ $\quad \bar{R}^2 = 0.77$

$(t = 8.0) \quad df = 18$

Area under cane = 178.68 hectares

Corrected Investment :

Item	End 1977 (R)	Raising factor	End 1979 (R)	Depreciation (R)
Movable investment	39 449	1.2355	48 739	9 748
Fixed investment	69 949	1.3109	91 696	3 668
Total investment	109 398		140 435	

Region : North Coast hinterland

Equations : $MI = -11.6139 + 0.2787 A$ $\quad \bar{R}^2 = 0.66$

$(t = 6.5) \quad df = 20$

$TI = -13.5704 + 0.7604 A$ $\quad \bar{R}^2 = 0.71$

$(t = 7.3) \quad df = 20$

Area under cane = 155.78 hectares

Corrected Investment :

Item	End 1977 (R)	Raising factor	End 1979 (R)	Depreciation (R)
Movable investment	31 802	1.2341	39 247	7 849
Fixed investment	73 083	1.3109	95 805	3 832
Total investment	104 885		135 052	

Region : North Coast lowlands

Equations : $MI = -2.5304 + 0.2199\ A$ $\bar{R}^2 = 0.74$
(t = 7.4) df = 18

$TI = 11.2937 + 0.6072\ A$ $\bar{R}^2 = 0.68$
(t = 6.5) df = 18

Area under cane = 170.32 hectares

Corrected Investment :

Item	End 1977 (R)	Raising factor	End 1979 (R)	Depreciation (R)
Movable investment	34 923	1.2380	43 235	8 647
Fixed investment	79 789	1.3109	104 595	4 184
Total investment	114 712		147 830	

Region : South Coast lowlands

Equations : $\log MI = -0.4207 + 0.8925 \log A$ $\bar{R}^2 = 0.42$
(t = 3.9) df = 19

$\log TI = 0.6723 + 0.6047 \log A$ $\bar{R}^2 = 0.44$
(t = 4.1) df = 19

Area under cane = 163.18 hectares

Corrected Investment :

Item	End 1977 (R)	Raising factor	End 1979 (R)	Depreciation (R)
Movable investment	35 818	1.2350	44 236	8 347
Fixed investment	66 582	1.3109	87 282	3 491
Total investment	102 400		131 518	

Region : South Coast hinterland

Equations : $\log MI = -1.2532 + 1.2875 \log A$ $\bar{R}^2 = 0.56$
(t = 4.7) df = 16

$\log TI = -0.1868 + 0.9957 \log A$ $\bar{R}^2 = 0.63$
(t = 5.4) df = 16

Area under cane = 178.44 hectares

Corrected Investment :

Item	End 1977 (R)	Raising factor	End 1979 (R)	Depreciation (R)
Movable investment	44 218	1.2429	54 958	10 992
Fixed investment	69 286	1.3109	90 827	3 633
Total investment	113 504		145 785	

Region : Natal Midlands South

Equations : $MI = -15.2850 + 0.3802 A$ $\bar{R}^2 = 0.72$
(t = 6.8) df = 17

$TI = -43.6576 + 0.9492 A$ $\bar{R}^2 = 0.70$
(t = 6.6) df = 17

Area under cane = 194.17 hectares

Corrected Investment :

Item	End 1977 (R)	Raising factor	End 1979 (R)	Depreciation (R)
Movable investment	58 538	1.2380	72 471	14 494
Fixed investment	82 111	1.3109	107 639	4 306
Total investment	140 649		180 110	

Region : Natal Midlands North

Equations : $\log MI = 0.2230 + 0.6087 \log A$ $\bar{R}^2 = 0.49$

(t = 3.3) df = 9

$TI = 55.1216 + 0.3488 A$ $\bar{R}^2 = 0.45$

(t = 3.2) df = 9

Area under cane = 208.39 hectares

Corrected Investment :

Item	End 1977 (R)	Raising factor	End 1979 (R)	Depreciation (R)
Movable investment	43 102	1.2373	53 330	10 666
Fixed investment	84 706	1.3109	111 041	4 442
Total investment	127 808		164 371	

APPENDIX 6

ENTERPRISE BUDGETS : INTEREST COSTS

Appendices 7 to 10 provide a detailed breakdown of costs of various enterprises used in this study. Before these are presented, one aspect that needs further discussion concerns the rates of interest to use on machinery investments and for operating capital in budgets. A review of literature indicates that there is conflict among economists as to what rates of interest to charge, particularly with respect to machinery. For example, Mueller and Hinton (p. 935) used 8% per annum for machinery while Hoffman and Gustafson (p. 13) suggested 4% per annum. Griliches (p. 423) used 7% in his production function study.

As regards machinery it would seem appropriate to use a real rate of interest if depreciation is based on replacement value. One method of determining the appropriate rate is to find the proportion of funds that farmers in similar situations obtained from different sources. Using the real rate of interest from these sources a weighted average rate can be computed.

The sources of debt capital in South African agriculture are given by the Agricultural Economic Trends Division (p. 117). However, the proportions of debt capital indicated may bear no relationship to the proportions of capital supplied by the various institutions in the cane areas under study. For example, with the strong cooperative movement in the Maize Triangle a greater proportion of debt capital would be received from this source. With the above in mind four economists employed by the S.A. Cane Growers' Association were approached independently to give estimates of the proportion of funds derived from different sources for machinery purchases. The overall result was a follows :

Sources of funds	Proportion (%)
Hire purchase	65
Overdraft (and coops in certain areas)	19
Own capital (retained earnings)	10
Land Bank	6
	100

It is interesting that a significant proportion of debt for the purchase of machinery stems from the use of overdraft facilities.

