ETHANOL, EMPLOYMENT AND DEVELOPMENT: LESSONS FROM BRAZIL

A. PEREIRA

36673

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PREFACE

This study by Armand F. Pereira of the ILO Technology and Employment Branch assesses the impact of Brazil's biomass alcohol (ethanol) programme on oil import substitution, the balance of payments, employment and income distribution in its first five-year period (1975-76 to 1980-81).

Where possible, the analysis extends to 1984, but lack of data does not allow a consistent examination of all the major issues after 1981. The effects on oil import substitution and the balance of payments are assessed up until 1983 and major policy-related developments up until 1984. In addition, the study reviews the main issues which may be of potential interest for the planning of commercial programmes in other developing countries. Although it concerns energy policy in particular, it also analyses the social consequences of agricultural expansion and modernisation, and the conflicts that may arise between growth and income distribution objectives.

Many earlier studies have focused on various aspects of ethanol production and some have provided discerning analyses of specific elements of production in Brazil and other countries. However, there is still no in-depth study providing an overall assessment of the impact of the ethanol programme in Brazil.

There is continued interest in ethanol programmes in developing countries, in spite of the recent decrease in oil prices. Brazil's experience cannot be regarded as a blueprint for other countries in which ethanol is being (or will be) considered as a substitute for petrochemicals and transport fuels. Nevertheless, such an experience provides a number of important lessons regarding planning and implementation.

The study shows that ethanol programmes can save foreign exchange and generate employment, but they can also promote disparities of income and social conflicts associated with the production of raw materials. The extent to which this agricultural activity will redistribute or concentrate incomes depends primarily on agrarian structure and related legislation. Nevertheless, trade-offs tend to exist between cost efficiency and income redistribution: these have complex implications for planning and policy-making. At the existing levels of technology, large-scale programmes will tend to rely on crops which require good quality soils. This may conflict with food production even in countries with surplus of arable land, particularly in the absence of effective land-use policies.

The findings of the study suggest that ethanol cannot be regarded as the solution to energy crises related to either price increases or scarcities of supply. It may play an important role in energy strategies aimed at a diversification of fuel supplies, but it is not likely to cause a significant reduction in overall oil consumption and

imports in any particular country, because of two factors, apart from questions regarding choices between energy and food. First, the patterns of transport dictate a certain pattern of demand for liquid fuels, because of the very limited possibilities of substitution between fuels in this sector. Second, there is limited flexibility to change the relative supply of oil derivatives in connection with the configuration and size of oil-refining facilities in countries where these exist. These findings also illustrate the complexity of ethanol programmes. Many sectors are involved and, because of this, planning for large-scale production must take intersectoral linkages carefully into account.

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ABBREVIATIONS AND ACRONYMS

ABRA	Brazilian Association of Agrarian Reform
ABRAVE	Brazilian Association of Auto-Vehicle Retailers
ANFAVEA	National Association of Automotive Manufacturers
bbl	Barrel
BNDE	National Development Bank
bu	bushel
CACEX	Banco do Brasil's Export Bureau
CDI	Industrial Development Council
CENAL	Executive Committee for National Alcohol
CMN	National Monetary Council
CNAL	National Alcohol Council
CNP	National Petroleum Council
CNPq	National Research Council
c.i.f.	cost insurance freight
cr$	cruzeiro - Brazilian currency
C/S	Centre-South (a macro-region in Brazil)
CTA	Aerospace Technology Centre
CTI	Industrial Technology Company
CTP	PROMON Technology Centre
DEDINI	A major manufacturer of distillery equipment in Brazil
EMBRAPA	Brazilian Enterprise for Agribusiness Research
EMBRATER	Brazilian Enterprise for Rural Extension and Technical Assistance
ESCAP	Economic and Social Commission for Asia and Pacific
FAO	Food and Agriculture Organisation
FEBRASA	Brazilian Rail Company
f.o.b.	free on board
FGV	Getúlio Vargas Foundation
FS	Fermentable sugars
FTI	Industrial Technology Foundation
ha	hectare
hp	horsepower
IAA	Institute of Sugar and Alcohol
IBGE	Brazilian Institute of Geography and Statistics
IBRASA	Brazilian Investments S.A. (a BNDE agency)
IEA	Institute of Agricultural Economics, University of Sao Paulo
INT	National Institute of Technology
ISA	International Sugar Agreement
lb	pound (unit of weight)
LIBOR	London Interbank Offered Rate (of interest)
LPD	Litres per day
LPG	Liquefied petroleum gas
LPT	Litres per tonne

LPY	Litres per year
kg	kilogramme
km	kilometre
ktoe	kilotonnes of oil equivalent
Mcal	Mega calories
m.bbl	millions of barrels
m.l	millions of litres
MIC	Ministry of Industry and Commerce
MME	Ministry of Mines and Energy
N/NE	North/North-East (a macro-region in Brazil)
NE	North-East (a region within the N/NE macro-region)
ORTN	Obrigaçoes Reajustáveis do Tesouro Nacional - A financial indicator used for monetary correction (to adjust for price inflation)
PETROBRAS	Brazil's National Oil Company
PETROQUISA	A subsidiary of PETROBRAS
PNA or PROALCOOL	The National Alcohol Programme (same as PNA)
PROMOCET	Programme for Development and Technology of Sao Paulo
PLANALSUCAR	IAA's Sugar-Cane Research Centre
R and D	Research and Development
SUDENE	Superintendency for the Development of the NE
STI	MIC's Industrial Technology Bureau
TCH	Tonnes of cane per ha
TSH	Tonnes of sugar per ha
UNCTAD	United Nations Conference on Trade and Development
UNIDO	United Nations Industrial Development Organisation
UNICAMP	University of Campinas, Campinas, State of Sao Paulo
USc	United States cents
USP	University of Sao Paulo
ZANINI	A major manufacturer of distillery equipment in Brazil
$	United States dollars

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Geneva, December 1984. Armand F. Pereira

INTRODUCTION

Ethanol is, so far, the most suitable substitute for transport fuels derived from petroleum, as well as for some major petrochemicals. It can be competitive with oil products in some countries, even at the oil-price levels of 1982-84,[1] and its production may have a number of secondary benefits as well.

The substitution of ethanol for oil imports can have positive effects on the balance-of-payments and economic growth. The direct employment impact may be very high if ethanol is produced from relatively labour-intensive crops (e.g., sugar-cane and manioc), and crop displacements are minimal or generate a net gain in employment. The spillover effects on the capital-goods sector on research and development (R and D) may be significant. In addition, ethanol industries may provide a number of by-products which can contribute to rural development.

Such considerations have led a number of countries to initiate some production of ethanol as fuel and/or material for the chemical industry. Besides Brazil (the only country with a large commercial-scale fuel ethanol programme), India, Kenya, the Philippines, Zimbabwe, Sri Lanka, Australia, Thailand, Indonesia, the United States, Malawi and possibly a few others already have some production. India (the second largest producer) has over 100 small distilleries based on molasses, which produce mainly for the chemical industry. Nicaragua and Mali have planned to begin some production in 1985, and a number of other countries in Central America, the Caribbean and Australasia have plans for production, although implementation may have been temporarily discouraged in some cases by the decrease in oil prices since 1981.

Despite the general attractiveness of ethanol in the context of inter-fuel substitution, not all developing countries have appropriate conditions for commercial-scale production. Even those which do may find it economically unattractive to produce ethanol on a large scale. Some countries may choose to produce ethanol for strategic reasons, even if it is more expensive than oil imports, because of continuing instability in the oil market and for promoting self-reliance.[2] However, in all countries which may have sound justifications for producing ethanol on a commercial scale, production is complicated by intersectoral linkages which are addressed in this study.

Brazil's ethanol programme (PNA)

PNA was launched in 1975, when the ex-distillery unit costs of ethanol fuels were substantially higher than those of ex-refinery petrol. This situation continued until the second oil shock in

1979-80, when the average barrel (bbl) of ethanol produced in Brazil became clearly economic. It was mainly for this reason that ethanol production targets re-established in early 1979 were much higher than those that had been defined in 1975.

As a result of the decrease in oil prices after 1981, ethanol may have lost its competitive edge by 1983 or 1984. PNA would never have been launched if investment decisions had been made purely on the basis of the relative costs of ethanol and petrol. But such decisions were based partly on the uncertainties in the market trends of both oil and sugar, and partly on considerations related to foreign currency savings, employment, income distribution, development of R and D capacity and of the capital goods sector. Besides these considerations, other factors also made ethanol production an attractive proposition for Brazil.

First, ethanol had already been produced and used both as fuel and non-fuel in earlier decades, and its technology was well known. As one of the world's major sugar-producing countries, Brazil had (a) sugar mills that could easily annex ethanol distilleries to their facilities, using sugar molasses and/or sugar-cane as feedstock, and sugar-cane bagasse as fuel at practically zero opportunity cost; (b) institutional arrangements to support production (mainly those of the sugar industry), and (c) a fairly developed capital-goods sector capable of providing all the technological equipment for ethanol production.

Second, the low sugar prices in the international market between 1969 and 1974, and also between 1976 and 1980, stimulated interest in ethanol production among sugar entrepreneurs, who saw this as a means of generating the extra revenues they needed to recuperate their businesses.

Third, Brazil's privileged situation in terms of land resources did not restrain the production of sugar and ethanol. The latter could be produced from additional land, without necessarily interfering with the optimal supplies of sugar to meet the domestic and international demands for the product.

Being a member of the International Sugar Agreement (ISA), Brazil has had restrictions on sugar output, which has fluctuated below her total sugar-mill capacity throughout the 1975-1980 period. The sugar-cane grown for ethanol production cannot therefore be valued in terms of sugar export prices, unlike in some other sugar-producing countries. The additional 130 million tonnes of sugar-cane which would be required to meet the ethanol production target in 1985, for example, would represent an additional production of 12-13 million tonnes of sugar, or nearly 50 per cent of the world sugar trade. This would mean an increase in Brazil's share of world trade from under 10 per cent in 1980 to about 40-50 per cent in 1985. Even if such an increase were permitted, world sugar prices would fall substantially.

A pioneering venture such as PNA has positive and negative aspects which, as anyone would expect, have been a focus of debate both inside and outside Brazil. PNA has been praised as a programme that makes use of the country's land resources, while reducing dependence on imported oil (Brazil imported 78 per cent of its oil

requirements in 1974 and 75 per cent in 1982, although this dependence was reduced to 60-65 per cent by 1984). It has been criticised for its high cost and its dependence on government subsidies. Moreover, it has given rise to a number of questions such as: who has benefited most, and how have the government subsidies affected income distribution? Could PNA's favourable impact on the balance-of-payments have been achieved with a lower output of ethanol and less investment? Would more systematic planning have avoided unintended distortions, such as surplus of ethanol and petrol, displacement of crops increased concentration of landownership, rise in the number of landless farmers and an exclusive reliance of production on the traditional sugar sector?

Indeed, the PNA's impact during its first five-year period may offer more scope for criticism than for praise, but this period is too short to enable a sound judgement of its successes and failures. Furthermore, as shall be argued later, it is practically impossible to assess the full range of PNA's costs and benefits, because of data constraints. It is largely because of this problem that decisions on ethanol production in Brazil, as well as judgements on its social profitability, are based to some extent on qualitative criteria and political choices which are subject to controversy.

Whatever praise and criticism that it may deserve, PNA is now irreversible, due to changes that it has brought about in the pattern of demand for transport fuels and on the structure of both the vehicle manufacturing and the oil-refining sectors.

Thus, the primordial objective of this study is not to judge PNA, but rather to assess its major results with a view to providing useful inputs for national policy, and particularly for the planning of ethanol programmes in other countries.

The relevance of ethanol for other countries

Very few developing countries can be compared with Brazil in terms of the resource endowments necessary for large-scale ethanol production. Nevertheless, there may be many countries which can develop ethanol programmes of varying scale, using alternative feedstocks.

Some studies have tried to identify countries where ethanol would be relevant. Rask (1979), for example, developed a methodology, adopted by the World Bank (1980b) and the FAO (1980), whereby countries are placed in one of four situations ranging from "energy-surplus"/"agricultural-surplus" to "energy-deficit"/ "agricultural-deficit". Countries which are classified as having an "energy-deficit"/"agricultural surplus" are presumably those where ethanol programmes would be most relevant. This methodology is praiseworthy, but its results are inconclusive, due to a number of factors.

The concepts of agricultural and energy "surplus" and "deficit" are both irrelevant and misleading in the context of planning for ethanol, because of trade considerations and/or rigidities in both the supply of fuels and inter-fuel substitution. Countries may have

surpluses of biomass, coal, or natural gas, but they may have deficits of certain transport fuels. According to this methodology, India is placed at the margin of agricultural and energy self-sufficiency. In this country, however, the economic advantages of exporting more sugar or importing less oil would depend on the relative prices of sugar exports and of both petrol and naphtha imports, as well as on the quantity of sugar India can export under ISA quotas. Unlike Brazil and India, Thailand may be able to export more sugar at a given price without substantially affecting world sugar prices. Some countries may also have an "agricultural deficit" because land is badly managed. Others may have certain land areas that are unsuitable for cultivating food crops, but feasible for some ethanol feedstocks with low food value or no food value, such as wood. Ethanol produced from molasses does not require any land resources other than those required for sugar production. Hence, there may be sugar-producing countries with agricultural and/or food deficits, but with surplus molasses at low opportunity cost to sustain a minimal level of production. Similarly, countries with a large manioc-starch industry, for example, may find it attractive (depending on market demand and opportunity cost) to develop an ethanol industry based on this feedstock, for replacing oil products or for export. This could also help stabilise the starch market, while promoting employment and possibly higher incomes in rural areas.

Because of the above considerations, it would be necessary to do a detailed study to determine whether a country could or should develop an ethanol programme. As in Brazil, optimal choices may not necessarily be based on technical criteria alone. The adequacy of different raw materials, their yields, and economic value as food in domestic and external markets may vary from country to country. The amount of arable land required for production depends on the raw materials used and the scale of the programme envisaged. In addition, the relevance of ethanol production also depends on the patterns of supply and consumption of fuels.

Review of major literature

As a result of the inter-sectoral complexity of ethanol programmes, and because the experience of ethanol production is limited, most of the literature on ethanol focuses on selected issues and does not offer a comprehensive view of ethanol production processes or their economic, social and policy implications. Some recent studies deserve attention, however.

A study by the FAO (1980) was concerned with the crucial choice between ethanol and food production, having drawn information from its own sources and arguments from some previous contributions, e.g. Rask (1979), Brown (1980) and a few others. It offered a general overview of technologies available for different raw materials and of production costs, but its arguments on "fuel versus food" were distorted by the limitations of using only macro-level data on arable land and food production. A World Bank study (1980b) is perhaps the most important one to appear so far in international circles. This

study provided a useful analysis of basic economic parameters for ethanol distilleries, based on certain assumptions about capital costs, crop yields, distillery-gate costs of raw materials and ex-refinery costs of petrol. In addition, the study included a basic technological guide to industrial operations and some policy analysis. Nevertheless, it gave very limited attention to some important issues which are country specific: oil substitution and balance-of-payments, employment, income distribution, agricultural operations and potential non-energy uses and benefits of ethanol schemes for rural areas. The possible implications of the choice between sugar and ethanol for the balance-of-payments of sugar-producing countries have been analysed by Bhatia (1981) for India, and by Islam (1980) for Brazil, both offering important methodological contributions. Bhatia (1985) analysed the social costs and benefits that would result from an expansion of ethanol production in India, which rely on sugar-cane and molasses as raw material, for use as both chemical and fuel. His study assessed the net present values of two hypothetical ethanol programmes, based on different assumptions about the supply, consumption, and prices of oil, petrochemicals, sugar-cane, and food crops affected by additional sugar-cane cultivation. It also analysed employment and income distribution effects. Koide et al. (1981) reported on current ethanol production developments in South-East Asia, and analysed future prospects for the region. The study is inconclusive about these prospects, but it provides a useful problem-finding survey and gives ideas for further investigation at the country level. An earlier study by Brazil's National Research Council (CNPq, 1978) focused on technological issues; projections of supply of, and demand for, raw material, sugar, oil-derived fuels and ethanol; input requirements for ethanol production and implications of this production for the balance-of-payments. It was the first study produced in Brazil to assist PNA's policy-making. Some of its assumptions and forecasts were wrong, but this was largely unavoidable, given its prospective outlook and uncertainties about trends in demand for fuels. A study by PLANALSUCAR, University of Sao Paulo (USP) and Mauá Technology Centre (1981) analysed alternative agro-industrial scenarios up to the year 2000, using different raw materials and varying assumptions about levels of technological improvement. The objective of this study was to help formulate future policies for food and ethanol farming as well as R and D in these areas. CENAL (1983) analysed costs and benefits of ethanol production, based on earlier research by Fundaçao Getúlio Vargas, COPERSUCAR, and other local institutions. It included a useful review of supply and demand for fuels and the implications of ethanol supply for future investments in the oil-refining sector. However, it did not provide a complete assessment of the balance-of-payments impact. Geller (1984) reviewed CENAL's cost assessment as well as other recent literature on technological and socio-economic aspects of ethanol. These and many other studies on different aspects of ethanol technology, economics and planning are mentioned in the course of this study in the analysis of specific issues.

Purpose of the study

Aimed primarily at development planners and energy economists, this study assesses the extent to which PNA's explicit objectives were being achieved by the end of its first five-year period (1975-76 to 1980-81). These objectives were PNA's contribution to foreign currency savings, employment creation and income distribution. The study includes a review of policies and production trends up until 1984. In addition, by drawing on PNA's experience and available literature, it analyses the technological, economic and planning aspects of commercial-scale ethanol programmes.

Analytical scope

The initial objective of this study was to provide a detailed assessment of PNA's employment implications. This is an important theme because ethanol programmes offer a wide choice of technology, which can significantly affect their employment impact, particularly in the agricultural segment of production. However, it became clear that the isolated analysis of this topic would lead to infertile conclusions for three reasons. First, large-scale investments in energy, including "new and renewable sources of energy" (NRSE), are rarely selected and justified solely on the basis of their employment impact; natural-resource availability and relative economic costs of different energy options are normally much more important. Second, the choice of technology (hence, trade-offs between capital and labour) is largely constrained by production costs and other factors. Third, employment is not a sufficient indicator of real incomes in the rural areas of many developing countries, including Brazil. In some cases, wages are a supplement to non-monetary income, but in others they are a substitute, as occurs when the expansion of commercial crops including sugar-cane causes landless peasants to be displaced and to lose their access to land.

Therefore, it became necessary to disaggregate production costs and to review PNA's effect on landownership and its implications for the distribution of personal incomes. Since PNA was clearly promoting a concentration in landownership and inter-regional income disparities, it was also necessary to examine the extent to which these effects might be compensated by PNA's economic benefits, which are reflected primarily in the balance-of-payments and the Government's cash flow.

Apart from the disaggregation of production costs, none of these other issues had been adequately analysed in the literature available in 1981, when the field research was carried out. PNA's implications for employment generation could be roughly estimated on the basis of disaggregated costs of production surveyed by Fundaçao Getúlio Vargas and COPERSUCAR in particular, but this did not permit any conclusions about the composition of the workforce nor about qualitative aspects of employment. PLANALSUCAR had collected information on land owned by distilleries, but most of this information offered limited scope for analysis, because it listed land owned by distilleries'

shareholders as non-distilleries' lands, thus giving a misleading picture about PNA's effect on landownership. In addition, none of the literature provided an adequate methodological treatment of PNA's impact on the balance-of-payments. These research gaps determined both the objectives and the scope of this study.

Methodological framework and limitations of the study

To assess the balance-of-payments impact, we shall look first at the oil import substitution effect of ethanol, taking into account the patterns of supply and consumption of fuels. We shall then quantify oil import savings and export earnings related to ethanol production and the value of imported inputs to production. In principle, the production of ethanol in Brazil would imply foregone revenues from sugar exports, but in practice this did not happen until 1984 at least, because of existing supply and demand conditions. Furthermore, displacements of food crops by sugar-cane intended for ethanol may have caused losses in food exports or higher food-import bills. It will be argued later, however, that most of these displacements up to mid-1981 involved relocations and that their effect on the balance-of-payments, if any, could be hardly attributed to ethanol production.

The employment impact is assessed through a survey of ethanol distilleries of different scale and the use of labour coefficients in ethanol-related agriculture. The results are approximate and concern direct employment only. Accurate figures are virtually impossible to produce because of the overlap between sugar and ethanol production and regional variations in coefficients. There may be nevertheless some considerable indirect employment, associated with linkage effects, particularly in equipment manufacturing, R and D and construction. This impact could not be quantified, because of the lack of basic data and/or because these activities are not exclusively related to ethanol.

The impact on inter-regional income distribution is viewed through the analysis of the geographical distribution of investments. The analysis is based on the following consideration: Because of the large subsidies to investments in ethanol, a concentration of production in richer regions and states implies increased disparities of income between richer and poorer regions, whereas an opposite trend in production will have the opposite income effect. The impact on income distribution among individuals will be viewed through an analysis of the wages of PNA's workforce, the organisation of raw material supply, and the trends in landownership associated with ethanol agriculture. The considerations underlying this analysis are as follows: A large part of the rural population in Brazil rents, sharecrops, and occupies land illicitly for subsistence and commercial cultivation; because of this, increased landownership by distilleries' proprietors and shareholders means that the access of non-proprietors to land is reduced; this leads to the proletarisation of non-proprietors and, in Brazil, this often implies losses of income "in kind", which are not compensated by the low wages received from

additional job opportunities created by sugar-cane monoculture (mainly during the harvest season). Both of these analyses offer limited scope for precise conclusions, because of lack of data on (i) the income implications of development linkages in different regions; (ii) previous incomes of PNA's farmers and workers; and (iii) detailed changes in land use and land tenure, which affect cash income and income "in kind". Despite these limitations, these analyses will permit us to identify PNA's income-distribution effects and their implications for policy.