Information received from various financial institutions indicates that the real rates of interest under "normal" economic circumstances would be about 5% for commercial bank overdrafts (prime overdraft rates being ± 4%), 6% to 7% for hire purchase agreements and 0% to 2% for Land Bank funds. Sundell provides a review of literature on the adjustments of nominal interest rates to inflation. As regards retained earnings the opportunity cost of these funds is highly subjective. A real rate of 5% was taken. Considering all of the above factors a weighted average cost of capital of about 6% was calculated.

As regards operating capital, which is of a short-term nature, a nominal rate was used. However, the rate would usually be only effective for part of the year as income is received during the year (thus offsetting costs) and different costs are incurred during different times of the year. Thus, in estimating the effective nominal rate of interest a number of factors have to be considered, namely the regularity of income from various crops in the study, size of costs incurred at different times of the year and length of the crop cycle. For sugar-cane the crushing season is usually between 36 and 39 weeks (Frean). Certain vegetables have a plant to harvest cycle of about six months while for crops such as maize or cotton the cycle is nine months. Timber is usually harvested for between six months (wattle) to 12 months (pine) in a year. With regard to the timing of costs seed and fertilizer would usually incur the greatest interest cost while harvesting or transport costs would incur virtually no interest charge as they are incurred near the time when income is received.

Coupled with the above considerations is the issue concerning the nominal interest rate to use. During 1979/80 the prime overdraft rate was 9.5% and the Land Bank rate on machinery and operating capital was 8%. However, inflation during this period, as measured by the CPI, was just over 13% per annum. Obviously, during this time interest rates were subsidized. A prime overdraft rate of about 17% to 18% would have been more realistic. These rates should be considered for budgets on which future plans are based.

What inflation rates should therefore be considered? The mean inflation rate for the 5-year period 1977/78 to 1981/82 was 13.2%, and 12% for the 4-year period 1976/77 to 1979/80. Consultation with economists of the S.A. Cane Growers' Association indicated that 95% of operating capital used in the cane areas is financed through overdrafts or profits. Using a real rate of about 5%, the nominal interest rate using the above inflation rates would be about 18%. With an average overdraft period of 3 1/3 months, the nominal rate is estimated at (3 1/3 /12)(18%) = 5%. The effective nominal rates used in corn budgets in the USA on operating capital were 4% in 1979, 4.9% in 1980 and 5.4% in 1981 (Hoffman and Gustafson, p.11). Mueller and Hinton(p. 935) in 1975 used an 8% interest rate on operating capital over six months, an effective 4% per annum, in their study of corn and soybean farms in the USA. Rates in other studies are thus similar to that adopted in the present study. The inflation rate in the USA for 1979 averaged near 13% (Hopkin, p.5), a rate similar to the one in South Africa at that time.

APPENDIX 7

ENTERPRISE BUDGETS : SUGAR-CANE (1979/80)

Particulars	Region					
	Eastern Transvaal		Pongola		Nkwaleni Valley	
No. of farms/annum	29		28		18	
Production/farm (t)	10 496		4 794		6 986	
Area under cane (ha)	133.52		61.50		127.48	
Cane yield (t/ha)	78.61		77.95		54.80	
Sucrose yield (t/ha)	10.08		9.89		6.84	
	Costs					
	per farm	per ha	per farm	per ha	per farm	per ha
Seedcane	408	3	40	1	303	2
Fertilizer	12 686	95	5 849	95	11 658	91
Chemicals	1 709	13	794	13	1 952	15
Labour -wages	24 442	183	13 335	217	19 031	149
-rations	5 775	43	4 576	74	6 379	50
-misc.	1 060	8	262	4	882	7
Salaries	7 599	57	2 474	40	7 894	62
Machinery -fuel	10 434	78	5 903	96	9 337	73
-repairs	12 246	92	5 811	94	10 026	79
-depreciation	18 080	135	10 730	174	12 066	95
-interest	5 424	41	3 219	52	3 620	28
Improvements -repairs	1 818	14	1 722	28	2 550	20
-depreciation	4 853	36	3 256	53	2 886	23
Irrigation rates	1 022	8	1 187	19	458	4
Electricity	14 096	106	4 538	74	8 402	66
Hired transport	37 366	280	13 711	223	20 818	163
Sundries	8 045	60	6 871	112	9 052	71
Interest -op. capital	6 934	52	3 354	55	5 438	43
Total costs	173 977	1 303	87 632	1 425	132 752	1 041
Labour days		104.6		144.6*		100.2
Litres fuel -farm		188.3		224.8		174.8
-contractors		205.3		23.6		-