Organisation of the study

The study consists of two major parts. In Part I, Chapter 1 describes the basic technological issues of ethanol production, which are important for planning and which need clarification before other issues can be discussed without distractive explanations in the text. It also includes a brief discussion of fuel supply and consumption patterns which determine the oil-substitution potential of ethanol. Chapter 2 gives a general analysis of the economic aspects of production processes of interest to developing countries. Readers acquainted with these issues may skip these chapters and begin with Part II, but it may be useful to review these chapters, since they are written from a planning viewpoint.

Part II provides a detailed analysis of PNA's first five-year period. Chapter 3 begins with a review of PNA's institutional aspects and major developments, and gives a summary of PNA's socio-economic impacts. It also includes an analysis of the implications of PNA's policies and production trends for inter-regional income distribution and a discussion of ethanol costs. It is followed by analyses of PNA's impacts on oil substitution and balance-of-payments in Chapter 4, employment in Chapter 5, and personal income distribution in Chapter 6. Finally, Chapter 7 discusses the major findings and policy implications of PNA, followed by an analysis of further considerations for planning in other developing countries.

To make Part II as brief as possible, some important but cumbersome issues and information were relegated to the appendices. Appendix A disaggregates data on the patterns of ethanol supply, and Appendix B breaks down costs of ethanol production by macro-region and type of distilleries including a description of capital costs. Appendix C analyses the choices of techniques in sugar-cane agriculture which have implications for ethanol-related employment and costs. Finally, as a supplement to Chapter 6 and Appendix C, Appendix D analyses the relative importance of agrarian structure in determining incomes in sugar-cane agriculture.

Notes

1 Although variations in investment costs and the instability of the prices of oil and major raw materials do not allow firm up-to-date conclusions about the unit cost of ethanol in different countries, this statement is based on the author's assessment of the unit cost of ethanol in Brazil in mid-1981 and on information on other countries.

2 The continued dependence of oil-importing developing countries on oil is an indicator of their vulnerability. The share of oil products in their total energy consumption decreased only marginally from 65 per cent in 1970 to 63 per cent in 1980 (UN/DIESA, 1982). Data by the Asian Development Bank (1982) revealed that in a total of 24 Asian countries surveyed, oil accounted for over 90 per cent of the commercial energy consumed in 17 and 15 countries, respectively in 1970 and 1978. In world-wide terms, the average annual rate of growth of commercial energy consumption declined from 5.1 per cent in 1965-73 to 2.5 per cent in 1973-78. However, in industrial countries, these percentages decreased respectively from 4.7 per cent to 1.5 per cent (0.5 per cent in market economies), whereas in developing countries they increased from 6.9 per cent to 7.3 per cent (decreasing marginally to 6.8 per cent in market developing economies). The vulnerability of oil-importing developing countries to oil-price instability may be seen for example, in the ILO case studies on the socio-economic effects of higher oil prices covering India, Kenya, Egypt,the Sudan, Zimbabwe, Zambia, Peru, Colombia, Malaysia and Costa Rica (available as World Employment Programme Working Papers, which were published between 1982 and 1985); for a synthesis review of these country studies and other literature on the subject see Pereira, Ulph and Tims (1985).

CHAPTER 1

BASIC TECHNOLOGICAL ISSUES

There are no technical mysteries about ethanol. It was used in fuel blends in Brazil as early as 1919, and also in India, Mauritius, Australia and various countries of Europe and Latin America, during the 1930s. Some technological issues need clarification, however.

1. Ethanol and its production processes

Ethanol, also known as ethyl alcohol, biomass alcohol or simply alcohol, is produced from biomass containing sugars, starches or cellulosic materials. Sugar-bearing feedstocks (i.e., sugar-cane, molasses, and sweet sorghum) have their sugars extracted, and then fermented with a yeast enzyme to produce carbon dioxide and ethanol; this is followed by distillation to concentrate the ethanol. Starch-bearing materials (i.e., manioc, maize, babassu mesocarp and potatoes) and cellulosic materials (i.e., wood) must first be converted into sugar, via processes known as saccharification and hydrolysis, respectively, and then into ethanol.

2. Types and uses of ethanol

There are two types of ethanol - hydrous and anhydrous - which have different uses and implications for planning. Hydrous ethanol is 94 per cent water-free, and anhydrous ethanol is about 99.8 per cent pure. The production of the latter involves a final processing step to remove all water; this requires an extra distillation column (three or four instead of two or three) where benzene is added to hydrous ethanol. For this reason, the production cost of anhydrous ethanol is 5-9 per cent higher than that of hydrous ethanol.

As a petrol substitute, anhydrous ethanol can be mixed with petrol in amounts up to 20-22 per cent to make "gasohol" for use in cars or other vehicles equipped with petrol-type engines. Hydrous ethanol can be used only as a straight fuel in hydrous-ethanol vehicles equipped with Otto-cycle motors, or in petrol engines with appropriate adaptation. Earlier research in Brazil and in the United States concluded that the addition of anhydrous ethanol to petrol improves performance and saves energy. It increases the octane content of petrol, prevents pre-ignition, and replaces tetra-ethyl lead, which is toxic. The energy gain from anhydrous ethanol (as a petrol additive) depends on the quality of the petrol with which it is mixed. Tests conducted in Brazil with two Volkswagens (one running on a gasohol blend of 20 per cent ethanol, the other on normal

low-octane petrol) showed that the gasohol car had inferior acceleration and speed recovery, but slightly better fuel consumption at constant speeds up to 80 km per hour (Coimbra, 1979). In contrast, the fuel efficiency of hydrous ethanol is 17-18 per cent lower than that of petrol. Although this difference has to be taken into account in fuel pricing, it has marginal importance for planning. The most important consideration is that vehicles using fuel-hydrous ethanol cannot run on petrol or gasohol. Thus, they create a captive demand for fuel-hydrous ethanol, which can be undesirable if world petrol prices are significantly lower than the cost of producing ethanol.

As a chemical product, ethanol can be used directly or as an intermediate feedstock for the production of other chemicals, including petrochemicals. In Brazil, ethanol has been used in the chemical industry since the 1920s. It became a major input in the early 1960s, though yielding way to petrochemicals in the late 1960s and early 1970s, because of costs. Of total ethanol production in 1980, about 13 per cent was used as non-fuel (beverages and chemicals) including some 5 per cent used as petrochemicals. The latter percentage is expected to increase to about 7 per cent in 1985, implying a four-fold increase in absolute consumption over 1980. About 60 per cent of India's production in 1980, and most of Sri Lanka's production since the late 1970s have been absorbed by their chemical sectors.[1] The EEC and Japan are major consumers of ethanol for chemical applications and have been the main importers of ethanol from Brazil and other countries. The economic parameters for competition between ethanol and major substitutable petrochemicals have been unclear, however.[2]

As a substitute for fuel oil, ethanol is unlikely to become important, because (a) its energy value is comparatively low,[3] (b) the opportunity cost of this substitution tends to be high and (c) there are other more economic alternatives, such as coal, gas, bagasse, and wood.

The substitution of ethanol for diesel oil remains a technological challenge. In principle, there are four options. One is to replace diesel engines by Otto-cycle motors which run on hydrous ethanol; another is to develop dual-fuel engines; the third is to use hydrous ethanol with additives, including vegetable oils, in diesel engines and the fourth is to blend anhydrous ethanol with diesel.

By 1981, Brazilian subsidiaries of Volkswagen, General Motors, Chrysler and Ford had begun to introduce light lorries and buses, and Massey Ferguson, a small tractor, which were all equipped with Otto-cycle motors using hydrous ethanol. By the end of 1983, these initiatives had not had a significant effect on the pattern of fuel consumption, because of their restriction to light-weight vehicles, as well as the greater efficiency and the relatively lower price of diesel oil.

Engines using both ethanol and diesel in heavy buses and lorries have been studied in Brazil by Mercedes Benz, Scania-Volvo and Caterpillar. In mid-1981, Scania-Volvo announced the acceptable performance of a dual-fuel engine using 15 per cent diesel and 85 per

cent ethanol, unmixed,[4] but no decision about its mass production had been made until at least mid-1983.

Mercedes Benz, Caterpillar, and government-financed institutes have reported positive technical results with blends of ethanol and additives, such as fusel oil and diethylglicol (both by-products of ethanol), but this option is constrained by economic considerations. Because the calorific value of ethanol is about 60 per cent of that of diesel, the consumption of ethanol per mile is correspondingly higher. The production cost of ethanol with additives has been much higher than that of diesel; yet the unit price of the former would need to be about 55 per cent of that of diesel to make it attractive to consumers. In addition, this substitution would require consumer investments for adapting diesel engines, as well as public investments for distributing the new fuel.

Vegetable oils from soya bean, sunflower, jathropa, talarma ovata and olive may be used as straight fuels or in blends. The National Institute of Technology (INT) in Brazil, for example, has mixed different amounts of dende palm oil with diesel and ethanol. One experiment, using 20 per cent oil, 72 per cent diesel and 8 per cent ethanol, achieved a slightly lower consumption per mile than tests with diesel alone. Some of the problems in this and other experiments in Brazil were the gumming of engine blocks and difficult cold-weather ignition. In North America, satisfactory tests were carried out with sunflower oil in 1981. However, the key obstacle to the commercial use of vegetable oils as fuels has been their high opportunity cost. The oils that have proved most promising - dende palm oil and sunflower oil - have had higher market values than diesel oil.[5]

The possibility of blending ethanol with diesel has also been researched. Its technical feasibility depends on the volume and water content of ethanol, the temperature of engine operation, and the characteristics of the diesel used. The tests carried out under the sponsorship of the Industrial Technology Bureau (STI) concluded that a blend of different samples of diesel with up to 5 per cent anhydrous ethanol is feasible without requiring alterations to diesel engines. This is an important option, particularly in the event of an ethanol surplus and of severe restrictions on imports. However, the potential impact of this option on diesel replacement is small and, furthermore, ethanol is much more efficient as a petrol substitute.

In summary, there have not been any breakthroughs in the direct substitution of ethanol and vegetable oils for diesel, although R and D and relative prices may change this situation in the future.

In 1983, energy planners and technicians in Brazil were also considering the possibility of blending surpluses of petrol with additives to replace diesel. This would have some advantages over blending ethanol with additives, since petrol has a calorific value only 9 per cent lower than that of diesel and it would require lower amounts of additives per litre to correct the cetane index and viscosity. In Brazil, this option may be regarded as an indirect substitution of ethanol for diesel, since the surplus of petrol is mainly a consequence of ethanol supply.

3. Limitations on the oil import substitution effect of ethanol

Ethanol may have limited relevance as a substitute for imported oil in some countries, partly because fuel ethanol substitutes directly for petrol only, and partly for other reasons which are briefly discussed below. This issue depends on the interrelated patterns of supply and consumption of oil derivatives; it is of special concern for countries with an oil-refining sector.

There are two sets of factors which determine both the significance and the limitations of ethanol as a substitute for oil imports. One is mainly economic and concerns the demand for petrol and other oil derivatives, gasohol, and/or hydrous ethanol. The other is primarily technological and concerns the supply of oil derivatives. To explain this issue with its technological dimension and its implications for ethanol planning, one must begin with demand-related considerations.

Petrol is generally less important to economic growth than other major fuels, such as diesel, which is used in freight and public transport, industry and agriculture; naphtha, which is used in the chemical sector; aviation kerosene, which is used in commercial aircraft, or fuel oil, which is used in industry. If oil prices increase, the demand for diesel, for example, may continue to rise in conditions of economic expansion, whereas the demand for petrol, and therefore for fuel ethanol, may decrease. This situation is caused mainly by the fact that the price elasticity of demand for petrol is considerably higher than that for diesel in most countries. In other words, demand for petrol will tend to decrease much more than the demand for diesel if the same percentage increase in the market prices of petrol and diesel takes place. In particular, this seems to be true when steep price increases occur in a relatively short period of time, as in 1979-80. However, this general observation is not applicable to all situations and requires some qualifications and examples.

First, the price elasticities of different fuels will vary according to the range of possibilities for inter-fuel substitution in specific uses. The price elasticity of fuel oil is normally much higher than that of diesel in situations where the latter is mainly used in road transport and the former in industries; diesel in road transport has no direct substitute, whereas fuel oil in industry has several. Second, these price elasticities depend on the patterns of consumption of fuels which vary across countries.

In Brazil, where petrol is almost entirely consumed by private cars, consumption of petrol per vehicle dropped from 3,700 litres in 1973 to 2,470 in 1976 (before ethanol was commercialised) and to 1,656 litres in 1980. Even when allowance is made for the fact that in 1980 there was a 16.5 per cent content of anhydrous ethanol in gasohol and that some fuel hydrous ethanol was used (Chapter 4), car-fuel consumption per vehicle was reduced to about 2,000 litres. It is also noteworthy that, in 1982, the average fuel consumption of hydrous-ethanol cars was 3,324 litres, whereas that of gasohol cars was 1,440 litres. Differences in fuel prices provide the major

explanation for this. When fuel hydrous ethanol appeared on the market in 1979, its price was established at 60-65 per cent of the price of gasohol and was further reduced to 59 per cent since March 1982. Other explanations include the 17-18 per cent lower efficiency of fuel hydrous ethanol; the high share of hydrous ethanol cars used as taxis for public services and these cars, being largely newer than the average gasohol car on the road, normally run more miles per year than older ones. In the United States, where very few diesel-powered cars exist, a five per cent drop in petrol consumption was registered in 1979 in response to a real price increase of about 30 per cent in that year.[6] The same trend "continued into 1980 with petrol demand down 8.4 per cent" from the 1979 level.[7] From 1979 to 1980, petrol consumption decreased by about 21 per cent in Mauritius, 23 per cent in the Philippines, and some 10-15 per cent in Sri Lanka, among many other countries. In contrast, the consumption of diesel increased in Brazil, Sri Lanka and the Philippines from 1979 to 1980; it decreased in Mauritius, but by a much lower percentage than petrol.[8]

The price elasticity of demand for petrol may not necessarily be the only cause of the drop in its consumption. Restrictions on car production or imports, fuel rationing, or the tightening of credit facilities for car purchases can also reduce demand. In Brazil, the price elasticity of demand for car fuel was the major factor accounting for its sharp decrease in consumption from 1979 to 1980 (this will be discussed further in Chapter 3). In Europe and in some developing countries, where there is considerable consumption of diesel in cars, the price elasticities of demand for the major fuels may differ somewhat from those in Brazil. Similarly, in countries where petrol is used in freight and public transport, its consumption is less affected by price changes. Whatever the reasons for decreases in car-fuel consumption, however, the fact remains important.

It is the linkage between the pattern of fuel consumption and that of fuel production which is crucial for planning. As the relative consumption of different oil derivatives changes, countries also need to change the relative supply of these derivatives. If these are imported separately, due to the lack of domestic oil-refining capacity, there is no immediate problem in changing the pattern of fuel supply. However, in countries with oil-refining capacities nearly equal or larger than the total consumption of oil products, it may be difficult to change the supply mix. This may limit the oil import substitution effect of ethanol. Although Brazil's case is discussed in Chapter 4, it is important to make some general remarks about this issue here.

In the oil-refining process, each bbl of crude oil yields certain proportions of petrol, diesel, fuel oil and other less important derivatives. These fractions (commonly referred to as the "crude slate" or "oil-product slate") may be slightly changed depending on the type of crude oil refined. The flexibility to change them significantly, however, depends on the existence of "secondary" and "conversion" processing facilities. Secondary facilities enable marginal changes to be made in the crude slate and may be used to improve the quality of certain oil derivatives. They include

hydrosulphurisation of kerosenes and diesels, catalytic reforming of naphthas to yield high-octane petrol, merox treatment of gases and naphthas and vacuum distillation of residues. Conversion processing facilities allow more significant changes in the crude slate; these include catalytic and thermal cracking, coking and hydrocracking.[9] This output flexibility also depends on the number of refineries, their relative configuration and capacity utilisation. For example, if conversion processing facilities are limited, the lower their capacity utilisation the greater the flexibility of production.

Countries whose refining sector has limited flexibility to change the crude slate may adjust to changes in consumption by importing more of certain oil derivatives and less of others, or by changing the refining structure. The former option will tend to increase overall fuel-import costs, while the latter will require varying investments, depending on the output flexibility envisaged. Thus, there may be situations where the pattern of fuel consumption and the oil-refining options may reduce the significance of ethanol as a substitute for oil.

This can be particularly true in countries where (a) domestically refined petrol virtually equals petrol consumption, (b) the price elasticity of demand for petrol is higher than that of other major fuels and (c) the trends of consumption of these other fuels may justify a certain refining configuration which cannot reduce the petrol fraction within certain economic parameters for investment. For example, in situations where the consumption of diesel, kerosene, naphtha, LPG and/or fuel oil is increasing, it may be economically justifiable to increase crude-oil imports rather than to import increasing amounts of these refined products. If oil-cracking facilities are limited, this typically leads to an increase in the supply of different oil derivatives including petrol and may make the substitution of ethanol for petrol economically unattractive. This can happen particularly if surpluses of petrol and ethanol cannot be easily exported, if petrol gluts cause its price to fall to levels near its production cost, and if ethanol is not economically competitive with petrol. However, a demand pattern which includes similar increases in the consumption of the main fuels other than petrol is not typical of oil importing countries after the second oil shock. As a result of higher oil prices, economic recession, oil substitution and energy conservation, the following pattern has become much more common. The consumption of fuel oil decreases as a result of substitution and conservation; the consumption or petrol decreases or stabilises in response to higher prices and improvements in public transport systems; and the consumption of diesel and, to a lesser extent, kerosene, LPG and naphtha possibly increase as a result of economic growth and of limited substitution possibilities. Many countries with a consumption pattern similar to this are changing, or may need to change, the configuration of refineries in order to reduce heavy fractions of fuel oils and increase middle fractions (e.g., diesel and kerosene) and/or light fractions (petrol and naphtha).

A rudimentary refinery equipped with atmospheric distillation, for example, will yield roughly 40-43 per cent of fuel oils, 29-32 per cent of middle distillates, 14-16 per cent of petrol, 9-11 per cent of naphtha and a small remaining fraction of LPG. Adding vacuum

distillation and catatytic cracking facilities will normally decrease heavy fractions, but will increase the output of petrol and/or naphtha as well. Thus, they may reduce the significance of fuel ethanol, unless export markets for ethanol and/or petrol are favourable (which is not the case for all countries at all times). In principle, these facilities allow a shift from petrol to naphtha production, and therefore increase the potential import-substitution effect of ethanol. In practice, however, this is not always the case, because the consumption of naphtha may be limited and its export price lower than that of petrol. Hydrocracking facilities may considerably increase or decrease the ratio of petrol to diesel (or of light to middle distillates in general), for example, but these require larger investments and longer pay-back periods than any other secondary oil-processing facilities.

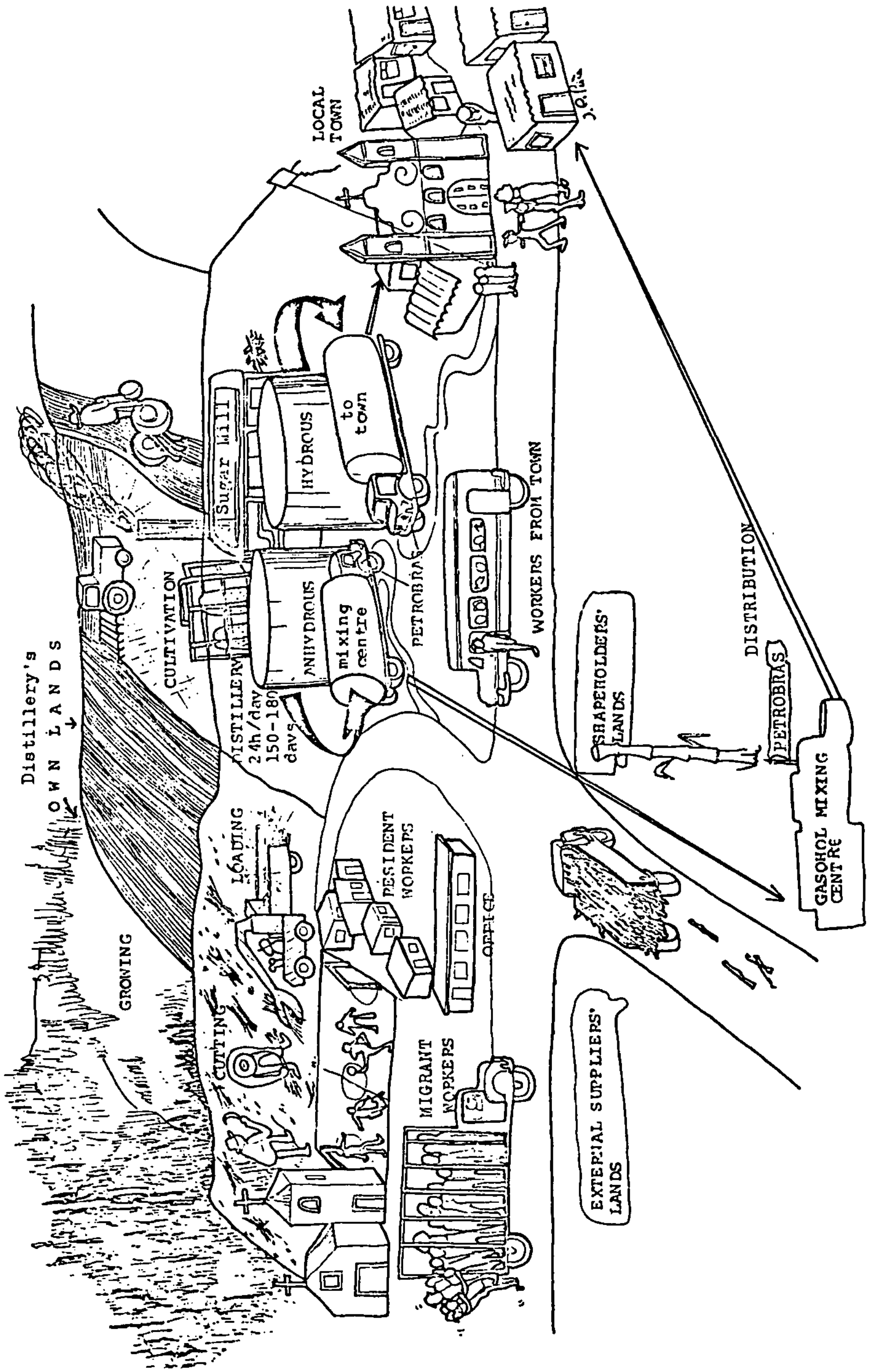
In summary, the patterns of fuel consumption and supply - particularly rigidities in the oil-refining sector which are related to its size and configuration - can determine the oil-substitution potential of ethanol. This constraint may eventually be relaxed once the possibilities of substituting ethanol for diesel increase. It may also not be very important in situations where ethanol production is small and can be favourably absorbed by the chemical industry in national and international markets. Nevertheless, these supply and demand patterns must be carefully studied before embarking on ethanol production programmes of any scale or purpose.

4. The system of ethanol supply

As suggested in the above discussion, ethanol production should not be seen in isolation, but as part of an integrated system. This involves not only the manufacturing of ethanol, including the disposal, treatment and/or reprocessing of solid residues, stillage (liquid waste) and carbon dioxide and sale of fusel oils,[10] but also the production of raw materials and the distribution of ethanol. In addition, the system depends on various subsectors through backward linkages, e.g., supply of distillery equipment and farm machinery; fertilisers and related inputs; R and D for agriculture and industry and government services. The selection of production strategies for individual projects will also involve choices of location, raw materials to be used and organisation of their supply, and type and scale of distilleries.

A sketch of typical ethanol production schemes in Brazil is illustrated in figure 1. A distillery complex based on sugar-cane operates 24 hours per day for a period of 150-180 days during the harvest season of the crop. The feedstock may be derived from lands owned by the distillery and its shareholders and/or by independent suppliers who sell the product to the distillery at a price stipulated by the Government. Because the latter expect high prices and the former expect low costs, conflicts of interest may often occur. Industrial activity in the off-season is reduced to normal working hours and comprises the maintenance of equipment, vehicles and buildings. The distribution of ethanol is not necessarily different

Figure 1: Sketch of a sugar/ethanol complex in Brazil



from that of petrol, depending on the type and markets of ethanol (Chapter 3). A commercial distillery complex must have, however, a minimal storage capacity, depending on the distribution flow. On the whole, the agricultural component of production is the most important both from private and social viewpoints. In typical conditions, raw materials alone account for 60-70 per cent of the unit cost of ethanol and their opportunity cost may be high. The bulk of employment and income-distribution effects of production take place in this sector.

5. Types of distilleries and their implications

It is important to distinguish between two types of distilleries. In countries with a traditional sugar (or manioc starch) industry, the production of anhydrous or hydrous ethanol may take place in distilleries that are built next to sugar or starch mills. In these cases, only the ethanol-related equipment (not buildings and other infrastructures, such as access road and facilities for the reception and preparation of raw materials) are added to the industrial complex. These so-called annexed distilleries have a number of economic advantages over autonomous distilleries. The latter are isolated investments for the production of ethanol and without any other related activity.

The advantages of annexed distilleries include: lower requirements (per litre) of investment capital, labour in the industrial component of production, and land (when using sugar-cane, because they may also produce ethanol from sugar molasses); less risk, due to product diversification; shorter installation periods; lower cost per litre (due to all the above factors) and normally better living conditions for the permanent workforce. These advantages are the result of a more efficient use of otherwise underutilised factors (e.g., labour and capital goods) and the type of process of industrial production. For example, autonomous distilleries produce ethanol directly from sugar-cane, whereas annexed units may also or exclusively produce it from molasses (7-13 litres of ethanol from the molasses left over from each tonne of sugar-cane used for sugar; the average direct yield is about 70 litres per tonne of sugar-cane).

A disadvantage of annexed distilleries from the social viewpoint, however, is that they may reinforce the existing pattern of agricultural production and landownership, since they have a predetermined choice of location and raw material. In principle, autonomous distilleries may be guided to poorer areas and use feedstocks cultivated by low-income farmers, but in practice this may be difficult because of financial considerations.

6. Scale and technology of sugar-cane distilleries

Ethanol distilleries are often classified as macro, mini and micro. This classification is adequate only in so far as it accommodates technological differences among distilleries. Two distilleries of identical scale may have different levels of

productivity, and a smaller but more efficient distillery may yield an equal or greater rate of return than a larger one. Therefore, the classification of distilleries needs to be made according to different levels of both scale and technology. This is shown in table 1 with reference to sugar-cane. Other raw materials are excluded due to limited experience with them in large-scale production.

Table 1: Scale/technology of sugar-cane distilleries in Brazil; efficiency levels by stage of production and final productivity (1981)

Distillery type and scale (thousands LPD)	Efficiency (in percentage)			Productivity (LPT)		
	Extraction	Fermentation	Distillation	Fermentable sugars[1] 10%	12%	14%
Micro						
5	50[2]			35	43	53[1]
0.8 EMBRAPA[3] A	60			44	45	47
B	70			52	54	56
Mini						
10-20	90	80	84	41	52	58
Agro-industrial						
120-440	93	90	96	55	68	77
Industrial						
120-1 000	96	95	98	61	76	85

[1] Final productivity (in LPT) depends not only on the efficiency of the three stages of production but also on the percentage of fermentable sugars in the sugar-cane. LPD - Litres per day; LPT - Litres per tonne.

[2] Data from Saccharum Stab (1979).

[3] The EMBRAPA micro-distillery is available in two models, A and B:

A This prototype has better technology than most typical micro distilleries available in Brazil until at least 1984; it uses stainless steel and continuous fermentation, and operates with one set of crushers.

B Same as above, but operating with two sets of crushers.

Source: DEDINI except where noted.

The figures show that the level of technology used in each scale group affects the efficiency of each of the three main processing steps: juice extraction, fermentation and distillation. Their separate efficiency levels determine the final productivity rates, measured in litres of ethanol per tonne (LPT) of raw material. However, these rates depend not only on the technology used, but also on the amount of fermentable sugars (FS) contained in the sugar-cane.

The most critical item affecting the overall productivity of industrial production is the juice extraction equipment. In Brazil, only crushers[11] have been used which are not the most efficient equipment (other equipment is discussed in section 7). The variation in the efficiency of extraction is caused by differences in cane preparation and by the number of sets of crushers used (there are three crushers per set).

The few micro-distilleries which have been installed in Brazil use simple equipment, although the EMBRAPA version is a bit more sophisticated (see table 1). Typically, the cane receives no preparation and there is only one set of crushers. In the mini-distilleries, four sets of crushers are employed, and the raw material is partly prepared. In the macro-distilleries, the agro-industrial category involves more complex equipment; it is much more efficient, and the investment required is also considerably higher. Finally, also in the macro-group, the industrial distilleries are equipped with more energy-efficient technology with better controls. Most large-scale distilleries in Brazil, however, are of the agro-industrial category.

7. Technological innovation and diffusion

In the long term, technological innovations in ethanol-related agriculture are likely to have a greater impact on overall productivity and economic performance than innovations in the industrial component of production. This is because any minor improvements in agricultural yields have significant impacts on total costs and returns. However, unlike in the industrial sector, agricultural improvements tend to occur in a gradual fashion. In the short term, most innovations will be centred on industrial technologies, due to their generally backward state.

Targets for innovation in ethanol agriculture include: (a) crop-yield improvements; (b) more efficient use of stillage in soil irrigation and fertilisation and (c) rotation and integration of ethanol raw materials with food crops, including "consortia" of two or more raw materials for ethanol production[12] to permit an extension of the industrial operations (from 150-180 days to about 300-330 days), which would increase returns and allow more stable employment.

Targets for innovation in the ethanol industry include: (a) the reprocessing of solid residues and liquid waste into biogas and other by-products; (b) the introduction of more efficient juice extraction equipment to increase the output per tonne of raw material and permit a better utilisation of residues; (c) the development of more energy-efficient distillation and heat-recovery systems; (d) the

substitution of batch-type fermentation by continuous fermentation;[13] (e) the development of processes to yield lower ratios of stillage volume to ethanol; (f) the commercialisation of more efficient equipment for small-scale distilleries; (g) the development of new technologies to separate ethanol from water[14] and (h) greater resistance of industrial equipment against corrosion. All of these require, in differing degrees, further technological development and favourable market conditions.

Crop rotation and integration depend as much on price and credit policies as on site-specific agronomic research. The reprocessing of industrial residues and stillage depends primarily on market regulation, since the basic technologies are well established. A choice of juice extraction equipment for sugar-bearing feedstocks already exists, permitting different levels of productivity. It is also possible to select processes which integrate high fuel efficiency, continuous fermentation, stillage reprocessing and the use of two raw materials.[15] Some of these innovations deserve further analysis and are discussed below.

Reprocessing of industrial residues and liquid waste

Each tonne of sugar-cane used for sugar or ethanol yields 210 to 250 kg of bagasse with a calorific value of 1.3 Mcal per kg (Silva, 1976). In Brazil's case, about 70 per cent is burnt for the generation of steam and mechanical power, leaving 30 per cent for other applications and/or unproductive burning.[16] Surplus bagasse can be used for cellulose, paper, briquettes, animal feed, some chemical applications and chipboard.[17]

In the case of manioc, rama (the part of the plant above-ground which is produced at a rate of about 22 tonnes per ha), may be used as animal feed, but also as a source of fuel, provided its average humidity of about 76 per cent is reduced to about 50 per cent (Leitao, 1979). The possibility of drying ramas in open air is mentioned in the literature, but no details were found about terrain space and time requirements, daily flow of material, etc.

The effluent from distilleries, commonly referred to as stillage, is produced in amounts of about 12 litres per each litre of ethanol. Its chemical content varies from place to place, but normally includes (in kg per m^3) 40-64 of organic material, 0.7-1 nitrogen, 0.1-0.2 phosphorus, and 4.5-8 potassium.[18] This chemical composition makes stillage either a water-polluting agent or an economically valuable resource, depending on what is done with it. If discarded in rivers or small lakes (to minimise costs) it kills fish[19] and may adversely affect the incomes of people who depend on fishing. If reprocessed, various by-products with potential economic value may be derived from it.

Stillage can be used directly in irrigation with fertilising effects; biogas can be produced from it to generate steam and power; potassium ashes can also be produced and used as an input to the fertiliser industry; unicellular protein can be made from stillage concentrate for the animal-feed market. The financial feasibility of

these applications depends on the scale of their production, the chemical composition of the stillage, and market competitiveness compared to other conventional alternatives. The last of the above applications is constrained by the limited use of processed animal feed and the potentially high cost of stillage evaporation, especially in the case of large-scale distilleries.

Research in Brazil suggests that direct irrigation/fertilisation with stillage, using water lorries (or infiltration, where topography permits this),[20] can be cheaper than conventional fertilisation methods.[21] However, the findings of site-specific studies are not always relevant to other places, because the characteristics of soils and stillage will produce different results. Thus, the choice of location of a new distillery should take these factors into account, as they will affect financial returns on investments. Since distilleries based on sugar-bearing feedstocks normally use low-opportunity cost bagasse for steam and power, the attractiveness of biogas production depends on the availability (or the creation) of local markets for biogas and bagasse. Electricity can also be produced from biogas and/or bagasse. Since these three fuels (and their by-products) can play a catalytic role in the development of isolated rural areas, it should be in the interest of government institutions to guide new distillery projects to areas where an optimal balance can be struck between financial returns and socio-economic benefits. The choice of project location may have obvious implications for rural development.

Until at least 1983, very little investment had been made in stillage reprocessing in Brazil. To avoid water pollution, the distilleries are required to have a minimum capacity for the chemical treatment of stillage; many of them use a small portion of it in irrigation, but its occasional disposal into rivers and lakes has become a public concern.[22] Ecological considerations alone may justify investments in stillage reprocessing, but financial and economic benefits are possible and should be explored by planners.

Juice extraction equipment

The juice extraction equipment available for sugar-bearing raw materials consists of three different types: crushers, diffusers and dual-function extractors/separators.

The crushers attain efficiency rates of 93 and 96 per cent in the agro-industrial and industrial scale/technology groups, respectively (table 1). The diffusers reach an efficiency of 98 per cent, thus producing more litres per tonne of sugar-cane. The differences between the emersion and the percolation types of diffusers, as well as their advantages and disadvantages compared with crushers, have been described in the literature.[23] According to experts, one special advantage of diffusers is their greater appropriateness to micro- and mini- distilleries because of both efficiency and cost.
The third juice extraction technology available - the dual-function extractor/separator[24] - approaches 100 per cent efficiency, with the additional advantage of separating the bagasse for its different

purposes. The stalks are separated into their main components: pith, rind and epidermi. "Twenty to twenty-five centimetre segments are split longitudinally into halves. A rotating coring device removes the pith, while leaving the rind fibres intact,"[25] thus allowing a more efficient use of surplus bagasse for chipboard manufacturing, animal feed or other purposes.

Notes

[1] See World Bank, 1980b, p. 14 and Koide et al., 1981, pp. 117-118.

[2] For example, Antunes (1980, p. 14) claimed that ethanol would be competitive in Brazil with oil prices above $32-35 per bbl, whereas the World Bank (1980b, p. 64) mentions a price frontier of $40-45 per bbl, both using comparable assumptions about ethanol costs.

[3] Approximately 65 per cent of the energy value of fuel oil when both are compared in units of weight.

[4] Veja, 19 Aug. 1981, p. 94.

[5] The average c.i.f. prices per tonne of dende palm and sunflower oils were $600 and $653, respectively in 1978, and $664 and $762 in 1979 (considerably above those of soya oil for example), whereas an equivalent amount of diesel fuel would have cost almost three times less in the same period. This cost gap decreased to about one-and-a-half times during the second oil shock, but has increased again since 1982.

[6] Beijdorff, 1981, pp. 127-28.

[7] Sawhill, 1981, p. 26.

[8] See World Bank/UNDP, 1981d, p. 12 and Koide et al., 1981, pp. 107-116.

[9] For a comprehensive discussion see, for example, Bhatia (1983) and Nelson (1970).

[10] Solid residues and stillage are discussed in section 7. Fusel oils, produced at an average of 5 kg per 1,000 litres of ethanol can be sold for use in some fuel blends (see World Bank, 1980b).

[11] This machinery consists of cylinder-shaped rolls, which crush the sugar-cane or sorghum to extract juice. After each production cycle, they are usually refurbished, as their surfaces get virtually worn out.

[12] Crop rotation is a technique which uses two seasonal crops with complementary cycles of production (e.g., sugar-cane and peanuts or beans), whereby the harvesting of one does not interfere with the cultivation of the other. Crop consortia or crop integrations are techniques whereby the production of more than one crop takes place in a specific farm unit. Consortia of sugar-cane with sweet sorghum or manioc for ethanol mean that two of these (instead of one) can be used in industrial production. These consortia are reported to be technically and financially feasible; they are much discussed in Brazil, but had not been implemented in commercial production at the end of 1983.

[13] See Guidoboni, 1984.

[14] According to the literature, technologies using suspended solids would substitute, at considerable savings, the traditional distillation method which was conceived for beverage grade alcohol. Promon Engineering in Rio de Janeiro and Purdue University have studied these technologies to some extent. On the latter case see Soft Energy Notes (Dec. 1979, pp. 94-96). Scientists at the University of Pennsylvania also have studied an "enzymatic and bacteriological process for breaking down husky celluloses, fermenting them to ethanol, and extracting the product without distillation" (Soft Energy Notes, July 1979. p. 64). See also Larsson and Mattiasson, 1984.

[15] An engineering firm in Brazil, Scientia, patented a pilot-level industrial process incorporating high fuel efficiency with a method of continuous fermentation and the biodigestion of stillage. Scientia experts reported in 1981 that this process reduces stillage output by 12-17 times, energy consumption by 30.3 per cent, and production costs and annual investments per litre by 26 and 60 per cent respectively (these figures were based on a controlled experiment).

[16] According to experts in Brazil, efficiency improvements are possible, which could allow a higher surplus of bagasse for other uses.

[17] See Alexander (1980), Paturan (1982) and World Bank (1980b).

[18] See Magro (1978), INT (1978), Rotenberg and Iachan (1979), Coleti (1978), Brasil Açucareiro (1980b) and Lamb (1978).

[19] At an expert meeting on stillage held in Brazil in 1981, a thesis was presented, according to which the polluting effect was evident only in the case of over-concentration of stillage in rivers and lakes; if diluted with larger volumes of water, it would have a positive effect on fish feeding and reproduction. Empirical evidence was not presented, however.

[20] Magro (1978), Lorenzetti and Freitas (1977) and INT (1976).

[21] Experiments in four different documented cases show cost savings and higher yields. In one of these cases, irrigation with stillage cost about $60 per ha against $100 per ha, for three applications by lorry in the same conditions. These findings by Usina Sao Joao in the State of Sao Paulo, in 1979, are consistent with those of Magro (1978), Lorenzetti and Freitas (1977) and Leme et al. (1980). Some uncertainty still exists in Brazil over the effects on soil quality due to the characteristics of soils and of stillage, as well as the variable sensitivity of soils to potassium.

[22] Until recently, many firms had not even complied with the stillage treatment procedures required by the Government, and frequent news articles have drawn attention to the water pollution problem. In the district of Campos, State of Rio de Janeiro, various distilleries were installed without the proper treatment facilities, and the stillage was piped directly into the river. Only in 1980-81, did the State's Environmental Protection Agency manage to enforce anti-pollution controls on all the State distilleries, according to its President (Jornal do Brasil, 3 July 1981). He was quoted in an article of the same source (7 July 1981) as saying: "last week in the Coqueiro river tonnes of fish died due to the direct disposal of stillage by the industries...". Another article on 1 September 1981, reported a "leakage" of a tank where 25 million litres of stillage were contained; according to the Director of Mato Grosso's Environmental Protection Agency, the accident was the company's fault, and a $6,000 fine was enforced. Accidental leaks have been frequent, but not all of them have been reported. In some towns with adjacent rivers, such as Piracicaba and Sertaozinho in the State of Sao Paulo, and Escada in Pernambuco, there was no fishing activity left in mid-1981 according to locals.

[23] Baccaro (1980), Ebeling (1978) and Payne (1976).

[24] This very recent technology is known so far as the Tilby Separator and, unlike crushers and diffusers, it was produced, in 1982, by one company only - Intercane of Canada, a subsidiary of Arvid Machine and Tool Company Ltd, Ontario, Canada.

[25] Soft Energy Notes, July 1979, p. 63.

CHAPTER 2

ECONOMICS OF ALTERNATIVE PRODUCTION PROCESSES

The economic performance of alternative ethanol-production schemes using different raw materials depends on many factors. Apart from oil prices, these are mainly the scale and technology of distilleries discussed in the previous chapter; variation in the productivity of different raw materials in terms of litres per ha per year and regional variation in crop yields. These variations, however, depend partly on agronomic research and institutional infrastructure, particularly credit and price policies and technical assistance offered to crop producers. Agrarian characteristics of production, farmers' incomes and choice of techniques can be important factors as well. Thus, comparative economic analyses of ethanol production from alternative feedstocks, types and scales of distilleries must be done at the local level, and in the light of specific policy objectives of ethanol production.

This chapter examines the economic parameters that are considered important for the appraisal of ethanol production schemes. It also discusses the limitations of comparing costs and benefits of different agro-industrial strategies.

1. Alternative raw materials

Ethanol feedstocks fall into three groups - sugar-bearing raw materials (sugar-cane and sweet sorghum), starches (manioc, babassu mesocarp, potatoes, etc.) and cellulose (wood). Their comparative yields are shown in table 2. In the context of ethanol production, they must be compared in terms of energy balance (energy produced minus energy used); seasonality and stability of supply; share of agricultural cost in the total cost per litre; opportunity cost, including balance-of-payments considerations; employment creation and income-distribution implications; requirements of soil quality, irrigation, machinery, fertilisers and pesticides.

Some of these aspects may be of greater importance for some countries than for others. Moreover, since there might not be enough information about them, there is no simple way to take them all into account in a comparative economic analysis. Before these points are discussed in more detail, we will summarise some of the characteristics of each major ethanol feedstock.

Sugar-cane requires high humidity, relatively fertile soils and fertilisers. It allows considerable choice of agricultural techniques. Many sugar-producing countries have very good support infrastructure for sugar-cane. Furthermore, the price elasticity of consumer demand for basic food products derived from sugar-cane is

generally lower than for products made from maize, wheat, grain sorghum, manioc or sweet potatoes since any of these have a wider range of substitutes. Sugar prices are mainly affected by hedging practice and speculation among traders and by fluctuations of supply.