*Because of the relatively high production cost at Pongola (see section

Particulars	Region					
	Tala Valley		Umfolozi Flats		Zululand high rainfall	
No. of farms/annum	1		21		36	
Production/farm (t)	5 958		7 374		12 382	
Area under cane (ha)	103.38		135.83		207.54	
Cane yield (t/ha)	58.50		54.29		59.66	
Sucrose yield (t/ha)	7.17		6.87		7.41	
	Costs					
	per farm	per ha	per farm	per ha	per farm	per ha
Seedcane	249	2	362	3	158	1
Fertilizer	16 100	156	10 908	80	21 772	105
Chemicals	1 313	13	1 567	12	4 214	20
Labour -wages	21 798	211	25 968	191	37 499	181
-rations	5 374	52	8 228	61	10 536	51
-misc.	301	3	1 300	10	1 771	9
Salaries	11 026	107	9 164	67	12 229	59
Machinery -fuel	15 196	147	8 409	62	10 977	53
-repairs	13 422	130	8 418	62	11 213	54
-depreciation	9 713	94	7 398	54	11 211	54
-interest	2 914	28	2 219	16	3 364	16
Improvements -repairs	2 241	22	3 212	24	6 016	29
-depreciation	3 317	32	3 785	28	4 342	21
Irrigation rates	568	5				
Electricity	10 875	105	1 624	12	1 751	8
Hired transport	-	-	23 818	175	23 154	112
Sundries	9 898	96	8 072	59	9 396	45
Interest -op. capital	5 418	52	5 564	41	7 516	36
Total costs	129 723	1 255	130 016	957	177 119	853
Labour days		118.2		126.7		91.3
Litres fuel -farm		364.7		139.1		123.9
-contractors				8.9		75.6
Costs excl. labour & fuel				627		532

Particulars	Region					
	Zululand low rainfall		Zululand hinterland		North Coast hinterland	
No. of farms/annum	46		34		40	
Production/farm (t)	9 309		9 288		9 079	
Area under cane (ha)	192.54		178.68		155.78	
Cane yield (t/ha)	48.35		51.98		58.38	
Sucrose yield (t/ha)	6.20		6.78		7.46	
	Costs					
	per farm	per ha	per farm	per ha	per farm	per ha
Seedcane	250	1	309	2	90	1
Fertilizer	18 265	95	20 197	113	16 588	106
Chemicals	3 135	16	3 786	21	1 804	12
Labour -wages	32 158	167	29 250	164	32 188	207
-rations	9 775	51	8 682	49	9 161	59
-misc.	1 284	7	1 158	6	1 192	8
Salaries	8 524	44	9 068	51	9 853	63
Machinery -fuel	10 753	56	11 566	65	8 592	55
-repairs	11 718	61	12 228	68	8 639	55
-depreciation	10 027	52	9 748	55	7 849	50
-interest	3 008	16	2 924	16	2 355	15
Improvements -repairs	4 380	23	4 128	23	4 293	28
-depreciation	4 098	21	3 668	21	3 832	25
Irrigation rates	0	0	0	0	0	0
Electricity	2 160	11	1 314	7	1 024	7
Hired transport	11 916	62	31 579	177	23 061	148
Sundries	7 356	38	7 941	44	6 791	44
Interest -op. capital	6 079	32	7 060	40	6 119	39
Total costs	144 886	752	164 606	921	143 431	921
Labour days		80.0		90.4		85.6
Litres fuel -farm		28.1		148.5		131.0
-contractors		38.6		133.0		105.5
Costs excl. Lab.& fuel		458		588		554

Particulars	Region					
	North Coast lowlands		South Coast lowlands		South Coast hinterland	
No. of farms/annum	52		32		28	
Production/farm (t)	10 967		7 941		8 996	
Area under cane (ha)	170.32		163.18		178.44	
Cane yield (t/ha)	64.53		48.75		50.32	
Sucrose yield (t/ha)	8.26		6.21		6.51	
	Costs					
	per farm	per ha	per farm	per ha	per farm	per ha
Seedcane	116	1	324	2	504	3
Fertilizer	19 278	113	14 915	91	18 061	101
Chemicals	2 143	13	2 598	16	4 459	25
Labour -wages	38 554	226	28 006	172	27 968	157
-rations	10 678	63	7 942	49	6 362	36
-misc.	1 016	6	827	5	727	4
Salaries	9 497	56	7 148	44	10 101	57
Machinery -fuel	8 424	49	7 796	48	13 156	74
-repairs	9 420	55	10 084	62	14 152	79
-depreciation	8 647	51	8 847	54	10 992	62
-interest	2 594	15	2 654	16	3 298	18
Improvements -repairs	6 453	38	2 182	13	2 922	16
-depreciation	4 184	25	3 491	21	3 633	20
Irrigation rates	0	0	0	0	0	0
Electricity	1 213	7	972	6	966	5
Hired transport	15 683	92	17 232	106	25 639	144
Sundries	7 508	44	6 220	38	5 938	33
Interest -op. capital	6 390	38	5 296	32	6 534	37
Total costs	151 798	891	126 534	775	155 412	871
Labour days		93.9		105.8		96.8
Litres fuel -farm		117.8		114.3		176.4
-contractors		60.5		72.1		105.4
Costs Excl. lab.& fuel		524		476		562