Thus, the alternative use of sugar-cane for ethanol can help stabilise sugar prices, especially since there is some flexibility in how much sugar or ethanol is produced from a given supply of sugar-cane. Similarly, the joint production of sugar, molasses, ethanol and bagasse in annexed distilleries implies relatively low risks for sugar/ethanol complexes.

Sugar-cane employment in Brazil (measured in man-days per ha) is about one half that of manioc, and about two-and-a-half times that of sweet sorghum. The seasonal variations in the demand for labour on sugar-cane plantations are generally high, but this depends partly on the techniques used and the management of labour.

From the industrial viewpoint, sugar-cane has advantages over any other raw material except molasses at current levels of technology. It has the highest yield of ethanol per ha per year, apart from sweet sorghum, and has a most favourable energy balance. These advantages may diminish, however, if crop yields and the processing technology of other raw materials improve. Whether the energy balance is important depends on the opportunity value of the fuel used in processing. The bagasse from sugar-cane (and also sweet sorghum) is sufficiently dry to be used as the main fuel. With other raw materials, the possibility of using their residues as fuel is more difficult; usually, high opportunity cost fuels would be necessary, although the use of biogas produced from stillage may be an option. The principal disadvantage of sugar-cane is its seasonality, which limits operation of distilleries to 150-180 days.

Manioc (also known as cassava) is generally grown by low-income farmers on small plots of land[1] with very limited mechanisation. Its potential for increasing rural employment and incomes may be an important consideration in some conditions, but the very limited choice of techniques in most countries may restrain the diffusion of projects based on manioc. Saint (1980, p. 15) throws light on this point:

> Harvest is likely to present a particularly nettlesome bottleneck since it is accomplished entirely by hand. In the absence of mechanised root harvesters, the daily capacity for unearthing tubers with family labour is limited. Similarly, large-scale production would require back-breaking labour on an ongoing basis by organised work gangs in order to provide a timely flow of raw material to the alcohol [ethanol] distillery. Second, the cultivation of cassava in extensive tracts - whether by small or larger farmers - is likely to create disease (e.g., bacteriose) and pest problems (e.g., aphids, thrips, cassava hornworm). Although manageable in theory, little experience exists to date in large-scale sanitary control for cassava [manioc].

It is commonly argued in the literature that manioc can be grown on poor soils, but this conflicts with the general expectation of increasing the crop yields from the present world level of 10-15 tonnes per ha to 25 tonnes or more, in order to make manioc ethanol production feasible. Some experts argue, in fact, that high manioc yields need fertile soils. CTI (1980) refers to yields in Brazil varying from 11 to 80-90 tonnes: the latter in two very small locations with no significance for Brazil's average. Saint (1980, p. 10) notes that experimental yields of over 50 tonnes per ha have been consistenly obtained in Colombia. Thus, improved technology may increase the current low yields with soil conditions, but the varying yields in Brazil also suggest that these depend very much on soil quality.

Manioc diseases have apparently no generalised cure; they vary with location and species, and local research is therefore required. In Brazil, most diseases have been catalogued by EMBRAPA and can be controlled. Recent research by this institution concluded that, in some cases, chemical control is inefficient, because it kills the predators (nature's pest controllers). It also concluded that if manioc is cultivated with other agronomically compatible crops, it becomes more resistant and better results are obtained.

From the industrial viewpoint, the disadvantage of requiring an external source of fuel for its processing may be counterbalanced, in some cases, by the advantage of allowing a much longer period of industrial production than sugar-cane. However, there is some controversy about the feasible length of annual operation. Most literature refers to 330 days, but the only commercial manioc distillery in Brazil (which closed down in 1982-83) operated for a much shorter period, as a result of problems concerning the supply of raw material and labour. We consulted some experts in Brazil in 1982 who claimed that a plant based on manioc roots would not be able to operate for more than 180 days. They argued that, in practice, the 330-day operation (35 additional days per year for maintenance) would only be possible for distilleries annexed to starch factories ("flour houses"), whereby part of the starch milk would be used directly to produce ethanol and part of it dried and stored for use during the off-season (the storage of roots is not viable and the storage of manioc chips may pose technical problems).

Compared to sugar-bearing crops, manioc (or any other starch-bearing feedstock) also has the disadvantage of requiring two extra steps of production - cooking and saccharification, to convert starch into fermentable sugars. These make the total investment 12-20 per cent higher than that of a sugar-cane distillery (if a 120,000 LPD unit is taken as a base for comparison). Adaptations to a sugar-cane distillery to allow the consortium of sugar-cane and manioc would increase the investment by about 20-30 per cent. Equipment for the additional steps of production would have to be added, as well as the machinery to grind the manioc roots, which differs from the crushers used for sugar-cane.

Table 2: Ethanol yields from main biomass raw materials

Raw material	Ethanol Litres/tonne	Raw material tonnes/ha/yr	Ethanol Litres/ha/yr
Sugar-cane	70	50	3 500
Molasses	280	-	-
Manioc	180	12	2 160
Babassu	80	2.5	200
Sweet sorghum[1]	86	62.5	5 165
Wood	160	20	3 200
Maize	370	6	2 220
Sweet potatoes	125	15	1 875

[1] Stems plus grains (plant and ratoon).

Source: World Bank (1980b). This source was selected to facilitate cross-references. Small variations were noted among various studies, e.g., Silva (1976), FAO (1980), Lipinsky (1978), etc.

Molasses is a low-value by-product of sugar. In the production of sugar in Brazil, each tonne of cane yields about 100 kg of sugar and 45 kg of molasses which are partly discarded and/or used as low-value meal, and ocasionally as animal feed.[2] In general, each tonne of sugar-cane used for sugar production yields 7-13 litres of ethanol from molasses; this variation is directly related to the amount of fermentable sugars, which range from 40 to 70 per cent.[3]

Molasses can be used either in a distillery equipped to process sugar-cane or in a distillery designed for molasses only. Its use for ethanol production does not require juice extraction equipment or land. An autonomous 120,000 LPD distillery in Brazil, producing only ethanol from sugar-cane, would require about 5,140 ha. The same area used by a sugar/ethanol complex could produce 514,000 sacks of sugar (50 kg each) and 21,600 LPD of ethanol from the molasses. Therefore, if increasing supplies of sugar can be marketed at higher prices than ethanol, the joint production of sugar and molasses ethanol may be more profitable (depending on the opportunity cost of molasses) than the sole production of sugar-cane ethanol. The former option would earn nearly twice as much foreign exchange as the latter, at f.o.b prices of sugar and ethanol of August 1981, and assuming a zero opportunity cost of molasses.[4] This shows a major advantage of sugar-cane annexed distilleries. It may be also inferred from this example that the financial feasibility of an annexed distillery using molasses depends on the scale of the sugar-mill, that is, on the volume of sugar and molasses produced. For example, the production of 12,000 tonnes of sugar per year would make the installation of a 10,000 LPD distillery feasible. Where the opportunity cost of molasses as a food product for animal and human consumption is low or

zero, annexed distilleries using molasses as raw material and surplus bagasse as fuel are unquestionably the most attractive option for ethanol production in sugar-producing countries.

Sweet sorghum has similar advantages to those of sugar-cane in terms of yields and energy balance. It needs moderately fertile soils, but its fertiliser requirements are about 2-3 times lower than those of sugar-cane (Silva, 1976). This advantage, however, seems to be offset by the higher cost of other production inputs, such as seedlings and farm machinery. For example, the "narrow-row" planting techniques introduced in the United States (Lipinsky et al., 1978) mean that the crop cannot be harvested with standard equipment, and thus requires different machinery. However, sweet sorghum can be industrially processed with the same equipment used for sugar-cane, with very minor changes or additional costs. Its disadvantages are mainly associated with the lack of R and D, as in the case of manioc.

Research conducted in Brazil by EMBRAPA on sweet sorghum has focused mainly on its potential use in consortia with sugar-cane, rather than on its sole use for large-scale ethanol production. This was because of the general lack of experience with the feedstock; its high susceptibility to some types of diseases, such as "leaf anthracnos" and "stalk red rot", and the need for improved crop yields. Research in the United States, by the Sugar Crop Field Station of the Department of Agriculture in Meridian, Mississipi, has focussed on the development of varieties with high and consistent yields. Most of them do not reach the levels shown in table 2, because of their low sugar content.

Maize has even fewer advantages than manioc. Its energy balance is generally less favourable;[5] capital and operating costs are higher; the economic risks are also high, because of its opportunity value as a food commodity; also its use can have a worse impact on food prices than that of any other major raw material. The emphasis given to this crop in a number of fact-finding studies by the United States Department of Energy in the late 1970s was due to the lack of other options rather than its advantages over other ethanol feedstocks.

Babassu mesocarp, another starch-bearing feedstock, is one of the five elements comprising the coconut (10 cm in diameter) of the babassu palm, which is a native of North Brazil. The tree starts producing some 7-10 years after planting and has yields ranging between 2.5 and 7.5 tonnes of coconuts per ha (Rosenthal, 1977). Traditionally, only the inner nuts are extracted for use as animal feed and for the production of oils. The breaking of the coconuts is done manually, often by children, with a typical labour productivity of 3-6 kg of inner nuts per day.[6]

According to INT technicians in Brazil, the different characteristics of babassu starch require some modifications in the normal methods used in the production of manioc ethanol. They concluded that, at 1981 prices, ethanol from babassu mesocarp would be viable only if the coconut were processed as a whole, to yield its various products, that is, primary forms of fuel; fibres; ethanol and/or other forms of processed starch; charcoals; combustible gases; acetic acid, tar and methylene solvents; oils, soaps,

glycerine and brans. This group of products makes it potentially attractive to invest in the integral industrialisation of the babassu coconut. Moreover, depending on the social organisation of the plantations, such investment could make important contributions to employment and incomes of semi-landless peasants who predominate in the babassu areas of Brazil. Despite the potential attractiveness of the above line of products, there were no firms using babassu in integrated processes in Brazil in late 1981, probably because of market uncertainty.

Wood is the most attractive ethanol raw material in agricultural terms. Its major advantage is its relatively low cultivation cost, since it may be grown in soils of marginal quality and on irregular surfaces unsuitable for the production of most food crops. Its production can have very little impact on crop displacement, provided that adequate land-use policies are implemented.

From the agricultural viewpoint, there are two prerequisites for producing ethanol from wood, namely a well-organised forestry network and available land, even if marginal in quality. For a given ethanol-production level, the land requirements of a wood-based plant are significantly greater than those of other major raw materials. In principle, wood can yield about 3,200 litres/ha/year if the fuel needs for power and steam are provided from non-wood sources. However, productivity falls to 1,600 litres/ha/year, if the fuel needs (50-55 per cent of the total raw material) are provided by the wood farm. In this case, a production of 5,000 million litres per year would require over three million ha of land, while the same production based on sugar-cane, manioc and sweet sorghum (at current average yields) would only need land areas of 1.4, 2, and 1 million ha, respectively. However, the greater land requirements can be compensated by the lower quality of soils necessary and lower agricultural costs per litre.

These agricultural advantages of wood have been offset by its industrial disadvantages. The industrial process of cellulose-bearing feedstocks is more complex and expensive than those of sugar-bearing and starch-bearing feedstocks. The water requirements and the stillage produced are also greater than those of the other two types of raw materials. Industrial technologies still require further development, hence providing limited incentives for investments on wood-based ethanol schemes in the short term.

2. Alternative production processes

The economic performance of sugar-cane distilleries of different scale and molasses, manioc and maize distilleries of 120,000 LPD, producing anhydrous ethanol, is shown in tables 3 and 4. The figures are derived from data in a World Bank study (1980b) and represent economic rates of return on investments, assuming different economic costs of raw material at the distillery gate and different ex-refinery costs of regular petrol (i.e. before taxes and distribution costs). In calculating economic revenues, the ex-distillery price of ethanol is assumed to be equal to the ex-refinery cost of petrol. Other

critical assumptions concerning capital costs, gestation period, plant life and oil-price escalation rates are footnoted.[7] Overall, the World Bank report (1980b, pp. 134-38) suggests that -

> ... (i) ethanol economics are most sensitive to the economic price of gasoline; (ii) agricultural feedstock cost is a major determinant of the economic viability of ethanol production; (iii) plant operationg costs, excluding agricultural feedstock costs, are relatively less critical for sugar-cane and molasses-based plants; (iv) for distilleries based on cassava and corn, which have to rely on external energy sources, production costs are substantially higher and fuel accounts for about 70 per cent of variable production costs excluding feedstock and (v) while capital costs are less critical in determining ethanol economics than the gasoline [petrol] price, cost of agricultural feedstock and fuel source, they still remain a significant factor.
>
> The economic viability of alcohol [ethanol] production is of course also sensitive to the economic (or opportunity) cost of biomass raw materials. The two main cases to analyse, therefore, are (i) where the agricultural feedstock is internationally traded and is diverted to ethanol production and (ii) where new crops can be grown for energy production.
>
> Sizeable expenses on the agricultural side are incurred during the distilleries' construction period - land preparation, purchase of agricultural equipment, planting and fertilising of the crops. These investment costs should be considered along with annual production costs to calculate the economic cost of supplying the agricultural feedstock to the distilleries. The total alcohol production system - agricultural and industrial - would then be analysed on a discounted cash-flow basis.

The Bank's data on capital costs are, except for maize, based on Brazil's conditions. This requires some analysis. First, these figures (which refer to autonomous distilleries) may be on the low side. An autonomous distillery of 120,000 LPD in "middle-cost" countries (which are assumed to have capital costs 25 per cent higher than in Brazil) is quoted by the Bank at $9.5 million in late 1979 prices (footnote 7). In Brazil, it was costing $10.1 million at prices and official exchange rates of January 1981 (about $7 million at the shadow exchange rate - this rate is explained in Chapter 3), but excluding freight, storage facilities, land, access road or personnel training (Appendix B). Moreover, it included minor investments for stillage treatment, but none for reprocessing. The costs and benefits of stillage reprocessing are not yet well established, and it is uncertain how rates of return would be affected if reprocessing facilities were included. Second, the assumption of a 20-year plant life may overestimate rates of return, because of unexpected costs of corrosion and repairs, in particular. The 12-15 per cent contingency costs included in the Bank's analysis may be too low to cover these and other unexpected expenses throughout the 20-year period, as some recent developments in Brazil suggest.[8] Third, the Bank assumption that a sugar-cane distillery will operate 180 days per year may also overestimate returns in some cases, since many distilleries in Brazil operate for only 150 days.

Table 3: Sugar-cane autonomous distilleries of different scale, fuelled by bagasse (180-day operation): approximate economic rates of return (in percentages) on investments, assuming different values of petrol and raw material[1]

	Sugar-cane autonomous distilleries (LPD)																							
	20 000								120 000								240 000							
$ per tonne	Ex-refinery petrol value USc per litre																							
of	25		27		30		35		25		27		30		35		25		27		30		35	
cane	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC	LC	MC
$ 8	14	10	17	13	21	16	28	22	25	20	29	23	35	28	44	36	30	24	34	28	41	33	51	42
$10	11	7	13	10	18	13	24	19	19	15	23	18	29	24	39	32	23	18	28	23	34	28	45	37
$12	7	3	10	6	14	10	21	16	14	10	18	14	24	19	33	27	17	13	22	17	28	23	38	32
$14	2	-	6	2	10	7	18	13	8	5	12	9	19	15	28	23	11	7	15	12	22	18	33	27
$16	-	-	1	-	7	3	14	10	2	-	7	4	13	10	23	18	4	2	9	6	16	13	27	22

[1] Based on plant costs typical of Brazil in 1979-80, and other assumptions described in footnote 7.

LC - "Low-cost" countries - where plant costs match those in Brazil (see also footnote 7).

MC - "Middle-cost" countries - where plant costs are 25 per cent higher than in Brazil.

Source: Elaborated from World Bank (1980b) data.

Table 4: Autonomous distilleries: Approximate economic rates of return (in percentages) on investments, assuming different values of petrol and raw material in "middle-cost" countries - molasses, manioc and maize[1]

	Molasses (a)									Manioc (b)									Maize (c)							
	120 000 LPD middle cost									120 000 LPD middle cost									120 000 LPD middle cost							
	Fuelled by bagasse				Fuelled by fuel oil					Fuelled by fuel oil				Low-cost energy input[2]					Fuelled by fuel oil				Low-cost energy input[2]			
	Ex-refin. petrol value: USc/litre									Ex-refin. petrol value: USc/litre									Ex-refin. petrol value: USc/litre							
$/t	25	27	30	35	25	27	30	35	$/t	25	27	30	35	25	27	30	35	$/bu	25	27	30	35	25	27	30	35
$0	48	51	57	65	32	35	39	45	$10	12	15	19	24	26	29	34	41	$1.0	-	6	12	18	27	31	37	47
$20	34	38	43	52	18	21	25	32	$15	6	9	13	19	20	24	28	36	$1.5	-	2	7	14	16	20	26	36
$40	20	24	30	39	3	6	12	19	$20	-	2	7	13	14	18	23	31	$2.0	-	-	2	9	4	8	14	25
$60	7	10	17	27	-	-	-	5	$25	-	-	.5	7.5	8	12	17	25	$2.5	-	-	-	4	-	-	2.5	13
$80	-	-	3	13	-	-	-	-	$30	-	-	-	1	2	6	12	20	$3.0	-	-	-	-	-	-	-	3
$100		-	-	-	2	-	-	-	$35	-	-	-	-	-		6.5	15	$3.5	-	-	-	-	-	-	-	-

t - tonne.
bu - bushel.
1 Based on assumptions described in footnote 7.
2 Assuming the energy cost is reduced to one half of that of fuel oil.
(a) 180 days.
(b) 330 days.
(c) 330 days.

Source: Elaborated from World Bank (1980b) data.

The economic rates of return given in tables 3 and 4 may provide some parameters for further country-level analysis, but they have some limitations. For example, in the valuation of economic benefits, the assumption that "the ex-distillery price of ethanol would be equal to the ex-refinery cost of regular petrol" has limited relevance. Governments may wish to start production before ethanol becomes competitive with petrol. The instability of world oil supply and prices may justify such a strategy. In some cases, it may also be justified by scarcity of foreign exchange or by employment creation objectives. The above rates of return also indicate that sugar-cane is more attractive than any other raw material apart from molasses. However, this depends not only on the state of agricultural technology, but also on the weight given to different costs and benefits including employment and income distribution. A short digression is needed to illustrate this point.

Table 5: Ranking of "economic" and "social" performance of hypothetical agro-industrial strategies for ethanol production

Strat.	Feedstock	Level of technology[1]	Output in l/ha year	Organisation of feedstock production	Impact evaluation "Econ." rank	Impact evaluation "Social" rank
1	Cane	Current	4 000	80% I-LP + 20% S-ML	7	5
2	Cane	Improved	7 200	100% S-LP	2	6
3	Cane	Improved	6 600	40% I-LP + 60% S-ML	1	4
4	Manioc	Med.-improv.	3 330	50% S-SL + 50% S-SL	5	3
5	Manioc	High-improv.	4 680	60% S-SL + 40% S-ML	4	1
6	Cane/ manioc	Improved	-	80% I-LP + 20% S-SL	3	2
7	Sorghum	Improved	7 200[2]	100% I-LP	6	7
8	Wood	Current	2 500	100% I-LP	8	8

I - Industry's own raw material; S - External suppliers' raw material; LP - Large plantation; ML - Medium-size land units; SL - Small-size land units; [1] Refers to level of agricultural technology including yields; [2] One harvest and one ratoon per year.

Source: PLANALSUCAR et al. (1981).

A study by PLANALSUCAR et al. (1981), which was carried out to assist future policy-making in Brazil, examined eight hypothetical agro-industrial strategies from so-called "economic" and "social" viewpoints. A summary is given in table 5. The eight strategies varied in terms of feedstocks and levels of technology used, and the way in which the feedstocks were supplied. The comparative evaluations

were done by adding up points given to the relative performance of each agro-industrial strategy in terms of their (a) economic, (b) social, (c) energy and (d) environmental impacts. Respectively, these four impact areas included (a) costs of production, investments and demand for foreign currency; (b) employment and organisation of raw material production; (c) energy balance and (d) erosion, dependence on herbicides,fungicides and insecticides, as well as chemical residues. Each of the four impact areas was then weighted depending on the selected viewpoint. From the economic viewpoint, the economic impact was weighted by 40 per cent, the social impact by 25 per cent, the energy impact also by 25 per cent, and the environmental impact by 10 per cent. From the social viewpoint, these four impact areas were weighted by 20, 55, 10 and 15 per cent, respectively. According to the authors, the study reached the following conclusions. From the economic viewpoint, the highest ranking strategies were numbers 3, 2 and 6 which, in decreasing order, also had the lowest cost per litre. The only significant difference between strategies 3 and 2 was the larger number of jobs created and the more equitable production of raw material. The strategy using sweet sorghum (which assumed current techniques but slightly higher crop yields, and all of the raw material produced from the distillery's own lands) was reported to have a good energy balance and a good economic performance, but a comparatively low social impact. From the social viewpoint (with the economic impact weighted by 20 per cent and the social one by 55 per cent), the three highest ranking strategies were numbers 5, 6, and 4, but with little difference in points; all are manioc based, the cane/manioc consortium ranking second. The best strategy from the economic viewpoint ranked fourth in this assessment, and sweet sorghum and wood scored last, as in the economic assessment.

The PLANALSUCAR study is mentioned simply to show that comparisons of the economic performance of alternative raw materials should take into account not only the measurable costs and benefits but also more subjective factors such as the amount of employment created, the share of small farmers in total raw material supply and potential improvements in crop yields which depend on technology. Notwithstanding the need for site-specific analysis, some very general conclusions may be reached on the comparative advantages of alternative raw materials for ethanol production.