Particulars	Region			
	Midlands South		Midlands North	
No. of farms/annum	30		32	
Production/farm (t)	9 958		9 083	
Area under cane (ha)	194.17		208.39	
Cane yield (t/ha)	51.34		43.59	
Sucrose yield (t/ha)	6.59		5.37	
	Costs			
	per farm	per ha	per farm	per ha
Seedcane	336	2	827	4
Fertilizer	19 099	98	18 681	90
Chemicals	5 330	27	5 833	28
Labour -wages	26 996	139	20 621	99
-rations	7 054	36	4 931	24
-misc.	1 450	7	1 054	5
Salaries	3 914	20	6 440	31
Machinery -fuel	11 986	62	14 477	69
-repairs	13 777	71	15 182	73
-depreciation	14 494	75	10 666	51
-interest	4 348	22	3 200	15
Improvements -repairs	2 407	12	2 214	11
-depreciation	4 306	22	4 442	21
Irrigation rates	0	0	0	0
Electricity	1 111	6	864	4
Hired transport	46 703	241	5 177	25
Sundries	6 784	35	7 762	37
Interest -op. capital	7 338	38	5 204	25
Total costs	177 433	914	127 575	612
Labour days		80.9		58.3
Litres fuel -farm		153.2		165.4
-contractors		184.5		16.7
Costs excl. labour & fuel		602		408

APPENDIX 8

ENTERPRISE BUDGETS : OTHER CROPS (1979/80)

Region : Eastern Transvaal

Particulars	Enterprise				
	Tomatoes -market	Tomatoes -processing	Cucumbers	Green beans	Gem squash
Yield/ha(t)	30	30	21.4	8.5	31.4
	Costs per hectare (R)				
Seed/plants	45	30	75	80	20
Fertilizer	300	190	200	190	180
Chemicals	470	295	90	70	50
Labour	820	280	400	220	310
Salaries	110	40	40	40	40
Machinery	510	225	340	310	250
Irrigation	155	65	65	85	60
Interest -movables	70	30	45	45	35
Fixed improvements	20	5	10	10	10
Packing materials	1 230	5	290	110	630
Marketing	840	15	315	230	640
Sundries	160	50	90	60	70
Interest -op.capital	220	55	90	65	110
Total costs	4 950	1 285	2 050	1 515	2 405
Labour days/ha	443.2	162.2	216.2	118.9	167.6
Litres fuel/ha	393.3	173.5	262.2	239.0	192.8
Costs excl. labour & fuel	3 967	913	1 541	1 196	2 015

Region : Eastern Transvaal

Particulars	Enterprise				
	Hubbard squash	Seed dry beans	Dry beans	Cotton -dryland	Cotton -irrig.
Yield/ha(t)	18	1.4	1.5	1.0	2.2
	Costs per hectare (R)				
Seed/plants	15	140	100	15	15
Fertilizer	150	100	80	60	120
Chemicals	40	70	55	115	200
Crop insurance					30
Labour	275	80	55	100	190
Salaries	35	35	15	10	20
Machinery	250	100	75	80	150
Irrigation	60	50	35	-	60
Interest -movables	35	15	10	5	25
Fixed improvements	10	10	5	5	10
Packing materials	150	40	20	-	-
Marketing	370	-	-	-	-
Sundries	70	50	35	20	40
Interest -op.capital	65	30	20	20	40
Total costs	1 525	720	505	430	900
Labour days/ha	148.6	40.0	27.5	50.0	95.0
Litres fuel/ha	192.8	77.1	57.8	61.7	115.7
Costs excl. labour & fuel	1 170	608	426	304	662

Region : Eastern Transvaal

Particulars	Enterprise				
	Bananas	Pawpaws	Mangos	Litchis	Guavas
Yield/ha(t)	17	20	7.25	3	30
	Costs per hectare (R)				
Seed/plants	-	40	20	10	15
Fertilizer	310	280	90	70	245
Chemicals	60	-	110	-	20
Labour	365	440	220	205	430
Salaries	80	50	50	50	50
Machinery	260	205	170	170	340
Irrigation	170	165	55	80	95
Interest -movables	45	40	25	30	50
Fixed improvements	20	20	20	10	10
Packing materials	610	780	400	300	320
Marketing	835	460	910	660	560
Sundries	375	140	60	20	25
Interest -op.capital	150	125	100	75	100
Total costs	3 280	2 745	2 230	1 680	2 260
Labour days/ha	182.5	220.0	110.0	102.5	215.0
Litres fuel/ha	200.5	158.1	131.1	131.1	262.2
Costs excl. labour & fuel	2 832	2 239	1 956	1 421	1 721

Region : Eastern Transvaal

Particulars	Enterprise	
	Valencias	Grapefruit
Yield/ha(t)	26.5	28
	Costs per hectare (R)	
Seed/plants	30	20
Fertilizer	120	130
Chemicals	480	480
Labour	340	350
Salaries	70	70
Machinery	360	360
Irrigation	80	80
Interest -movables	50	50
Fixed improvements	10	10
Packing materials Marketing	620	825
Sundries	80	70
Interest -op.capital	100	110
Total costs	2 340	2 555
Labour days/ha	170.0	175.0
Litres fuel/ha	277.6	277.6
Costs excl. labour & fuel	1 885	2 090