At current levels of technology, crop yields and rates of productivity shown in table 2, sugar-cane alternatives, including consortia with molasses, and possibly with sweet sorghum or manioc, are generally the most attractive in countries which have a sugar industry and related infrastructure (e.g., regulation of supply and prices, credit arrangements, etc.).

The manioc alternatives may also be attractive in some countries with a well-developed infrastructure of production, especially if the objectives of employment creation and income redistribution are regarded as important. For reasons discussed in section 1, however, manioc does not seem to be, in general, a good choice for large-scale production. Increased crop yields and fuel self-sufficiency could change this, but both of these factors depend on R and D and on the scale of production.

Sweet sorghum may become more relevant in a number of countries, but there are still uncertainties about the costs of ethanol production. Lipinsky (1977), for example, made estimates of $0.24-0.32 per litre in projected 1980 prices, assuming a productivity of 5,100-6,200 litres per ha per year in the United States. In mid-1980, the average production cost per litre of sugar-cane ethanol in Brazil was about $0.21 (Chapter 3). This suggests that the above unit cost of sweet sorghum ethanol may have been underestimated, given the technological considerations discussed in section 1. Unpublished research by EMBRAPA in Brazil in 1981 found that sweet-sorghum ethanol would have a higher cost per litre than any alternative based on sugar cane or manioc, due to its high agricultural costs. Based on these findings, the study by PLANALSUCAR et al. (1981) estimated its total per litre cost and agricultural cost at 10 per cent and 68 per cent, respectively, above those of sugar-cane ethanol; this assumed a productivity of 4,000 litres per ha per year for sugar-cane (a slight improvement over the current average shown in table 2), and 7,200 litres per ha per year for sweet sorghum (a considerable improvement from about 5,000) and assuming other economic parameters based on 1980 conditions. One may conclude from this that sweet sorghum does not compare well when used on its own. However, it may be economically attractive if used with sugar-cane. In this case, the higher agricultural cost may be compensated for by the increased revenues derived from the extended period of production.

Due to the disadvantages of the industrial processing technologies available for wood-ethanol production, its economic performance compares unfavourably with that of ethanol from sugar-cane, manioc, or even sweet sorghum. The agricultural cost per litre of wood ethanol is roughly 40 per cent of that of sugar-cane ethanol, but its industrial and total per litre costs are 180 per cent and 50 per cent higher than those of sugar-cane ethanol, respectively (PLANALSUCAR et al., 1981).

Apart from the above raw materials, no other alternatives can be given further analysis in this study. There is lack of data on some feedstocks, such as broken rice, used in Thailand, and coconut sap (lanbanog) used in the Philippines. Furthermore, other ethanol crops, such as maize and other cereals, sugar beets, potatoes, and some agricultural residues have limited economic attractiveness for large-scale ethanol production at recent prices and technology. Ethanol from babassu mesocarp may nevertheless have some future prospects if all the elements of the coconut are industrialised.

3. Further notes on the scale effect

The scale and the type of distilleries have important implications for the economic performance of ethanol production based on different raw materials. The optimal scale for one crop may not be the same for another. Hence, comparisons based on the same scale of production, as in table 4, have drawbacks.

On the basis of the data shown in table 3, the World Bank (1980b, p. 41) presents the following considerations concerning scale:

> While increasing the distillery size from 120,000 litres/day to 240,000 litres/day increases the return between 3-5 points, its reduction to 20,000 litres/day involves substantial cost penalties and reduces the return by as much as 7-11 points. Therefore, ethanol plants below about 120,000 litres/day should be considered only if the economic value of their output is also substantially higher due to locational reasons.

Thus, an increase in scale increases the return, all other factors being equal. This is very important for sugar-cane, because the agricultural and industrial technology for alternative scales are well established. For manioc however, this conclusion has limited relevance, because an increase in scale tends to increase risks and costs, associated with the limited commercial experience of this crop in most producing countries. A comparison between sugar-cane and manioc ethanol on the basis of autonomous 120,000 LPD distilleries (tables 3 and 4) puts manioc at a strong disadvantage, because it is much less suitable for such large-scale production. An autonomous manioc distillery of this scale would normally depend on wood or on a high-cost fuel such as fuel oil, whereas a micro- or mini-distillery could be more easily self-sufficient in fuel. At these scales, dried rama or even biogas from stillage, would be much more feasible options.[9] Furthermore, a 330-day operation would probably require that the distillery be annexed to a starch factory, and this also has implications for scale. The generally small capacity of these factories in Brazil and elsewhere implies that the optimal scale of the distillery will be relatively small. However, its economic performance would be better than that of a sugar-cane distillery of the same capacity, provided the rama is used as the source of fuel, and the price of raw material is not more than 50 per cent higher than that of sugar-cane.[10]

The optimal scale depends not only on the type of raw material used, however. Savings in distribution costs may be an important consideration in some cases (this is discussed in more detail in Chapter 3). Furthermore, a discounted cash-flow analysis of alternative investments in distilleries is insufficient for public-sector decisions, because there are advantages and disadvantages of different scales of distilleries which cannot be objectively measured in such type of analysis. table 6 summarises the comparative economic characteristics of distilleries in the three main groups of scale (their technological features were discussed in Chapter 1). The greater suitability of small-scale distilleries for making productive use of residues and liquid waste and for increasing rural jobs and incomes means that these investments should not be compared to those of large-scale distilleries using standard methods of financial and economic analysis.

Sugar-cane micro-distilleries

Given the level of technology, oil prices, capital costs and other financial considerations typical of Brazil in 1981, sugar-cane micro-distilleries could be profitable to a firm producing ethanol for its own consumption, but not for sale on the regulated market (i.e., where ethanol is purchased from the distillery at a standard price before final sale to consumers).[11] In Brazil, there are some micro-distilleries which supply public car fleets running on hydrous ethanol, but their diffusion has been constrained by three factors. First, they have been allowed to produce hydrous ethanol only, since the production of anhydrous would imply the blending of this fuel with petrol at the distillery site. Second, only large fleets can justify even the smallest distillery available (800 LPD). Third, the attractiveness of these distilleries for large farms or co-operatives depends either on technological adaptations to permit the use of hydrous ethanol in light farm vehicles and irrigation motors (these would normally consume diesel oil) or on the purchase of new equipment.

More favourable marketing conditions for these distilleries may be justified by their potential benefits to rural communities. One possibility (for cases where such benefits can be realised) would be to allow them to produce both anhydrous and hydrous ethanol, for which the Government would pay a higher price than that stipulated for agro-industrial distilleries. Thus, the location of each distillery would preferably be linked to the creation of a local market for the by-products under stipulated price controls. It might also be possible to allow the direct sale of hydrous-ethanol surpluses to retailers under appropriate forms of taxation, which would guarantee producers a minimum rate of return. The following example throws some light on these issues.

EMPRAPA's 800 LPD distillery

EMBRAPA examined the viability of the 800 LPD autonomous distilleries. These are equipped with one or two sets of crushers; use stainless steel, and include a number of other technical innovations in the fermentation and distillation stages (further technical details were given in table 1). At August 1980 prices and official exchange rates, and based on a sugar-cane cost of $8.4 per tonne at the site, a one-crusher unit with an average productivity of 45-46 litres per tonne and an investment of $73,000 had a cost of $0.31 per litre for hydrous ethanol ($0.25 at a shadow exchange rate, reflecting a 19.5 per cent overvaluation of the local currency - see Chapter 3). If the ethanol were sold at the consumer price of $0.45 ($0.36 at the shadow exchange rate), the pay-back period would be 3.7 years and the rate of return 27 per cent. The two-crusher model yielding 54 litres per tonne, with an investment of $82,000, had a cost of $0.30 per litre ($0.24 at the shadow exchange rate); a pay-back period of 2.7 years, and a rate of return of 37 per cent. According to EMBRAPA's technicians, these distilleries require about 60 ha of sugar-cane. They can be installed on medium-size farms that

have a minimum requirement of two cubic metres of water per day, and electricity to run 20-25 hp of installed power. This electricity can be produced from stillage and/or bagasse (although this has so far not been done). An advantage of small distilleries is that feedstock costs can be considerably lower than those of large distilleries. In 1981, EMBRAPA's technicians claimed that one tonne of sugar-cane in a medium-sized farm with crop integration would cost about 24 per cent less than in a large farm under monoculture.

Manioc mini-distilleries

In general, mini-distilleries, ranging from 10,000 to 20,000 LPD, are the least attractive from both social and private viewpoints. However, molasses and manioc distilleries of this scale may have special advantages, particularly if they are annexed to sugar or starch mills. In comparison with the previous case, 10,000 LPD manioc distilleries have a higher investment cost per litre, higher raw material cost and risks, and the further disadvantage (in Brazil's case) of producing for the regulated market only. However, these disadvantages may be compensated for by the longer period of production, and by their potentially greater benefits over larger distilleries based on other feedstocks. These mini-distilleries may also assist rural development, if appropriate policies are implemented to regulate supply and prices of manioc, to provide technical assistance and credit to traditional producers and guarantee them the right to supply a large amount of the raw materials. Furthermore, their scale of production is still sufficiently small to permit productive use and reprocessing of stillage, part of which could be used as the main source of fuel supply, rather than wood or dried rama. Special incentives may be also justified in situations where their social benefits are high, but their financial performance is comparatively unfavourable.

CTI's project

The Industrial Technology Company (CTI), a semi-autonomous branch of Brazil's INT, examined the feasibility of hydrous-ethanol production from autonomous mini-distilleries of 10,000 LPD. The project was based on the following optimistic assumptions of crop yields and technology: 25 tonnes of manioc per ha; 161 litres per tonne, 330-day operation, and the utilisation of the rama at the rate of 45 tonnes per day, or wood at the lower rate of approximately 20 tonnes per day. With these rates and a manioc cost of $24 per tonne (May 1980 prices and official exchange rate), this alternative, which required an investment of approximately $920,000 excluding land costs, was said to cost $0.25 per litre ($0.23 at the shadow exchange rate), and have a rate of return of 21.9 per cent.[12] These figures are somewhat questionable, considering that (a) Brazil's yields were 13 tonnes per ha per year in 1977 (IBGE, 1977), and (b) the operation of plants based on manioc roots may face difficulties in obtaining raw material all year-round.

Table 6: Summary of characteristics of different scale of distilleries

Type of distillery	Characteristics
Micro-distilleries	Decentralised production. Possible savings in distribution costs, depending on the type of ethanol. Relatively low investment. Higher costs per litre. Highest industrial demand for labour per litre. Best possible use of residues and stillage. Greater possibility of producing for own consumption. Economic viability depends partly on market regulation. Greater possibility for integrating food and energy farming. Best social impact in isolated rural areas. Most dependent on technological development and diffusion.
Mini-distilleries	Mixed advantages and disadvantages of the other alternatives. The final balance leans to the negative side, especially in situations of close competitiveness of price between petrol and ethanol. More suitable than micro-distilleries for molasses and manioc.
Agro-industrial and industrial distilleries	High investment. Highest efficiency in the present state of technology due to and economic reasons only. Lowest costs per litre. Lowest demand for labour per litre. Greater economies of scale up to a certain radius of agricultural production. Greater pressures of raw material supply and higher costs of transport. Most profitable for commercial purposes under standard market regulation. Greater pressures to concentrate land and to rely on monoculture. Most attractive (at least financially) for concentrated markets, provided their negative effects are avoided by appropriate policy, especially as regards the organisation of raw-material supply and labour management. Most difficult recycling of residues and stillage because of volume.

As stated at the beginning of this chapter, the objective has been to discuss basic guidelines to assist country-specific

analysis. Some of the above assumptions and data may not be relevant for certain countries due to variations in local costs, crop yields, and production objectives.

Notes

[1] In the mid-1970s, 87 per cent of the manioc producers in Brazil cultivated land units of less than 10 ha (CNPq 1978, p. 108). Apparently, this feature is also evident in most other producing countries (see FAO, 1980a).

[2] According to the World Bank (1980b, p. 17) the estimated "total world production of cane and beet molasses was 33.5 million tonnes" in 1978-79, "of which, about 22 million were consumed in the countries of origin, and another 6.6 million entered world trade mainly for use as animal feed. The remaining 5 million (15 per cent of the total) was most probably disposed of as valueless waste."

[3] These sugars are sucrose, glucose and fructose. The higher the productivity in sugar per tonne, the lower the fermentable-sugar value of molasses, and the lower the indirect yield of ethanol per tonne of cane.

[4] Ten tonnes of sugar-cane in the former option would yield one tonne of sugar plus about 126 litres of ethanol from molasses; whereas in the latter option the same ten tonnes would yield about 700 litres of ethanol. The above conclusion was based on f.o.b. prices of $450-500 per tonne of sugar and $60 per bbl of ethanol, which prevailed in August 1981.

[5] Brown (1980) states that ethanol from maize contains 8 per cent less energy than that invested in it. If the maize is processed in an oil-fired distillery, there is little or no gain in liquid fuel. If fired by coal or solar energy, then at least 2-3 United States gallons of fuel would be produced for every gallon consumed.

[6] According to Rosenthal (1977, p. 35), "an efficient strong woman may produce up to 15 kg per day".

[7] The World Bank estimates assumed that: (a) anhydrous ethanol (for gasohol) would substitute regular petrol on a 1:1 basis (p. 37); (b) "ethanol plant would take two years to complete and operate at 60 per cent of daily rate capacity in the first year after start up, 90 per cent in the second year, and 100 per cent thereafter" (p. 38); (c) sugar-cane and molasses-based plants would operate 180 days/year, and manioc 330 days (p. 38); (d) the "ex-distillery price of ethanol would be equal to the ex-refinery cost of regular gasoline in countries which have large domestic refineries and where average distribution distance (and hence cost) for ethanol and gasoline is about the same" (p. 38); (e) the average plant life would be 20 years (p. 38); (f) "the oil prices have been assumed to increase at 3.5 per

cent per year in real terms for the foreseeable future" (p. 38); and (g) the capital costs ("excluding taxes, working capital and interest during construction") and including 12-15 per cent contingency costs, were as follows (late 1979 prices):

Raw material	Sugar-cane			Molasses	Cassava/maize
	($ million)				
(Thousand LPD)	20	120	240	120	120
Low-cost countries	2	7.6	12.5	6.1	9.1
Middle-cost countries	-	9.5	-	7.6	11.4
High-cost countries	-	14.3	-	11.4	17.2

Low-cost countries would be those "which could match plant costs in Brazil", whereas middle- and high-cost countries would have plant costs 25 and 50 per cent higher, respectively (p. 32).

8 Corrosion has been one of the major problems of distillery equipment in Brazil. According to STI technicians, the cost of corrosion during the 1978-79 season was around 110 million dollars (these data were concluded from a survey of 32 distilleries when there were 172 units in operation for a production of 2,000 million litres).

9 This consideration is related to the volume of fuel required and the capacity to produce it economically. A 10,000 LPD distillery will require approximately 45 tonnes of dried rama or 20 tonnes of wood. The requirements of a 120,000 LPD unit are not known by the author, but they are significantly higher.

10 This differential in raw material price is inferred from the Bank's data in tables 3 and 4, by comparing the raw material costs at which point the sugar-cane distillery and the manioc distillery (using the low-cost energy input) would have more or less the same rate of return at a given value of petrol (based on aforementioned assumptions).

11 In Brazil, micro-distilleries have not qualified for investment subsidies, but PNA's regulations allow them to produce for their own consumption.

12 At $28 per tonne the rate of return would drop to 14.8 per cent.

CHAPTER 3

PNA's POLICIES; PRODUCTION TRENDS AND THEIR SOCIO-ECONOMIC IMPLICATIONS

This chapter begins with an overview of PNA's institutional aspects (section 1) and of its major developments up to the end of 1983 (section 2). This is followed by a summary of PNA's socio-economic impacts in its first five-year period, including an analysis of PNA's policies and production trends (section 3). Finally, the costs of ethanol are analysed (section 4).

1. Institutional aspects

Objectives and institutional roles

PNA was created in November 1975. It was initially supervised by the National Alcohol Commission, and had the following objectives:[1]

1. Savings of foreign exchange as a result of oil-import substitution.
2. Reduction of disparities of income among regions and individuals.
3. Growth of national income through the deployment of underutilised resources, partiuclarly land and labour.
4. Growth of the capital goods sector through the rising demand for equipment witH a high level of national participation.

The Decree also defined the responsibilities of the original Commission, but its decision-making process was inefficient. This, coupled with the 1979 rise in oil prices, led to the redefinition of both production targets (section 2) and institutional roles. Saint (1980, p. 8) summarised the early events:

> During the first years of the PNA, there was little information or back-up research to guide decision-making. In consequence, decisions were made on an ad hoc basis. For example, during 1978, alcohol distillery projects were approved which possessed estimated internal rates of return varying from 1 per cent to 78 per cent. This discouraging scenario led to the first major effort at assessing PNA, financed by the National Research Council, to decry "... a total lack of policy-making capacity" within the PNA. These shortcomings led Brazilian President Joao Figueiredo to issue an executive order in July 1979, aimed at strengthening the institutional base of PNA. This proclamation dissolved the National Alcohol Commission and replaced it with the National Alcohol Council. In addition, an Executive Committee was created to provide

technical support to the Council, to serve as a decision-making body for alcohol distillery projects and encourage alcohol-related research.

Under the control of the National Monetary Council (CMN), the 13-member National Alcohol Council (CNAL) was given authority for (a) defining PNA's guide-lines and criteria for project appraisal; (b) establishing incentives and financing conditions, annual production quotas and prices and (c) authorising exports of molasses and ethanol. This body of high-level executives has very little day-to-day involvement in decision-making concerning resource allocation. Its five-member Executive Committee (CENAL) is responsible for this task with the aid of subordinate bodies. Under CENAL's administration, PNA became more attached to the Ministry of Industry and Commerce (MIC) and associated agencies (e.g., the Secretariat of Industrial Technology (STI), the Institute of Sugar and Alcohol (IAA) and its subordinate research entity, PLANALSUCAR, as well as the National Institute of Technology (INT) and its associate Industrial Technology Foundation (FTI)).[2]

This new institutional arrangement has allowed greater co-ordination and flexibility in decision-making. However, it has reduced some of the earlier political representation that may have been necessary to look after PNA's different objectives and interests other than those of the sugar-cane lobby, which is very strong in the MIC and its main agencies (IAA and PLANALSUCAR).

CENAL's major role is to approve or reject project proposals after a financial analysis is carried out by an authorised bank, and a technical appraisal is done by the IAA for projects based on sugar-cane, or STI for manioc projects.[3] Though more efficient, this process became more dependent on appraisal by lower-level technocrats using pre-established criteria. Under the previous arrangement, the technical and financial characteristics of the project proposals were often inconsistent (CNPq, 1978), whereas the new process has led to an obvious uniformity in the proposals, which do not always coincide with the actual operations once the projects are implemented.[4] The investors know which consultants should prepare the proposals and the consultants know what must be written in them to get them approved.

Policy guide-lines

The attainment of PNA's objectives and production targets - 10,700 and 14,000 million litres in 1985-86 and 1987-88 - has been based on the following guide-lines:[5]

- PNA will be undertaken by private business;
- PNA guarantees to buy all ethanol produced under defined specifications and authorised volumes;
- the pricing policy for ethanol will guarantee prices which will reward producers;
- the development of national technology for the production of ethanol and by-products will be stimulated;

the possibility of installing mini-distilleries located in strategic sites will be considered, with the aim of utilising the participation of small agricultural and industrial producers according to regional characteristics;
- the norms regarding the treatment and/or the utilisation of stillage will be rigorously complied with;
- special training programmes for medium-level and upper-level technicians will be established whenever necessary for the development of PNA;
- the production of material inputs will be orientated to meet supply and regional needs.

These general guide-lines were supplemented by a number of criteria to guide the financial and technical appraisal of projects by the lower technocracy. According to CENAL, "projects which are to receive priority must be capable of attaining the following":[6]

- lowest investment to production-capacity ratio;
- best technological and economic use of raw materials, equipment and other materials, which will lead to the optimisation of the agricultural and industrial processes;
- lowest cost of infrastructure adjustments necessary for the production and utilisation of ethanol;
- industrial deconcentration;
- reliability of production.

Other technical criteria were also defined by CENAL, though in a more textual and comprehensive style. For example, distilleries would be required to have a minimum storage capacity, equal to one-twelfth of their annual production multiplied by the number of off-season months. Projects integrating food crops or other ethanol raw materials with sugar-cane were also to be stimulated in order to increase the annual period of ethanol production and reduce the migration flows of agricultural labour.[7] In addition, the production of raw materials for ethanol was not to interfere with the existing cropping pattern; it should rely on new areas and promote higher agricultural productivity.

Price policy

Under CNAL's guide-lines, the IAA establishes the prices of sugar-cane, different types of sugar, molasses and ethanol,[8] and specifies their use. All the ethanol and sugar produced in the country is purchased by the Government at prices above cost, which are readjusted every six months. The prices of ethanol paid by the Government to the producers, varying slightly according to its type (anhydrous and hydrous) and use (fuel and non-fuel), are established at a parity with those of sugar (38 litres to 60 kilos, in 1981).

The consumer price of hydrous ethanol has been stipulated at 60-65 per cent that of petrol or gasohol. The distribution of these fuels is controlled by the Government, and their prices are the same throughout the country.[9] The consumers do not have a choice between petrol or gasohol, since these are not sold separately. This price mechanism gives the Government flexibility to increase the consumer prices of gasohol and hydrous ethanol; this allows the

distilleries, for example, to pay higher prices for raw material. This policy has been effective and responsible for the fast growth of ethanol production from sugar-cane and molasses. The price fixing of manioc, for example, cannot be nearly as effective, because of extreme variations in crop yields in different producing areas.

Policy of production quotas

It is also the IAA's responsibility (under CENAL's control) to determine the quotas for ethanol and/or sugar production in each distillery and/or sugar mill. This enables adjustment between the supply of the two products for domestic and foreign demands. Sugar output is affected by international quotas established by the ISA. The production of ethanol may exceed the level stipulated, provided the IAA authorises it, but sugar producers are not allowed to exceed their quotas in any circumstances unless international prices increase beyond the ISA provisions, as occurred in 1980, for example.

Financing policy

Public funds for PNA have consisted of loans for investments (15 years with 3 years of grace) at negative real interest rates. Until January 1981, these loans covered up to 80 per cent of industrial investments in sugar-cane distilleries and up to 90 per cent for those based on other raw materials. Nominal interest rates on these loans varied from 2 per cent to 6 per cent (depending on the type of distillery, raw material and macro-region), which were increased by 40 per cent of the general price index as a partial adjustment for inflation.[10] Loans for agricultural investments associated with ethanol projects covered 60-100 per cent of the total, at nominal interest rates between 15 and 29 per cent and without any adjustment for inflation, depending on farm size, measured in terms of market value of output, and on macro-region - Centre/South (C/S) and North/North-East (N/NE).

With inflation rates rising from 80 per cent in 1979 to about 160 per cent in 1983 and some 200 per cent in 1984, interest rates were indeed very negative. After January 1981, loans covered up to 70 and 80 per cent of industrial investments (depending on the type of distillery) and up to 90 per cent for distilleries owned by co-operatives. Nominal interest rates on these loans were established at 45-55 per cent (depending on macro-region) or, for projects approved in 1982 and after, at 5 per cent nominal interest increased by 55-70 per cent of the general price index. For agricultural investments, loans continued to cover 60-100 per cent of the total at nominal interest rates of 35-45 per cent.[11] These interest rates are nevertheless very negative at recent rates of inflation.

2. Summary of events

PNA has been through three conceptually different periods. The first five-year period was marked by general optimism and smooth implementation until late 1980. Between then and the end of 1981, PNA underwent an institutional crisis, followed by a period of adjustment from early 1982 onwards. Some of these events are important.

As a result of the decrease in world sugar prices after 1975, the sugar producers responded quickly to PNA's financial incentives. By 1978, ethanol production had increased faster than initially expected - a 76 per cent growth from 1976 to 1977 and 86 per cent from 1977 to 1978 (see Appendix A for details on the 1976-83 period). This early success, coupled with a positive image of PNA, was fundamental in convincing the local car manufacturers to increase their production of hydrous-ethanol cars.

The goals established in 1979 for the 1985-86 harvest year were 10,700 million litres of ethanol;[12] 900,000 new hydrous-ethanol cars, and an additional 270,000 gasohol cars to be converted to hydrous ethanol. In the 1980 calendar year,[13] production of anhydrous and hydrous ethanol reached 3,500 million litres (22.6 m.bbl; about 6 per cent of the total consumption of oil). About 253,000 new ethanol cars were produced; 30,600 gasohol cars were converted to hydrous ethanol,[14] and some light vans, lorries, and tractors also fuelled by hydrous ethanol were introduced on the market. However, the target figures for the production of these cars was increased, as a result of the outbreak of the war between Iran and Iraq and the oil-price shock that followed, coupled with the interest of the local car manufacturers in improving their markets[15] and the low R and D costs of hydrous-ethanol cars.[16] In mid-1980, a further agreement was reached between the car industry and the Government to nearly double the production of hydrous-ethanol cars in 1981, and to increase the share of hydrous ethanol (although total supply was not changed).[17] The following news article summarised the events:[18]

> The car industry will probably surpass the production target of hydrous-ethanol cars initially agreed with the Government. There will be an increase from 300,000 to over 500,000, which is more than half of all car production, and more than double the number of existing hydrous-ethanol cars. Ethanol producers believe supply should reach 5,000 million litres by 1981-82, "... and the car industry must be prepared to produce the vehicles because we have the fuel", stated Mr. Gianetti of DEDINI which not only manufactures distillery equipment but also owns some ethanol plants. The President of ANFAVEA, noted that the car industry plans to produce 800,000 vehicles in 1981, and that the majority will be hydrous-ethanol cars. Today, almost 60 per cent of Volkswagen's total production consume hydrous ethanol, and the company plans to increase this to 80 per cent by February 1981. Fiat's and Ford's production is around 60 per cent, and

General Motors has begun to produce its "Chevette" line including the small ethanol lorry, the Marajó. Chrysler is the only company that has not, as yet, any hydrous-ethanol vehicles.

As a result of demand projections for hydrous-ethanol cars, the production of hydrous ethanol increased from 3.4 m.bbl. in 1979 to 7.1 m.bbl. in 1980. However, its consumption as car fuel increased from 2.0 to 2.1 m.bbl only. The production of anhydrous ethanol increased slightly from 1979 to 1980, but gasohol consumption dropped by about 12 per cent.

The bottleneck in the sales of hydrous ethanol, in particular, was caused not only by a consumer reaction to higher fuel prices (following the 1979-80 oil shock) but also by the limited sales of hydrous-ethanol cars. With the introduction of the new 1981 model, the number of these cars on the road was reported to have increased by about 80 thousand from October to November 1980 after low sales in the first nine months,[19] but decreased sharply thereafter. Sales in 1981 were only about 55 per cent of those in 1980 (table 7).[20] The production of hydrous ethanol continued to increase steadily in 1981, but only 63 per cent of it was consumed.

The steadfast introduction of hydrous-ethanol cars in the market, which was a result of planning deficiencies and of political lobbying, was both risky and premature, due to the following considerations. First, the percentage of anhydrous ethanol in gasohol blends may be decreased if the costs of oil imports fall below the net export revenues derived from the sale of oil-equivalent amounts of ethanol (or of alternative amounts of sugar, molasses or starch if these can be exported). Hydrous-ethanol cars reduce this flexibility since they cannot run on petrol or gasohol. Although it is unlikely that losses in export revenues were caused by this problem until 1983, they could have happened, or might happen in the future, depending on the world market for ethanol. Second, if fewer hydrous-ethanol cars had been produced (and the number of gasohol cars had been higher), the total demand for car fuel could have been met by the minimal amount of petrol that the refineries could produce, plus a much lower amount of ethanol (Chapter 4). Third, any problems in the technical performance of the new ethanol cars (resulting from their embryonic development) would deter buyers. Indeed, problems of corrosion in the fuel tanks of many vehicles produced in 1977-79 had this effect.

The above events led to a polarisation of views about PNA's effectiveness. Furthermore, the rise in world sugar prices in 1980 and the temporary suspension of the sugar export quota provoked some uncertainty about future supplies of sugar-cane for ethanol. In addition, sporadic statements in the press by well-known policy-makers in late 1980 and early 1981, concerning the constraints on the growth of raw material and ethanol supply, were often misinterpreted by the public as an indication of future shortages of hydrous ethanol. These various problems left a negative image of PNA, if only temporarily. The following excerpts from a new article by Rocha Filho[21] reflect the institutional turmoil within PNA's decision-making circles:

Table 7: Economic indicators - Brazil (1974-83)

Year	Real GNP growth (%)	Gross foreign debt ($mill.)	Cost of debt ($mill.)	Balance of payments ($mill.)	Oil imports ($mill.)	Oil imports as % of exports	General price index (% incr.)	Minimum wage (% incr.)	Currency value (Cr$/$)	Total car sales (thousands)	Sales of hydrous ethanol cars (thousands)	Share of hydrous ethanol cars (%)
1974	9.8	17 166	2 595	-4 690	2 969	35.3	34.5	33.1	7.4	854.2		
1975	5.7	21 171	3 666	-3 540	3 100	32.7	29.4	28.3	9.0	931.5		
1976	9.0	25 985	4 814	-2 255	3 842	35.0	46.3	44.1	12.3	974.6		
1977	4.7	32 037	6 226	+97	4 080	31.5	38.8	44.1	16.5	908.6		
1978	6.0	43 511	8 122	-1 024	4 483	33.0	40.8	41.0	20.8	1 067.3		
1979	6.4	49 904	10 713	-2 840	6 773	42.0	77.2	88.0	42.3[1]	1 121.2		
1980	8.0	53 847	13 013	-2 829	9 800	47.2	107.2	97.4	50.6[2]	1 010.6	240.7	24
1981	4.5	61 410	15 000	-500	10 600	45.5	110.4	95.0	82.0[3]	635.1	137.2	22
1982	0	69 650		+780	9 570	47.4	100.0		179.1[4]	691.3	235.1	34
1983	-3.9	73 600		+540			160.0		576.2[5]	730.5	585.2	80

1 December
2 May
3 May
4 July
5 November

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> The Government, in conjunction with ANFAVEA (the National Association of Vehicle Manufacturers), COPERSUCAR and other business organisations, is preparing to relaunch PROALCOOL. The object is to repair PROALCOOL's image and regain the approval of public opinion, which is on the decline due to a misunderstanding of information about the programme. Public slogans such as 'Alcohol is our petroleum', and 'Alcohol is Brazilian fuel', have already been prepared. According to businessmen, the atmosphere of distrust, in which the new programme will be launched, has been caused by the diverging reports from the Government authorities about PROALCOOL. They also mentioned that various ministers have declared different goals for PROALCOOL, and one even announced recently that the goal of 10,700 million litres will not be met by 1985.
>
> The President of General Motors of Brazil ... stressed that '... everything will be done to re-establish confidence in PROALCOOL, a good programme for the country'. He thought that trying to create a market for alcohol cars through legislation had been an error. 'One should move forward slowly. I believe that 25,000 to 30,000 cars produced annually, would have been sufficient at the beginning. The growth would have been more reliable'.
>
> Today, factory managers are convinced that at the beginning of PNA, the production of ethanol cars occurred too quickly. Volkswagen's own President, ... admitted as much last week.
>
> To the Director of the Votorantine Group, ... now is the time to relaunch PNA ... 'The moment is crucial, since the programme means domestically produced energy without spending foreign currency'. COPERSUCAR through its President, '... is entirely in favour of relaunching PNA and will work towards that goal.'

Indeed, the worst propaganda for PNA was based on some well-intentioned but contradictory statements by government executives. While most of CENAL's members have faithfully backed PNA, the ex-President of the Central Bank, and the ex-Minister of Planning had at times been more objective. According to the former:[22]

> In thesis, PROALCOOL pretends to finance ... with interest rates that are extremely negative about 80 and 90 per cent ... of the total investment. ... This way of aiding priority sectors is not always the most adequate one. What is worse is the fact that when operating with highly subsidised resources, the criteria for selecting entrepreneurs end up being exclusively bureaucratic. In such a way, it is impossible to know, a priori, whether the entrepreneurs that are being attracted to PROALCOOL are, in fact, the most competent, thus representing a healthy option for renewing a highly traditional sector, or whether they simply represent privileges as a result of greater political influence.

In similar style, the ex-Minister is not known for criticising PNA in public, but he has not always been able to hide some of its problems either:[23]

> If it is true that PROALCOOL is a programme that gives us employment in agriculture and in industry, it is not less true that it carries a clear inflationary effect. ... The real truth is that the substitution of ethanol for petrol is, today, an instrument for the maintenance of the car industry - an expansion without which all levels of development in this country would suffer.

With the introduction of less attractive financial conditions in January 1981, PNA became the focus of frequent criticisms in Brazil's media and of heated debate between its critics and defenders,[24] which did not help to improve its public image.

By early 1982, however, this institutional crisis had begun to disappear, as a result of government's better public relations, together with improvements in the technical performance of hydrous-ethanol cars. The downtrend in world sugar prices after early 1981, and a revision of both production targets and consumer incentives also helped. In 1981, road taxes for ethanol cars were reduced and, unlike gasohol, hydrous ethanol was sold on Sundays. In March 1982, the price of hydrous ethanol was defined at 59 per cent of the price of gasohol (the lowest price ratio ever established). Partly as a result of these measures, conversions of cars from gasohol to ethanol were about four times higher in the last quarter of 1982 than in the same period in 1981. Sales of hydrous-ethanol cars also began to increase in 1982, although at a lower rate than expected. Hydrous-ethanol production had increased by 15 per cent over 1981, but consumption remained at less than 70 per cent of production. At the end of 1982, the Government announced that the 1985 target of 10,000 million litres of ethanol would be deferred until 1987. Meanwhile, further incentives were given to consumers. By early 1983, as a result of lower taxes, hydrous-ethanol cars for private use became 6-7 per cent cheaper than gasohol cars and about 40 per cent cheaper for use as taxis. Consequently, sales of hydrous-ethanol cars rose sharply, reaching an 80 per cent share of total car sales in 1983 (table 7).[25] Moreover, the consumption of fuel-hydrous ethanol reached nearly 80 per cent of production, which had increased by 51.6 per cent over 1982's output, in accordance with the original target for 1985. Gasohol consumption may also have slightly increased from 1982 to 1983, but less so than the aggregate production of anhydrous ethanol and petrol.

The sequence of events since 1982 has restored consumers' confidence in PNA. Ethanol consumers have been happy, because of the price advantages of both ethanol and ethanol cars, and because these cars are performing well. The continuing growth of production and consumption of fuel ethanol may suggest that PNA is being successfully implemented. But this is hardly a good indicator of PNA's social effectiveness. It comes as no surprise that if price

and fiscal incentives are given to ethanol and ethanol cars, consumption will go up. The real questions are whether this increased consumption is needed in the light of petrol supply, and whether the continued emphasis on fast growth of ethanol output is producing optimal benefits for Brazil's economy. Increased ethanol consumption (partly in substitution for petrol and partly in addition to it) represents a boost for the ethanol and car industries and to related employment, but it also means more government spending on subsidies for PNA which could be spent on other programmes. Furthermore, this increased consumption has a limited impact on economic growth, because gasohol and fuel-hydrous ethanol are consumed almost entirely by private cars, which are rarely used for income-generating activitites. In addition, such consumption does not necessarily result in net foreign currency savings, because of rigidities in the supply of domestically refined oil products and other factors discussed below.

A major consequence of the PNA's fast growth has been a rising surplus of ethanol since 1979. A petrol surplus also began to appear in 1978-79 and again after 1981. In 1978-79, this was caused by the increased production of petrol from the national refineries, due to the rising consumption of crude oil. Since 1981, the surplus has been due to the fact that the petrol fraction has not been sufficiently reduced to match both the drop in gasohol consumption and the increasing supply of anhydrous ethanol.

Total car-fuel production, as a percentage of total car-fuel consumption (gasohol plus fuel hydrous ethanol), increased from 100 per cent in 1977 to 107 per cent in 1978; decreased to 103 per cent in 1980, but rose again to 115 per cent in 1981 and 118 per cent in 1982. The Government has exported as much ethanol as possible but, since 1980, the surpluses have been much greater than the international demand for ethanol. Petrol has also been exported, but export revenues may have hardly covered its import and refining cost, depending on cost assumptions discussed in Chapter 4.

Since 1982, PNA has been changing its policies which may improve its social impact by the end of its second five-year period and after. Planning linkages between the ethanol industry and other related sectors (oil refining, petrochemicals, transport and agriculture) have been strengthened. In order to increase the oil-substitution effect of ethanol, long-term investments in oil refining were being studied in 1982-83 in close collaboration with the planning machinery of PNA.

The use of ethanol in the chemical industry is expected to increase at least four-fold between 1980 and 1985. More emphasis is being given to R and D on the use of wood, manioc and sorghum as feedstocks for ethanol as well as to problems of land use, crop displacements and landownership concentration. The major producing states have already designated areas for new ethanol projects. Ongoing R and D efforts are also trying to improve the efficiency of distilleries and of micro-distilleries in particular. The latter can offer more opportunities for rural development, because they make better use of by-products and allow a greater distribution of the benefits.

The most critical factor determining PNA's social performance is the substitution of ethanol for diesel. A highly subsidised programme to satisfy the market of private cars, owned by a minority of the population, has been a point of contention among Brazil's decision-makers. Research efforts on diesel substitution have been accelerated, and promising technical results have been achieved. The problem, however, is not simply a technological one. Petrol, which has been replaced by ethanol, could increasingly be used instead of diesel, since petrol is in surplus and it is more efficient than ethanol as a substitute for diesel. However, this has been constrained primarily by the low price of diesel compared to that of petrol/gasohol. Changes in the price ratio between diesel and gasohol, which could change their relative consumption and, therefore, the demand for ethanol, were being examined in 1983-84.

Brazil's ethanol technology has also begun to face some challenges. The interest in ethanol production in various countries has promoted a race for the development of newer technologies. Whether Brazil can lead this race is not yet clear. Distillery equipment manufacturing in Brazil has been dominated by two major local firms (DEDINI and ZANINI), sharing 80-85 per cent of the market up to 1982. They had been protected from foreign competition[26] and had little incentive for technological innovation. In 1980, the World Bank agreed to lend $250 million to co-finance PNA . The Bank had an influence in establishing higher interest rates on PNA's loans after January 1981. It also stipulated in its contract that production and demonstration equipment are open to international bidding, although Brazilian competitors receive preference, providing that their bid does not exceed the lowest foreign bid by more than 15 per cent.[27] While this only applies to projects backed by the Bank, one of its consequences has been greater domestic competition and technological innovation. By spring 1984, Brazilian equipment manufacturers had been awarded 36 out of a total of 38 contracts financed by the Bank, but DEDINI and ZANINI jointly only received 74 per cent of those 36 contracts, implying an increased participation of other local firms.

3. Summary of PNA's impact

By the end of PNA's first five-year period, the production of 3,500 million litres, or 22.6 m.bbl., of ethanol, in 1980, required under one million ha. of harvested land, 207 distilleries of varying scale and a total investment of about $2,000 million in mid-1980 prices excluding land purchases. This is roughly equivalent to an investment of $0.57 per litre.

This production had a net impact on the balance-of-payments of about $520 million (in 1980 alone), and created 41,000 permanent jobs (16,000 in industry and 25,000 in agriculture) and 83,000 seasonal ones (6,500 in industry and 76,500 in agriculture). This is equal to an investment of about $15,000 per worker or $22,000 per job-year, which is considerably lower than the sum required in most energy subsectors including oil.[28]

PNA's indirect effects on economic growth and employment in other sectors through backward and forward linkages are apparently significant. These are concentrated in the production of various inputs, such as distillery equipment, hydrous-ethanol cars, tractors and fertilisers; the construction of distilleries and related infrastructure (buildings and access roads); government services; gasohol-mixing facilities; engine-conversion centres; R and D and transport. Although these linkage effects are often emphasised by the Government, they are very difficult to measure, because most of such activity is not exclusively related to ethanol production. There are some exceptions such as the installation and operation of gasohol-mixing facilities, the manufacturing of distillery equipment and other inputs and some specialised research, but information on these links is scanty. For example, research by Montes and Gomes (1978) on two gasohol-mixing facilities in the State of Rio de Janeiro estimated one man-year job per 1,530 cubic metres of gasohol blended. According to PLANALSUCAR's technicians, the annual increase of tractors in use to meet the demand of ethanol-related agriculture was roughly 8-9 per cent between 1978 and 1981, whereas the fertiliser industry had an annual growth impact of only 5-8 per cent in the same period. It is also estimated that 45-50 per cent of the industrial investments have been absorbed by the manufacturers of distillery equipment, but since the major manufacturers do not exclusively supply the ethanol industry, it is difficult to assess their ethanol-related output and employment. Spillover effects on other sectors seem negligible. For example, the production of hydrous-ethanol vehicles is mainly a substitute for the production of normal vehicles, hence with a negligible effect on additional economic growth and employment. PNA's spillover effects are nevertheless obscured by the uncertain opportunity cost of public investments and, therefore, what might have been achieved with alternative investments which could have been made with the same capital.

Against the above achievements, PNA may have contributed to a concentration in inter-regional and personal income distribution, during its five-year period. Although PNA's effects on oil import substitution and the balance of payments, direct employment and personal income distribution require more detailed analysis (Chapters 4-6), the following discussion allows some conclusions about the general implications of PNA's policies and production trends for inter-regional income distribution.

Analysis of PNA's policies and production trends

Even a limited analysis can show that some of PNA's objectives and guide-lines are intrinsically inconsistent. For a number of reasons discussed below, maximising the output of ethanol to save foreign exchange, while attempting to minimise costs, is incompatible with the objectives of reducing disparities in income distribution, particularly among the regions of Brazil. On the one hand, there is a strong emphasis on economic efficiency criteria for project

approval, for example, "lowest investment to production-capacity ratio"; "best technological and economic use of raw materials ..." or "lowest cost of infrastructure adjustments ...". On the other hand, symbolic incentives are given to the use of alternative raw materials and to projects in the poorest macro-region (N/NE). Indeed, the patterns of crop distribution and the socio-economic characteristics of farmers in Brazil dictate that production based on manioc would allow a greater share of poorer regions and poorer farmers in total production. However, because of the generally backward state of manioc farming, its use as raw material for ethanol would normally imply higher risks associated with its supply and, thus, higher unit costs of ethanol. Even with sugar-cane, the reduction of regional disparities of income through a greater share of subsidised investments in the N/NE is restrained by the above criteria of economic efficiency. The capital and operating costs of sugar-cane and ethanol are higher in that macro-region than in the richer one and so are "investment to production-capacity ratios" (section 4). Other considerations reveal further inconsistencies among the above guide-lines and permit clear conclusions about inter-regional income distribution. Before looking at these, however, some brief considerations about Brazil's macro-regions and regions are necessary.