Region : Pongola

Particulars	Enterprise				
	Tomatoes -market	Cotton -dryland	Cotton -irrig.	Valencias	Grapefruit
Yield/ha(t)	42	1.2	2.4	25	25
	Costs per hectare (R)				
Seed/plants	20	15	20	30	20
Fertilizer	290	65	120	120	130
Chemicals	450	130	200	480	4 80
Crop insurance	380	15	35	-	-
Labour	1 085	120	200	320	320
Salaries	110	10	30	70	70
Machinery	580	100	160	320	320
Irrigation	155	-	70	80	80
Interest -movables	80	10	25	45	45
Fixed improvements	20	5	10	10	10
Packing materials	1 740	-	-	780	735
Marketing	1 050	-	-		
Sundries	140	25	50	80	70
Interest -op.capital	290	25	40	110	110
Total costs	6 390	520	960	2 445	2 390
Labour days/ha	638.2	70.6	108.3	173.0	173.0
Litres fuel/ha	434.7	74.9	115.7	244.4	244.4
Costs excl. labour & fuel	5 119	368	771	2 021	1 966

Region : Nkwaleni Valley

Particulars	Enterprise	
	Valencias	Grapefruit
Yield/ha(t)	25	25
	Costs per hectare (R)	
Seed/plants	30	20
Fertilizer	120	130
Chemicals	480	480
Labour	320	320
Salaries	70	70
Machinery	320	320
Irrigation	80	80
Interest -movables	45	45
Fixed improvements	10	10
Packing materials Marketing	780	835
Sundries	80	70
Interest -op.capital	110	110
Total costs	2 445	2 490
Labour days/ha	173.0	173.0
Litres fuel/ha	244.4	244.4
Costs excl. labour & fuel	2 023	2 068

Region	Zululand coastal LR	Pongola
Enterprise	Cotton -dryland	Wheat -irrigated
Yield/ha(t)	1.5	4.0
	Costs per hectare (R)	
Seed/plants	15	50
Fertilizer	75	140
Chemicals	140	40
Crop insurance	20	-
Labour	160	50
Salaries	15	20
Machinery	110	130
Irrigation	-	50
Interest -movables	10	20
Fixed improvements	10	10
Packing) materials) Marketing)	-	-
Sundries	30	30
Interest -op.capital	25	25
Total costs	610	565
Labour days/ha	70.0	25.0
Litres fuel/ha	80.0	99.0
Costs excl. labour & fuel	405	473*

* Also applicable to Eastern Transvaal

Region	South Coast	North Coast	Natal Midlands
Enterprise	Bananas	Bananas	Maize
Yield/ha(t)	10.0	15.0	5.0
	Costs per hectare (R)		
Seed/plants	50	50	15
Fertilizer	240	350	100
Chemicals	65	90	65
Crop insurance			10
Labour	305	350	30
Salaries	60	80	20
Machinery	200	250	130
Irrigation	-	-	-
Interest -movables	20	25	10
Fixed improvements	20	20	10
Packing materials	260	510	-
Marketing	440	685	-
Sundries	290	350	30
Interest -op.capital	95	130	20
Total costs	2 045	2 890	440
Labour days/ha	152.5	175.0	16.2
Litres fuel/ha	153.1	191.4	99.0
Costs excl. labour & fuel	1 676	2 460	368*

* Also applicable to South Coast hinterland and Midlands South

APPENDIX 9

ENTERPRISE BUDGETS : TIMBER (1979/80)

1. EUCALYPTUS (SALIGNA)

Particulars	Homogeneous Region*							
	8	10	11	12	13	14	15	16
Yield/ha/an(t)								
Timber	16.33	14.5	11.22	13.50	11.22	11.0	10.0	12.24
	Costs per ha per annum (R)							
Planting	18	18	18	18	12	12	12	12
Maintenance	35	35	35	35	32	32	32	32
Harvesting	71	67	50	63	48	47	44	50
Transport	44	42	31	40	31	31	29	32
Interest	10	9	10	9	10	10	10	10
Total	178	172	144	165	133	132	127	136
Labour days/ha	27.4	25.4	21.7	24.3	21.7	21.5	20.4	22.9
Litres fuel/ha								
-farm	33.8	31.9	25.1	31.9	25.3	25.1	25.0	25.8
-contractors	4.6	4.4	3.4	4.3	3.4	3.3	3.2	3.4
Total costs excl. labour & fuel (R)	67	105	67	77	80	83	81	84

Sources : Rusk, Edwards, Furze and the Institute of Commercial Forestry Research, Pietermaritzburg

* Region 8 = Zululand high rainfall
" 10 = Zululand hinterland
" 11 = North Coast hinterland
" 12 = North Coast lowlands
" 13 = South Coast lowlands
" 14 = South Coast hinterland
" 15 = Natal Midlands South
" 16 = Natal Midlands North

2. WATTLE

Particulars	Homogeneous Area			
	10	14	15	16
Yield/ha/an(t)				
Timber	6.17	5.30	7.90	8.69
Bark	1.13	1.02	1.48	1.63
Total	7.30	6.32	9.38	10.32
	Costs per ha per annum (R)			
Planting	19	18	20	20
Maintenance	39	35	40	40
Harvesting	37	35	52	57
Transport	23	22	29	31
Interest	8	8	9	9
Total	126	118	150	157
Labour days/ha	26.4	25.2	28.8	29.9
Litres fuel/ha				
-farm	24.9	23.4	31.5	32.4
Total costs excl. labour & fuel (R)	62	65	87	92

Sources : Rusk, Edwards, Furze and the Institute of Commercial Forestry Research, Pietermaritzburg