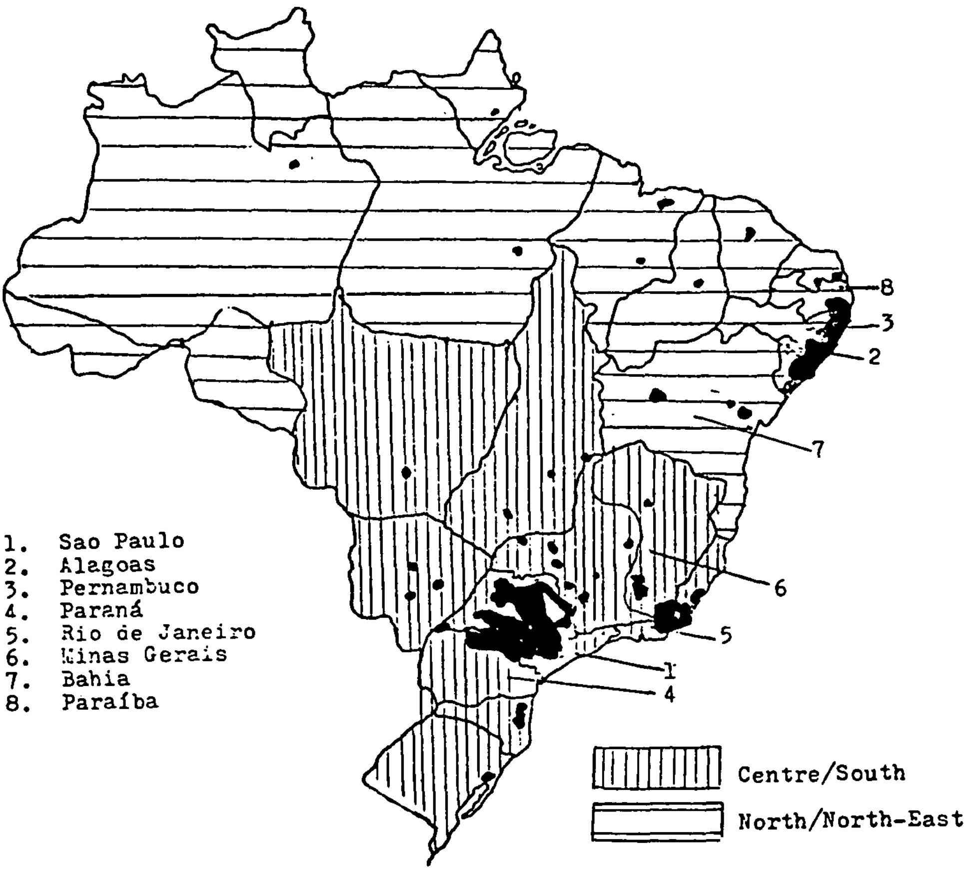
Brazil is a dualist economy comprising two major macro-regions - the richer C/S and the poorer N/NE. The C/S is subdivided into three regions (South, South-East and Centre-West), while the N/NE comprises the North and the North-East including north-western parts of the Amazon. This macro-regional classification is not arbitrary. It is used by the Government as a basis for national development planning, because of the huge disparity of income between the two macro-regions. As we had seen, PNA's financing conditions are different for these two macro-regions. The South-East and South are the richest regions comprising seven states, which are the richest in the country in absolute and per capita terms. The Centre-West is poorer in absolute terms and in development infrastructure, but because it has a small population and its per capita income is relatively high, it is considered part of the C/S in geographical and economic terms. In the N/NE, the North and most of the Amazon region are poor and thinly populated, while the North-East is heavily populated and is the poorest region in the country on a per capita basis. Because of income-related differences among regions and states, the above macro-regional classification is sometimes inadequate for analysis of trends in inter-regional income distribution. With regard to PNA, however, it is adequate not only because it provides the criteria for PNA's financing policies, but also because more than 95 per cent of the production of ethanol throughout the first five-year period was concentrated in the richest region of the C/S and the poorest region of the N/NE, that is the South-East and the North-East (NE) (see figure 2). In 1970, the NE had a per capita income of roughly half the national average and one-eighth of that in the State of Sao Paulo, whereas the per capita of the rural NE was about one-quarter of the national average.

Bearing these disparities in mind, we now turn to the analysis of implications of ethanol production for inter-regional income distribution.

The entrepreneurs most capable of meeting the "lowest investment to production-capacity ratio" were those already associated with the traditional sugar industry. They were also the most eager to respond quickly to the Government incentives because of the unfavourable sugar prices between 1974 and 1979. The subsequent dependence on distilleries attached to sugar mills (90.5 per cent of total production in 1975-76 and 82.5 per cent in 1980-81) meant that both the raw materials and the location of most of the projects were already pre-determined. This dependence on annexed distilleries has been the major factor constraining changes either in the regional allocation of investments, or in the pattern of agricultural production which might have helped redistribute income. Despite the more favourable financing conditions for autonomous distilleries (especially if based on alternatives to sugar-cane and located in the N/NE macro-region), they have considerably higher costs than the annexed distilleries (Appendix B). In 1980-81 there were 49 autonomous distilleries in operation of a total of 207, but only one was not based on sugar-cane or its by-products. By 14 January 1981, some 340 industrial projects had been approved by CENAL, but only 13 were to be based on alternative raw material (12 on manioc and one on babassu mesocarp) - see table 28, Appendix A. Nine of these 12 manioc projects were to be located in the C/S macro-region and three in the poorer N/NE states. By November 1981 however, only one of these was in operation - a 60,000 LPD distillery at Curvelo (State of Minas Gerais) run by PETROBRAS - which ceased operations in 1982-83. This project was implemented in PNA's early years to provide technological support for the development of manioc-based production, but its operation had been unsuccessful as a result of agricultural difficulties.[29] Its inadequate performance restrained the implementation of all the other commercial projects based on manioc. Most of these have been delayed due to uncertain financial feasibility and some had been given up by the end of 1981.

Choice of crops and type of distilleries thus determined the regional distribution of production. Most of the traditional sugar-cane areas are concentrated in the State of Sao Paulo, the richest state in the richer of the two macro-regions. In the N/NE macro-region, most of the production is located in the relatively more developed areas along the coast near the big cities rather than in the poorer hinterland. A disaggregation of IAA's official data reveals that subsidised investments have been highly, and increasingly, concentrated in the more developed C/S, macro-region, during the first five-year period - 83.1 per cent of total production in 1975-76 and 84.2 per cent in 1980-81 (table 27, Appendix A). Although this increase is very small, the concentration of subsidised invesments according to major producing states rather than macro-regions is more evident. Sao Paulo, the richest State and the major supplier of ethanol, increased its share of production from 65.2 per cent in 1975-76 to 70.8 per cent in 1980-81, although it reached 72.9 per cent

Figure 2: Brazil's macro-regions and major ethanol-producing states



in 1975-76 to 70.8 per cent in 1980-81, although it reached 72.9 per cent in 1979-80. The slight decrease in Sao Paulo's share from 1979-80 to 1980-81 means that other states in the richer C/S increased their share of total production. This is notable in the case of Paraná (the second largest producer in this macro-region), which increased its share from 2.7 per cent in 1979-80 to 4.6 per cent in 1980-81. However, the share of the C/S macro-region as a whole also increased slightly. Furthermore, 66.5 per cent of the annexed distilleries, but also 67.7 per cent of the autonomous distilleries, which could choose their location (including projects approved until 14 January 1981) were located in the C/S, and nearly half of the autonomous distilleries were situated in the State of Sao Paulo alone.

The only possible conclusion one can reach, based on the concentration of subsidised investments in the C/S, and Sao Paulo in particular, is that PNA has accentuated regional disparities of income. Evidently, the heavy concentration of production, and hence investment, in the richer areas is also influenced by the concentration of demand for ethanol in these areas (apart from the dependence on distilleries annexed to sugar mills, or the regional differences in production costs). However, the author's analysis of ethanol production by state concludes that only the States of Sao Paulo and Alagoas, from a total of 21 states, produced enough ethanol in 1980 to meet their demand for fuel ethanol, if this were blended with petrol in the maximum proportion of 20 per cent. This means that it would have also been possible to increase the production of ethanol in eight states of the poorer NE region. The fact that even the autonomous distilleries have been concentrated in the C/S, and particularly in Sao Paulo, is a clear indication of the ineffectiveness of PNA's policies in pursuit of improved inter-regional income distribution.

Thus, it could be argued that the negative outcome for inter-regional income redistribution was partly unavoidable. One may also argue that this may be reversed in coming years. This will happen because the traditional sugar-cane areas have become exhausted and production will be forced to poorer areas within regions.

The scale of distilleries has increased significantly, and this also constrains the geographical dispersion of investments. In 1975-76, 118 annexed distilleries, based on molasses, and with capacities under 60,000 LPD, produced 66.7 per cent of total production. In 1980-81, there were only 82 units in this size group, which produced 10.2 per cent of the total output (the other units had increased their capacities). Distilleries of 120,000 LPD accounted for 30.9 per cent of total production in 1979-80 and 31.2 per cent in 1980-81. Though non-existent in 1975-76, distilleries with a capacity of 360,000 LPD and above, produced 24.3 per cent of the total by 1980-81 (table 29, Appendix A).

Taking into account all the distillery projects approved by CENAL until mid-September 1980 (which will have been implemented by the end of 1983) the total capacity of the 120,000 LPD distilleries will have increased even further to 36 per cent of the total, whereas the

smallest units under 60,000 LPD will have decreased theirs from 10.2 per cent in 1980-81 to 6 per cent (table 30). Roughly 39 per cent of the projects approved by 1981 accounted for 62 per cent of the total capacity, and a more recent screening of proposals including projects in operation, in January 1981, showed an even higher concentration of production. This is not only the result of the establishment of new (mostly autonomous) large distilleries, but also through extensions in capacity of those already in operation. Most of the distilleries being extended, usually by increments of 120,000 LPD, are annexed units which started off with a smaller scale of production. Most autonomous distilleries, either in operation or approved, belong to the 120,000 and the 240,000 LPD categories. The NE State of Bahia (which is not a traditional sugar state, and thus has limited possibilities for annexed distilleries) is a good example of the trend toward large-scale production. Among 16 projects approved in January 1981 for the State, 14 were autonomous distilleries; ten of these each had a capacity of 240,000 LPD. This trend toward increased scale of distilleries is caused primarily by industrial economies of scale, although this situation might be somewhat different if distilleries were required to have equipment to reprocess stillage and surplus bagasse. The trend is also caused by the large subsidies for distilleries which increase proportionately with the size of investment without any penalty to financial returns. Such a policy has a built-in incentive for distilleries of larger scale. This is because their lower investment per litre can be obtained at relatively low financial cost. Although larger distilleries have financial advantages, they also have social disadvantages which were discussed in Chapter 2.

Under the existing process of project appraisal (whereby junior technocrats are largely responsible for choice of projects), it is easy to justify investments with relatively high rates of return - invariably the case with large-scale sugar-cane distilleries in traditional sugar-producing areas. It is much more difficult to give a favourable evaluation of investments with lower rates of return, such as those based on manioc and small-scale projects, even though these may be located in poorer areas and bring about more social benefits (e.g., additional and more deconcentrated job opportunities on the productive use of stillage and crop residues).[30]

The policy-related support given to the use of alternative raw materials such as manioc and sweet sorghum (to be used separately or with sugar-cane) has been insufficient to decrease the dependence on sugar-cane. To encourage the use of manioc, it would have been necessary to establish the required levels of both output and inputs to production; the means of reaching these levels and the plans for improving crop yields and disease control. Some of these tasks have been performed by institutions without decision-making power in PNA's network and with very limited R and D budgets.[31]

In contradiction to PNA's criteria for project appraisal, food crops have been displaced and crop integration and rotation have been minimal. This is caused by a combination of factors, including the reliance on annexed distilleries and the expansion of their production

Table 8: Areas ceded by pastures and crops to sugar-cane in the State of Sao Paulo (1975-76 to 1980-81)

Districts	Campinas		Bauru + Marilia		Ribeirao Preto		TOTAL	
Products and markets	Ha	%	Ha	%	Ha	%	Ha	%
Export								
Cotton	9 929	21.22	2 112	2.43	6 203	2.56	18 244	4.85
Castor oil	-	-	2 608	3.00	3 075	1.27	5 683	1.51
Peanuts	-	-	2 140	2.46	-	-	2 140	0.57
Oranges	-	-	758	0.87	-	-	758	0.20
Subsistence or local market								
Rice	2 631	5.62	1 731	1.99	42 157	17.40	46 519	12.37
Beans	2 875	6.14	-	-	1 864	0.77	4 799	1.26
Maize	225	0.48	11 605	13.36	32 876	13.57	44 706	11.89
Manioc	2 796	5.97	3 990	4.59	1 190	0.49	7 976	2.12
Natural pasture	15 589	41.86	11 125	12.80	154 865	63.94	185 579	49.38
Prepared pasture	8 755	18.71	50 831	58.50	-	-	59 586	15.85
Total area ceded to sugar-cane								
Sugar-cane	46 800	100.00	86 900	100.00	242 230	100.00	375 930	100.00

Source: Instituto de Economia Agricola of Sao Paulo.

capacity; the need to minimise the costs of transporting raw material; the lack of effective land-use policies and the political influence of the sugar/ethanol entrepreneurs in the IAA, which is responsible for the technical appraisal of project proposals.

The areas for which reliable data on crop displacement were available, in mid-1981, comprised four of the six agricultural districts of Sao Paulo, which shared some 65 per cent of total ethanol production in 1980. About 376,000 ha, roughly 28.4 per cent of the total area dedicated to sugar-cane in the State, had been turned over to sugar-cane during PNA's first five-year period, displacing crops (10 per cent) and pastures (18.4 per cent). Most of this must have been intended for ethanol, since sugar production decreased between 1977-78 and 1979-80. These 376,000 ha were previously distributed as follows (in thousands of ha): pastures 245; rice 46.5; maize 44.7; cotton 18.2; manioc 7.9; castor oil 5.7; beans 4.8; peanuts 2.1; and oranges 0.8 (see table 8). Until at least 1983, the data which were available for other areas of the country, which shared the remaining 35 per cent of production, were not yet very reliable, although research is being carried out on a continuous basis in some states other than Sao Paulo. Thus, these findings underestimate the total displacement effect of PNA. The economic implications of such displacements are discussed in the following section.

4. Costs of ethanol

Given PNA's financing conditions, the surpluses of both ethanol and petrol and the fluctuations in oil prices, PNA's costs and benefits have been a controversial issue both inside and outside Brazil.[32] Both favourable and unfavourable views tend to be biased by value judgements which arise from the lack of adequate tools to assess them.

There are many difficulties involved in measuring the total costs of PNA. The difficulties in measuring the costs include uncertainties about the total amount and origin of public investments both directly in ethanol-related infrastructure and indirectly in the form of subsidies to private investments. Ethanol supply is also partly responsible for investments in oil-refining adjustments which have been or will be required in order to increase the oil-substitution effect of ethanol, and these cannot be clearly estimated. In addition, there are many factors which affect both direct and indirect costs; these include wide variations in inflation and exchange rates observed since 1975; variations in the gestation periods of investments; overlaps between ethanol- and sugar-related investments for agricultural production, R and D and other government services, as well as substitutions of sugar-cane for food and export crops, which may have some negative implications for food-price inflation, balance of payments and income distribution. Similar difficulties also emerge in the economic valuation of benefits for the balance of payments; employment and income effects, and spillover effects on other sectors.

Due to the above constraints, it is virtually impossible to carry out a complete cost-benefit analysis of the PNA as a whole. Nevertheless, it is feasible to provide a general comparison between costs of petrol and ethanol, although these need to be qualified and interpreted with care.

Table 9 shows the annual average cost of petrol refined in Brazil in 1979, 1980 and 1981 (line 2.1), and the production cost (line 3.1) of petrol-equivalent fuel anhydrous ethanol from sugar-cane in autonomous distilleries, in December 1979, May 1980 and May 1981. Market prices and real exchange rates of these dates are used (official exchange rates were shadow priced to correct the overvaluation of the cruzeiro (cr$) in these months).[33] The figures are not entirely straightforward and require some detailed qualifications, however.

The cost of petrol per bbl is estimated at the margin: it is comprised of the import cost of a bbl of crude oil c.i.f. plus the refining cost of petrol. This estimated ex-refinery cost is very close to the c.i.f. cost of petrol imported at spot f.o.b. prices, which is what Brazil would have to pay at the margin to make up for deficits of petrol if ethanol were not produced. However, if we assume that crude oil must be imported to produce other oil products besides petrol, it can be argued that the economic cost of producing petrol is lower than the cost shown in table 9 (line 2.1). But is this assumption correct and, if so, how much lower is the true petrol cost? This depends on the relative supply and consumption of different oil products and on the comparative costs and benefits of importing crude oil and oil products separately. The fact that the relative consumption of fuels can vary from one year to another implies that the economic cost of producing petrol from crude-oil imports can vary as well.

After 1979, Brazil has had surpluses of fuel oil, petrol and kerosene and a deficit of LPG only, but the consumption of LPG was an insignificant 5 per cent of that of total crude oil in 1982 (details are provided in Chapter 4). If crude-oil imports were reduced, diesel and some minor additional supplies of LPG (and probably of some other fuels) would have to be imported separately, whereas the production of petrol and of other fuels in surplus would be reduced. It might have been more economic for Brazil to have done this in some recent years, but, to verify this, it would be necessary to do a very detailed analysis of refining costs and of the value of fuel imports and exports, which is beyond the scope of this study. The economic cost of producing petrol shown in table 9 is therefore debatable, but it would be equally controversial to guess a much lower figure on the basis of the information available. This issue will be discussed in more detail in the analysis of the balance-of-payments impact, where two different assumptions will be made about costs of petrol, but these are unnecessary here, since the purpose of this discussion is simply to provide a general idea of the costs of ethanol and petrol and of the difficulties involved in their estimation.

Unit production costs of anhydrous ethanol in Brazil vary substantially among regions. These ex-distillery costs in table 9 (line 3.1) are weighted averages, taking into account both the

regional distribution of production and the relative share of annexed and autonomous distilleries - $.202, $.212 and $.214 per litre, or $32.1, $33.7 and $34.0 per bbl, respectively for December 1979, May 1980 and May 1981 (details in Appendix B).

Table 9: Comparative costs of imported crude oil, petrol and petrol-equivalent anhydrous ethanol ($ per bbl)

Fuel	1979	1980	1981
1. Crude oil[1]	30.3	32.2	33.7
2. Petrol			
2.1 Ex-refinery cost[2]	42.5	44.4	45.9
2.2 Distribution cost[3]	12.7	12.7	12.7
2.3 Economic cost[4]	55.1	57.1	58.6
3 Anhydrous ethanol[3]			
3.1 Ex-distillery production cost[5]	32.1	33.7	34.0
3.2 Distribution cost[3]	12.7	12.7	12.7
3.3 Cost of government subsidies[6]	4.0	4.5	5.8
3.4 Economic cost[7]	48.8	50.9	52.5
4. Economic cost difference (Petrol - anhydrous ethanol)	6.3	6.2	6.1

[1] Annual average Rotterdam spot price f.o.b. of Arabian light crude oil.

[2] Crude-oil price, plus $10 for refining and $2.2 for shipping, as typical of Brazil in 1980-1981 (based on discussions with CENAL officials; see also Agroanalysis, 1979, p. 3, and World Bank, 1980b, p. 38).

[3] One bbl of anhydrous ethanol is equivalent to one bbl of petrol since both have about the same efficiency in gasohol blends. Costs of anhydrous ethanol refer to December 1979, May 1980 and May 1981, and were elaborated on the basis of cost data at market prices from Fundaçao Getúlio Vargas (FGV), IAA and CENAL. Official exchange rates on these dates were cr$42.3/$, cr$50/$, and cr$80/$, respectively. Shadow exchange-rate conversion factors of 1, 1.1, and 1.3 were used respectively for these dates, to correct the overvaluation of the cr$ (see footnote 33); these conversion factors were used for all costs incurred in local currency including capital costs and distribution costs. Distribution costs of anhydrous ethanol and petrol refer to May 1980 but are assumed to be the same

<u>Notes to table 9</u> (cont.)

for December 1979 and May 1981 since fuel prices were relatively stable throughout this period (they include retailers' margin as estimated by PETROBRAS); the same figure is assumed for both fuels because they are blended, have essentially the same markets and use the same transport equipment. See further explanations in the text.

4 This figure which is very close to the economic cost of imported petrol (table 11) may actually be lower, depending on the uncertain comparative advantages of (i) importing crude oil for producing various products and (ii) importing oil products separately (see text).

5 These costs are disaggregated in tables 31-33, Appendix B. They are in market prices and include financial costs of investments and working capital, but exclude the cost of government subsidies on investment loans which is taken into account in line 3.3.