3. PINES

Particulars	Homogeneous Area			
	10	14	15	16
Yield/ha/an(t)				
Timber	16.5	14.0	14.0	18.0
	Costs per ha per annum (R)			
Planting	16	14	14	16
Maintenance	55	50	50	55
Harvesting	84	71	71	91
Transport	74	66	66	78
Interest	18	16	16	18
Total	247	217	217	258
Labour days/ha	31.3	28.4	28.4	33.1
Litres fuel/ha				
-farm	49.4	45.2	46.9	53.7
- contractors	8.7	7.6	7.7	9.2
Total costs exlc. labour & fuel (R)	160	146	146	175

Sources : Rusk, Edwards, Furze and the Institute of Commercial Forestry Research, Pietermaritzburg

APPENDIX 10

ENTERPRISE BUDGETS : BEEF ON PASTURE (1979/80)

The information below is given for selected areas. Areas with similar carrying capacities are assumed to have the same net income before labour and fuel costs. Weaners are purchased at 190kg and gain 0.6kg per day.

Particulars	Region			
	Eastern Transvaal lowveld irrigated	Zululand high rainfall	North Coast	South Coast
No. of animals/ha	13	9	8	6.5
No. of days on pasture	270	270	270	240
Selling mass (kg)	352	352	352	334
Total income/ha (R)*	3 707	2 566	2 281	1 759
	Costs per hectare (R)			
Weaners @ R166*	2 158	1 494	1 328	1 079
Fertilizer	246	215	184	155
Supplements & vet. @ 7c/animal/day	246	170	151	109
Labour	90	88	75	50
Salaries	70	50	40	30
Machinery	300	200	180	150
Irrigation	100	-	-	-
Interest on equipment	44	18	16	14
Miscellaneous	80	50	45	35
Interest -op. capital	158	110	97	78
Total costs/ha	3 492	2 395	2 116	1 700
No. of labour days/ha	45	35	30	25
Litres of fuel/ha	231.3	150.2	137.1	114.8
Establishment costs/ha**	500	470	440	400
Est. costs/ha/an (R)	25	24	22	20
Total costs & est. costs/an	3 517	2 419	2 138	1 720
Net income/ha	190	147	143	39
Net income/ha excl. labour and fuel	386	305	276	137

* Prices for weaners and long yearlings were received from Eggers.

** Includes fencing

The information below is given for selected areas. Areas with similar carrying capacities are assumed to have the same net income before labour and fuel costs. Weaners are purchased at 190kg and gain 0.6kg per day. For KwaZulu and Makatini weaners are assumed to weigh 150kg (Nguni breed of cattle) and gain 0.5kg per day.

Particulars	Region			
	Natal Midlands	Nkwaleni valley irrigated	KwaZulu dryland	Makatini irrigated
No. of animals/ha	7	12	55	10
No. of days on pasture	200	270	240	270
Selling mass (kg)	310	352	246	258
Total income/ha (R)	1 758	3 421	996	2 090
	Costs per hectare (R)			
Weaners @ R166	1 162	1 992	650	1 300
Fertilizer	139	246	90	180
Supplements & vet. @ 7c/animal/day	98	227	36	81
Labour	37	80	60	120
Salaries	20	70		
Machinery	120	280	50	100
Irrigation	-	90	-	30
Interest on equipment	11	41	-	-
Miscellaneous	30	80	10	20
Interest -op. capital	78	147	45	92
Total costs/ha	1 695	3 253	941	1 923
No. of labour days/ha	21.0	45.0	40	80
Litres of fuel/ha	91.4	222.3	31.3	62.5
Establishment costs/ha*	400	500	200	300
Est. costs/ha/an (R)	20	25	10	15
Total costs & est. costs/an	1 715	3 278	951	1 938
Net income/ha	43	143	45	152
Net income/ha excl. labour and fuel	118	313	118	276

* Includes fencing.

APPENDIX 11

FINDING REPRESENTATIVE PRICES FOR ENTERPRISES USED IN THE STUDY

Prices of activities used in planning should be calculated on the same basis for all activities. This is necessary to prevent bias in the relative prices. In this study mean sugar-cane yields were calculated for the years 1976/77 through 1979/80. The latter year was the latest when the study was started. Since the capturing of data over these four years was a major undertaking yields used in the linear programme were based on these four years. Four years were considered appropriate because of the 18 month to two year cycle in many areas.

As regards vegetables, subtropical fruit and other cash crops in the Malelane area data of mean annual production could only be obtained for the years 1979, 1980 and 1981. These data were necessary for calculating the region's share of the total country's production, which in turn were used to construct the step demand functions for vegetables and subtropical fruit.

Ideally the product prices should correspond to the time period considered in calculating mean production. However, if this is done in the cases above, that is, the mean cane price based on the prices for the years 1976/77 through 1979/80 (using 1979/80 prices and the CPI) and the mean vegetable and fruit prices based on the three years 1979, 1980 and 1981 (also on a 1979/80 basis), sugar-cane may be favoured (disfavoured) by the LP relative to the other enterprises because conditions were different in the non-overlapping years. To avoid this happening, prices should be calculated on the same basis so that each crop has a chance of entering the final plan. The assumption must, however, be made that the yields used as coefficients in the LP matrix are representative of each crop.

Before considering various ways of calculating unbiased prices it must be pointed out that inputs used in production are common to the various enterprises considered. This means that changes in fertilizer, chemical or labour prices would affect costs of production of all enterprises. All input costs used are on a 1979/80 basis. Where production costs were available for a number of years, such as for sugar-cane, the various cost items in the individual years were placed on a 1979/80 basis by inflating with the relevant input price index.

All product prices, as for inputs, were required on a 1979/80 basis. The problem was which years to consider for calculating mean or unbiased product prices. A further question was, should the simple arithmetic mean be used or the weighted average price? The latter, with the weights being the tonnages produced, is the weighted average return to farmers. This may be the correct item to use in an LP exercise as it reflects the actual return to farmers per tonne. However, a study of the simple arithmetic means and weighted average returns per tonne for a number of crops showed differences of less than 5%. This reason and the fact that prices per tonne are more readily available resulted in a decision to use the simple arithmetic means of prices per tonne. Also, with the use of the step demand functions it is, according to theory, more correct to use prices per tonne than average returns per tonne.

As regards the calculation of mean prices a number of possibilities are available. Some considered include:

1) Averaging prices per tonne for the three years 1979 through 1981 : The fact that 1980/81 was a poor year for the South African Sugar Industry with a crop of only 14.06 million tonnes of cane, with a resultant price increase of 36.7% over 1979/80, meant that the average price over three years would be biased upwards. Use of a three-year mean would thus favour sugar-cane as the high increase in prices was not evident in the other crops.

2) Averaging the prices per tonne for the five years 1977/78 through 1981/82 centred on 1979/80 : This method may consider greater possible variability than 1) above and may give rise to a less biased price. Both this method and 1) above assume a linear trend in prices. A linear trend is more possible over three years than over five so that 1) has an

advantage in this regard.

3) Calculating real prices per tonne on a 1979/80 basis for the five years 1977/78 through 1981/82 and averaging. The CPI with 1979/80 = 100 is used to either inflate or deflate prices. The advantages of this method is that it eliminates common inflationary trends and takes into account a relatively wide spectrum of conditions over five years. Relative inflationary trends are not interfered with.

4) Calculating the real prices per tonne on a 1979/80 basis for the four years 1976/77 to 1979/80 and averaging. This period corresponds to the four years over which mean sugar-cane yields were calculated. However, using this method clashes with the interests of the vegetable and subtropical fruit activities as their average yields were based on the 1979 through 1981 periods. Real prices could just as well be based on the three years 1979 through 1981.

Considering all of the above methods and arguments it was decided to use method 3), that is, basing the mean price per tonne on the five years 1977/78 through 1981/82, centred on 1979/80, and using the CPI to eliminate inflation. In summary the advantages of this method include :

a) The prices are centred on 1979/80, the base year .

b) In general the five-year period takes into account a wider range of supply and demand situations than a three-year period. This may be important for certain enterprises which are subject to cycles, for example, beef.

c) Common inflationary trends are eliminated through the use of the CPI, that is, real prices are considered and relative trends are not interfered with.

d) The method is fair to all enterprises because prices have been calculated in the same way. However, this would also apply to the other methods mentioned. This method takes into account the majority of years on which the sugar-cane, vegetable and subtropical fruit yields have been based.

APPENDIX 12

INCLUSION OF RISK IN A LINEAR PROGRAMMING TABLEAU

Rows	Activities												
	BAN1	PAW1	MAN1	......	NDC11	NDC12	NDC13	NDC14	NDC15	NDC16	Z1	SDEV1	RHS
C	$PROFIT_B$	$PROFIT_P$	$PROFIT_M$	......								-0.25	MAX!
IRL1	1	1	1										5 000
.													
.													
.													
.													
YR11	-30.48	-142.48	-330.90	......	1								$\geq$ 0
YR12	-69.62	599.98	89.12	......		1							$\geq$ 0
YR13	135.24	-591.56	-285.85	......			1						$\geq$ 0
YR14	105.10	106.90	832.18	......				1					$\geq$ 0
YR15	-185.05	-126.65	491.21	......					1				$\geq$ 0
YR16	44.81	153.81	-795.76	......						1			$\geq$ 0
ZID1					2	2	2	2	2	2	-1		= 0
ZBAL1											0.229	-1	= 0

IRL1 = irrigation land

YR1t = year 1 to 6 (deviations from trend)

ZID1 = Z identity

ZBAL1 = Z balance

NDC = negative deviation counters

Z1 = sum of total deviations

SDEV1 = estimated standard deviation

-0.25 = Ø (risk aversion coefficient)

0.229 = $\sqrt{\Delta}/T$, where $\Delta = \pi T/2(T-1)$, T = 6 years

APPENDIX 13

GROSS INCOME DEVIATIONS FROM TREND

(Rand per hectare)

Region : Eastern Transvaal

Enterprise	Year					
	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82
Sugar-cane	114.81	-90.45	-24.70	-138.96	139.78	-0.48
Tomatoes						
-market	1120.05	-1980.64	-1891.32	-634.01	9264.30	-5878.38
-processing	327.29	54.57	-600.14	-570.86	1087.43	-298.29
Cucumbers	910.90	399.08	-833.75	-1330.58	-988.41	1842.76
Green beans	100.67	58.87	-5.93	-250.73	-219.53	316.65
Gem Squash	-42.52	432.42	-302.64	-355.70	62.25	186.19
Hubbard squash	-143.95	18.36	-29.32	108.99	516.30	-470.38
Seed dry beans	270.38	-59.70	-210.79	-365.88	251.04	114.95
Dry beans	206.48	-116.98	-111.44	-225.90	221.65	26.19
Cotton	-1.24	-215.41	138.42	239.25	-25.92	-135.10
Bananas	-30.48	-69.62	135.24	105.10	-185.05	44.81
Pawpaws	-142.48	599.98	-591.56	106.90	-126.65	153.81
Mangos	-330.90	89.12	-285.85	832.18	491.21	-795.76
Litchis	-97.57	-127.94	141.69	376.31	-178.06	-114.43
Guavas	252.57	240.14	-300.29	-383.71	-555.14	746.43
Valencias	-397.90	495.72	350.35	-129.02	-786.39	467.24
Grapefruit	87.71	-123.25	-236.30	34.64	693.58	-456.48
Beef on						
-veld	1.40	1.72	-5.36	-2.69	7.60	-2.67
-pasture	361.18	-435.37	-305.28	248.08	355.29	-223.90

Region : Pongola

Enterprise	Year					
	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82
Sugar-cane	193.24	-60.59	-175.42	-189.25	180.92	51.10
Tomatoes						
-market	236.24	767.41	-199.42	-609.25	-2434.08	2239.10
Dryland						
Cotton	18.38	-16.10	-31.59	-11.08	89.44	-49.05
Valencias	-434.13	107.61	320.04	707.47	-634.87	-66.12
Grapefruit	-291.31	-63.97	74.09	598.12	293.92	-610.85
Beef on						
-veld	1.26	1.55	-4.83	-2.42	6.84	-2.40
-pasture	361.18	-435.37	-305.28	248.08	355.29	-223.90

Region: Zululand

Enterprise	Year					
	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82
Sugar-cane	80.38	-33.30	-0.99	-118.68	-28.36	100.95
Valencias	161.90	-133.72	47.65	-85.98	-245.61	255.76
Grapefruit	34.71	-477.57	-353.86	973.86	850.57	-1027.71
Eucalyptus	6.38	12.70	-14.99	-16.68	-4.36	16.95
Wattle	28.33	-20.06	-40.47	28.13	3.73	0.34
Pines*	-35.76	-13.99	45.78	59.55	-21.68	-33.90
Maize *	-15.75	37.70	25.40	-55.61	-37.03	45.29
Beef on						
-veld *	5.29	-6.27	-0.89	-5.34	11.99	-4.78
-pasture 1)*	171.28	-206.46	-144.77	117.64	168.48	-106.17
-pasture 2)	250.05	-301.41	-211.35	171.75	245.97	-155.01

* Same as for Natal since no better figures were available.

1) @ 7 animals/ha (200 days)

2) @ 9 animals/ha (270 days)

Region : Natal

Enterprise	Year					
	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82
Sugar-cane	32.33	2.73	-46.87	26.53	-85.07	70.35
Bananas	40.19	173.25	-15.70	-379.64	-87.58	269.48
Eucalyptus	-25.57	55.26	-25.91	-13.09	10.74	-1.43
Wattle	26.95	17.64	-43.18	-52.99	30.20	21.38
Pines	-35.76	-13.99	45.78	59.55	-21.68	-33.90
Maize	-15.75	37.70	25.40	-55.61	-37.03	45.29
Beef on						
-veld	5.29	-6.27	-0.89	-5.34	11.99	-4.78
-pasture 1)	171.28	-206.46	-144.77	117.64	168.48	-106.17
-pasture 2)	222.26	-267.92	-187.87	152.67	218.64	-137.78

1) @ 7 animals/ha (200 days)

2) @ 8 animals/ha (270 days)

Region : Black Areas

Enterprise	Year					
	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82
Beef on						
-veld 1)	7.10	-9.45	-16.84	-4.12	61.07	-37.76
-veld 2)	2.84	-3.78	-6.74	-1.65	24.43	-15.10
Beef on pasture						
-dryland	97.08	-117.03	-82.05	66.68	95.50	-60.18
-irrigated	203.64	-245.47	-172.12	139.87	200.32	-126.24

1) @ 2 Hectares per A.U.

2) @ 4.3 hectares per A.U.

APPENDIX 14

DIESEL PETROL:LUBRICANT COST RATIOS IN DIFFERENT REGIONS OF THE SOUTH AFRICAN SUGAR INDUSTRY

Region	Diesel:Petrol:Lubricant ratios	Mean price (c/l)
Eastern Transvaal	76 : 16 : 8	41.5
Pongola	76 : 16 : 8	42.7
Hluhluwe	76 : 16 : 8	42.0
Nkwaleni	76 : 16 : 8	41.9
Glendale	70 : 22 : 8	42.0
Tala Valley	77 : 17 : 6	40.3
Umfolozi Flats	61 : 30 : 9	44.5
Zululand Coast high rainfall	71 : 20 : 9	42.7
Zululand Coast low rainfall	67 : 23 : 10	43.6
Zululand hinterland	70 : 20 : 10	43.6
North Coast hinterland	69 : 23 : 8	42.1
North Coast lowlands	70 : 22 : 8	42.0
South Coast lowlands	70 : 23 : 7	41.8
South Coast hinterland	74 : 18 : 8	41.8
Midlands South	77 : 17 : 6	40.3
Midlands North	73 : 20 : 7	42.0

Source : Calculated from cost data received from the South African Cane Growers' Association.