6 These estimates are based on the assumption that, given Brazil's scarcity of capital and rising foreign debt, government spending on ethanol investments leads to foreign borrowing at the margin. A total government investment of $1,500 for the 1980 production capacity (explained in the text with details in footnote 36) at a typical social discount rate of 12 per cent over the productive life of investments (20 years) or at 6 per cent over 10 years (ignoring grace periods), leads to an annual repayment of about $200 million or $8.8 per bbl. Since the production costs of ethanol (line 3.1) include interest and amortisation paid by sugar-cane and ethanol producers on subsidised government loans on investments, these payments per bbl are subtracted from the above. The interest and amortisation paid by private investors on subsidised government loans for industrial investments is calculated from data in table 32, taking into account the relative share of annexed and autonomous distilleries in total production; this was $2.2 per bbl in December 1979. Payments on government loans to agricultural investments were calculated on the basis of data in table 31. Since, in these data, financial costs are not disaggregated, we applied the percentage of interest and amortisation in total financial cost from table 32 (61.8 per cent - weighted average of the two types of distilleries) to the financial cost of sugar-cane production ($1.85 per tonne - weighted average of macro-regions); this leads to $2.6 per bbl (at the typical yield of 70 litres per tonne) in December 1979. Hence, total payments to the Government were $4.8 per bbl, leaving the cost of subsidies at $4 per bbl in December 1979. For May 1980 and May 1981, the payments to the Government increased in nominal terms but decreased in real terms. Bearing in mind the financing conditions prevailing for projects implemented before 1981 (section 1) and the rates of inflation over 1979-82 (table 7), nominal payments will have roughly increased by 22 per cent from December 1979 to May 1980 for an increase in inflation of about 45 per cent over this period, and by

Notes to table 9 (cont.)

about 40 per cent from May 1980 to May 1981 for an inflation of 90 per cent. In dollar terms, using the above shadow exchange rate conversion factors, payments in May 1980 and May 1981 can be estimated at $4.3 and $3.0, respectively.

[7] Economic cost is estimated as a proxy of production cost at market prices but increased by distribution cost and corrected for the real cost of capital. Since inputs other than capital are not shadow priced, this implies some distortion, but it is not significant (see text for further explanations).

Source: See notes.

Raw material costs alone account for 65-70 per cent of total production costs. The relative share of distilleries' own sugar-cane and that of sugar-cane purchased from suppliers at prices stipulated by the Government will therefore affect both raw material costs at the distillery gate and total unit costs of ethanol. Purely to illustrate this point, the considerably lower cost figure for December 1979 is based on the assumption that all raw material is from distilleries' lands at production cost, whereas figures for May 1980 and May 1981 are based on the assumption that 50 per cent of the cane requirements are purchased from suppliers at prices and real exchange rates of May.

However, the production cost of the average litre of ethanol produced in Brazil was a little lower than that of anhydrous ethanol for 1979-81 (table 9, line 3.1), because of the lower production costs of (a) hydrous ethanol from sugar-cane and (b) both types of ethanol from molasses. Hydrous ethanol shared 31 per cent of total production in 1980, and typically costs about 6-9 per cent less to produce than anhydrous ethanol. Ethanol from molasses accounted for about 25 per cent of total production in 1980, and typically costs 30-60 per cent less to produce than ethanol from sugar-cane. This is important from the economy's standpoint, but for producers this cost consideration is only relevant for sugar-cane annexed distilleries.

The economic costs of producing ethanol differ slightly from the costs at market prices shown in table 9 (line 3.1), depending on the opportunity costs of capital and other inputs and distortions in their prices. This table also shows a proxy of economic costs of anhydrous ethanol (line 3.4) including distribution costs and real costs of capital corrected for government subsidies on investments. These economic costs are estimated to be $48.8 in December 1979, $50.9 in May 1980 and $52.5 in May 1981. Since market prices are used for all inputs other than capital, there is some distortion, but it is unlikely to be significant.

While discussing the estimation of the economic costs of ethanol, the following paragraphs will add to the understanding of the main policy issues discussed in previous sections. We discuss inputs first, then subsidies and real capital costs, and then distribution costs.

In principle, the assessment of economic costs of production would require shadow pricing of major inputs, such as land, sugar-cane, labour, fuels and fertilisers. For PNA however, this approach is difficult and impractical. A lot of guesses would have to be made and the existing figures would not change significantly. This calls for some explanations. First, sugar-cane used for ethanol does not reduce sugar export revenues for reasons discussed in the introduction (this is discussed further in Chapter 4). Second, substitution of sugar-cane for other crops, which may yield higher net economic benefits per ha of land than ethanol, have apparently not been significant and may in reality imply relocation rather than loss of output. The documented crop displacements mentioned in the previous section included mainly rice, maize and cotton. Coffee, castor oil, peanuts and oranges have also been affected, but to a very minor extent. All of these crops except rice and maize are exported, and might earn or save more foreign exchange than ethanol under certain market conditions. However, data from IBGE (1983) on land-use trends show increases in land use for all the above crops from 1979 to 1982, except coffee. The decline in coffee output, however, is strictly related to the fall in world prices between 1980 and 1983; coffee output in 1983 was about 80 per cent higher than in 1982. These displacements may increase food prices in some specific locations and, thus, affect income distribution, but this cannot be measured on the basis of statistics available until at least 1982. Third, even if market prices of labour were shadow priced by a factor of 0.5-0.7 (i.e., 50-70 per cent of the market price, which reflects simply a guess about the social benefits of job creation),[34] total costs per bbl would only decrease by about 7 per cent. Diesel oil, fertilisers and pesticides are major inputs imported at the margin, and their market prices do not necessarily reflect their economic costs. Thus, for economic cost analysis, these should be valued at border prices using a "standard" premium on foreign exchange. However, market prices of diesel oil, converted into dollars at the official exchange rate, were priced above Rotterdam f.o.b. prices by about 14 per cent in mid-1980 and 60 per cent in mid-1981. On both dates, this overpricing was higher than the "standard" premium on foreign exchange, which was roughly 10 per cent and 30 per cent, respectively.[35] Fertilisers and pesticides which also share a large part of total sugar-cane costs (see table 31) have been subsidised, but this distortion is probably more than compensated for by using market prices of diesel and labour. Thus, in the light of the above considerations, the estimation of shadow prices of inputs other than capital (which is shadow priced and discussed below) would not significantly change the estimates of economic costs shown in table 9, line 3.4.

The real cost of government subsidies to PNA's investments is much more complicated; this is due to variations in financing conditions including foreign borrowing, social discount rates and market rates of interest, and inflation during the pay-back periods. The $2,000 million required for the production of 22.6 m.bbl in 1980,

included about $1,500 million in subsidised government loans, judging from the offical data on capital investments and government financing conditions for individual projects.[36] In principle, the subsidies might be viewed as the difference between what the Government allocated as loans and what it earns from repayments and net revenues in ethanol sales. From this viewpoint, there would be no subsidies at all, since such net revenues in 1980 alone amounted to about $773 million (weighted-average net revenue, table 10, multiplied by 22.6 m.bbl), which was more than one-half of the total public investment. But this is incorrect. As table 10 suggests, net sales revenues would have been even higher, had there been no ethanol production, that is, if petrol had been sold instead of gasohol and hydrous ethanol.[37] Therefore, the subsidies are determined by the difference between the opportunity cost of the government loans (measured by a social discount rate) and the repayment from the borrowers. However, under the financing conditions established before January 1981 for projects approved until that date, the Government gets virtually no return on its investment loans, due to the highly negative real interest rates.[38] Since the nominal interest rates increase more slowly than the rate of inflation (see footnote 38), the higher the latter, the lower the payments in real terms (as measured in dollars at parity exchange rates). Furthermore, the opportunity cost of the government funds depends partly on their source (i.e., whether they could have been used for alternative projects or only for PNA). The Government's investments in PNA are funded partly by tax revenues from sales of fuels (mainly gasohol and hydrous ethanol), and partly from foreign loans tied specifically to PNA. Moreover, the use of such tax revenues for ethanol projects implies a reduction of government savings (which could have been used for other purposes) and an increase in national debt. Thus, it can be assumed that most of these public funds were borrowed internationally. At a 6 per cent interest rate and 10-year repayment period (or at 12 per cent over the 20-year productive life of investments) and ignoring grace periods, the $1,500 million in government funds would have required annual repayments of about $200 million in interest and amortisation.[39] Table 9 (line 3.3) therefore includes an estimate of the cost of the government subsidies to investments as the difference between assumed payments by the Government per bbl to foreign lenders and payments received from private investors. The real subsidy over the life of investments, however, cannot be objectively estimated, since it depends on domestic and external inflation over the whole pay-back period and on borrowing rates of interest. Domestic inflation determines how much the Government gets back from its loans in real terms; external inflation and borrowing rates determine how much the Government pays to foreign lenders.

Table 10: Net government revenues from the domestic sale of anhydrous and hydrous ethanol: Brazil, May 1980 ($ per bbl)[1]

Item	Anhydrous	Hydrous
1. Retail price[2]	98.6	64.1
2. Price paid by Government to distilleries	42.9	40.6
3. Distribution costs	12.7[3]	9.0[4]
4. Net government revenue[5]	43.0	14.5
5. Weighted-average net revenue[6]	34.2	

[1] See notes in table 9 about exchange rates used.

[2] Data from CENAL and IAA.

[3] See notes in table 9.

[4] Author's notional estimate (see text).

[5] This shows that there were no price subsidies to consumers as of May 1980 since revenues from sales of both anhydrous and hydrous ethanol were much higher than the prices the Government paid to the distilleries. The net revenue from hydrous ethanol is lower than that of anhydrous, as the former had a retail price typically stipulated at 65 per cent of the price of the latter. Among other incentives to hydrous-ethanol cars, this parity was reduced to 59 per cent in 1983, but resulting nevertheless in positive net revenues.

[6] 1 per cent hydrous ethanol and 69 per cent anhydrous ethanol.

Source: See notes.

Both the amount and the source of government subsidies have important implications for income distribution, which deserve some remarks. Investment subsidies financed by taxes on car fuels, for example, imply a shift of income from middle-class and upper-class car owners particularly to upper-class entrepreneurs and, to a lesser extent, to low-income people for whom additional jobs are created. If, as we assumed, the subsidy is financed by foreign loans largely untied to PNA, the relative incomes of these groups remain unchanged as a result of PNA, but the taxes on car fuels could be used for other purposes. Should the Government be interested in preventing PNA from having an adverse effect on the incomes of poor people in ethanol-producing areas, it might explore, for example, the use of a portion of car-fuel taxes to subsidise prices of basic foods, which may have increased in some locations as a result of displacements of food crops by sugar-cane.

The economic costs of both petrol and fuel ethanols also include domestic distribution costs. It is often argued that distribution costs of ethanol fuels can be considerably lower than those of petrol because distilleries will be much more decentralised than oil refineries or import-entry ports. This is clearly true for hydrous ethanol because it is not blended with petrol and has to be transported separately. For anhydrous ethanol, which is consumed in gasohol blends only, the relative savings in distribution depend entirely on the decentralisation of gasohol blending centres as well as on their investment requirements.[40] Even if these were highly decentralised, gasohol blends with 20 per cent anhydrous ethanol would probably not involve more than 5-10 per cent savings in net distribution costs. It is assumed in table 9 that these costs are basically the same for petrol and anhydrous ethanol - therefore the gap in production and economic costs between these fuels is shown as being the same in 1980. Savings in distribution become increasingly important in Brazil as hydrous ethanol increases its share of the total ethanol production (from 18 per cent in 1979 to 56 per cent in 1983). Such savings, however, will not be important in most other ethanol-producing countries, since ethanol supply will have a much smaller effect on petrol-substitution than in Brazil, and hydrous ethanol will normally not be produced for fuel-use until anhydrous ethanol markets will have been exhausted.

To compare unit costs of fuel ethanols and petrol, the energy equivalence of these fuels should also be taken into account. This is not necessary for anhydrous ethanol, because it is equivalent to petrol in gasohol blends. The estimated economic costs per bbl of anhydrous ethanol in table 9 (line 3.4) thus represent the costs of replacing one bbl of petrol. These were significantly lower than those of petrol refined in Brazil in 1980-81 (under the aforementioned assumptions) as well as the c.i.f. prices of petrol from both Middle East and Caribbean markets ($42 and $41 per bbl f.o.b., respectively, plus $2-2.5 for shipping) increased by distribution costs. Due to trade agreements with major Middle East suppliers, average crude-oil f.o.b. prices paid by Brazil in 1979-81 were in fact lower than those in table 9, but this consideration is irrelevant for economic valuation of petrol replacement.

The ex-distillery cost of producing each petrol-equivalent bbl of hydrous ethanol, however, was 1.16 times higher[41] than that of anhydrous ethanol shown in table 9 (line 3.1), hence $37.3, $39.1 and $39.5 in December 1979, May 1980 and May 1981, respectively, which were also lower than both c.i.f. prices and ex-refinery costs of petrol. Earlier considerations about capital costs of anhydrous ethanol apply equally to hydrous ethanol. However, the gap between the economic cost of each petrol-replacement bbl of anhydrous and that of hydrous ethanol may be narrower than the gap between their production cost, because of the lower distribution cost of hydrous ethanol. In tables 10 and 11, we make the reasonable assumption that this cost is 30 per cent lower than the distribution cost of petrol/gasohol. Taking into account the share of hydrous and anhydrous ethanol in total production as well as distribution costs of petrol and ethanol, the weighted average economic cost of each petrol-replacement bbl of ethanol in Brazil is therefore estimated at $49.0, $51.1 and $53.5 compared with $54.5, $56.9 and $56.9 for imported petrol in December 1979, May 1980 and May 1981, respectively (see table 11).

Table 11: Economic costs of petrol and of petrol-replacement bbl of anhydrous ethanol including distribution costs ($ per bbl)[1]

Fuel	1979	1980	1981
1. Petrol (ex-refinery)	55.2	57.1	58.6
2. Petrol (imported c.i.f.)[2]	54.5	56.9	56.9
3. Anhydrous ethanol	48.8	50.9	52.5
4. Hydrous ethanol	50.3	51.7	54.3
5. Weighted average ethanol[3]	49.0	51.1	53.5

[1] Production costs of petrol (line 1) are ex-refinery and those of ethanol are ex-distillery. The latter are at shadow exchange rates and market prices corrected for government subsidies on investments - see text and notes in table 9 about these costs and exchange rates used. The petrol replacement costs reflect the relative energy equivalence of petrol, anhydrous and hydrous ethanol (see text and footnote 41). Distribution costs used are $12.7 per bbl for petrol and anhydrous ethanol and $9 per bbl for hydrous ethanol (see text).

[2] Rotterdam spot price f.o.b. plus $2.2 shipping cost.

[3] Hydrous ethanol shared 18 per cent, 31 per cent and 54 per cent of total ethanol production in 1979, 1980 and 1981.

Source: Elaborated from data and sources mentioned in tables 9 and 10.

The decrease in real oil prices after 1981 will have reduced the cost advantages of ethanol in Brazil. Oil prices of $29 per bbl (f.o.b.) in 1983 resulted in decreases in c.i.f. import prices and ex-refinery costs of petrol (per bbl) from $44.2 and $45.9 in 1981 to about $36 and $39 in 1983, respectively. The economic costs of producing ethanol may have been a bit higher than these in 1983, although a conclusive estimate cannot be made here, due to the lack of relevant data.

Highly indebted governments may nevertheless judge it appropriate to place a special premium on foreign exchange savings and spending associated with certain traded goods. For imported fuels, this special premium may be well above the "standard" premium (or conversion factor) for all traded goods,[42] because they account for a large share of foreign currency expenditure and their prices have been highly unstable. For Brazil in particular, this rationale has become an integral part of development planning in recent years, due to a number of considerations related to the debt crisis. First, Brazil's ability to borrow and import has been severely restricted by overall credit contraction, high interest rates, and lenders' perceptions of Brazil's credit-worthiness. Second, these real interest rates including spread rates on external debt may fluctuate to a point where the marginal cost may unexpectedly exceed the marginal benefit of borrowing in some cases. Third, interest payments have in turn been refinanced through new loans, making final payments much higher than those assumed under initial borrowing terms. Fourth, under high and unstable levels of inflation, the market exchange rate at which the domestic currency can be converted to purchase dollars or another hard currency may, at times, exceed the so-called real or shadow exchange rate (e.g., as measured in terms of the parity value of exports). Finally, devaluations aimed at import substitution and at additional earnings of foreign exchange may not produce such results beyond a certain point, depending on the import/export portfolio, markets, foreign exchange policies of trading partners, debt and debt servicing; in Brazil, where business minds think simultaneously in terms of two currencies (cruzeiros and dollars), such devaluations tend to speed up the rate of inflation, as entrepreneurs try to recuperate the dollar value of their assets. Although there are no clear answers for Brazil to the questions raised here, there may be situations in which the net social benefit of producing each additional bbl of ethanol may be higher than that of importing each additional bbl of petrol, even when the latter is cheaper in measurable terms.

Notes

[1] Republica Federativa do Brasil (1975).

[2] CNAL comprises the Ministers of MIC (its President), Planning, Energy, Treasury, Agriculture, Interior, Labour and Transport and representatives of the National Confederations of Agriculture, Industry and Commerce. CENAL is also presided over by the Minister of MIC and includes the Presidents of the National Petroleum Council (CNP), and the Executive Secretaries of STI (another MIC agency) and the Industrial Development Council (CDI).

[3] Under CENAL's request, other organs such as INT and EMBRAPA may be consulted for the technical appraisal of project proposals based on manioc, sweet sorghum or babassu mesocarp. The technical feasibility of industrial production is provided by the manufacturers of distillery equipment under CENAL's specifications.

[4] Over 40 approved proposals were examined by the author at IAA's headquarters. The vast majority was similar in style and content, and some were inconsistent with the findings of the field survey as regards land use, origin of raw material supply and stillage treatment.

[5] CENAL (1980, pp. 8-20).

[6] ibid., pp. 11-12.

[7] ibid., p. 11.

[8] This policy is aimed at better control over supply.

[9] The prices of gasohol must be linked to those of anhydrous and hydrous ethanol, because of the different energy value of these and the incentives for petrol substitution, as well as the need to adjust demand to supply, since a reduction of the latter might imply economic constraints to producers.

[10] Brazil has a policy to compensate the general increases in the cost of living, whereby wages, rents and capital earnings are corrected every six months, in April and October, by a percentage amount nearly equal to the rate of inflation (ORTN is the name of the indicator used in these adjustments).

[11] The new financing conditions did not apply to projects whose proposals were presented to CENAL before January and awaited financial clearance from an authorised bank before 1 May 1981. Agricultural costs and storage tanks also continue to qualify for subsidised loans.

[12] Hydrous ethanol: 6,100 million litres; anhydrous: 3,100 million for gasohol blends and 1,500 million litres for non-fuel purposes.

13 For an explanation of the difference between harvest year and calendar year, see table 25, Appendix A.

14 According to government estimates in Brazil, about 80,000 cars had undergone engine conversions by the end of 1980 in order to consume hydrous ethanol. Each conversion cost about $200 in early 1980.

15 Between 1975 and 1980, there was an annual average decrease in car sales, coupled with a decrease in petrol consumption, except in 1978 (Jornal do Brasil, 10 May 1980).

16 The initial tests and technology had been developed by governmental groups such as CTA, rather than local car manufacturers.

17 This did not imply an increase in total supply beyond what had been projected, since both the production and consumption of anhydrous-ethanol could be reduced.

18 Jornal do Brasil, 10 May 1980.

19 Jornal do Brasil, 27 May 1981.

20 See Jornal do Brasil, 30 Jan. 1981 and 30 Aug. 1981. See also Financial Times, 1 June 1983.

21 Jornal do Brasil, 30 Jan. 1981.

22 Quimica e Derivados (1980b, p. 23).

23 ibid., p. 12.

24 Two ministers had referred to the "enemies of PNA" in public addresses, as quoted by Jornal do Brasil (4 Sept. 1981 and 7 Sept. 1981), and a third minister repeated the phrase in a televised programme in late September 1981.

25 Information on car sales is from Conjuntura Econômica, Jan. 1984 and other issues, and from Financial Times, 1 June 1983.

26 PNA has been highly protective of Brazilian industry. On paper, foreign enterprises can invest in ethanol projects, but they do not classify for subsidised public financing.

27 The World Bank's loan was aimed at increasing the capacity by 5,600 million litres, "... of which 95 per cent was expected to be based on sugar-cane and 5 per cent on manioc" (World Bank, 1981c). These investments also include projects for infrastructures, research and policy assessment.

28 See MacKillop (1983), SERA (1981) and Geller (1984).

29 Such difficulties have been crop diseases, low yields, shortages of raw materials and even labour.

30 This difficulty is associated with the problem of assigning weights to costs and benefits which are immeasurable at market prices.

31 See CNPq (1978), Saint (1981) and Souza (1979).

32 For a comprehensive review of cost estimates see also COPERSUCAR (1981 and 1983), CENAL (1983), Geller (1984), Ghirardi (1983), O'Keefe (1983), Melo and Pelin (1983) and World Bank (1980b).

33 The relative value of the local currency is monitored by the Brazilian Government on a monthly basis and reported in journals such as Conjuntura Econômica (various issues - see, for example, Vol. 38, No. 1, Jan. 1984). A given overvaluation equals the shadow exchange rate factor, and represents the difference between the official exchange rate and the parity exchange rate (based on the parity value of exports). Following a 30 per cent devaluation in November 1979, the official rate in December 1979 was roughly at parity with the $).

34 This shadow conversion factor for labour is used by CENAL (1983), but according to a CENAL official, the World Bank used conversion factors of 0.7 for labour in the poor NE region and of 1 for the richer Centre/South regions in its pre-financing assessment in 1981.

35 Conversion factors of 1.1 in May 1980 and 1.3 in May 1981 are roughly equivalent to premia of 10 and 30 per cent, respectively. In practical terms, the difference between the two methods is that, in the former case, the value of a basket of non-traded goods in local currency is converted to the value of the same goods in foreign currency, and in the latter case, the value of traded goods is converted to their value in local currency. With the conversion-factor approach, the relative value of non-traded goods is reduced, and with the premium approach, the value of traded goods is increased. For details see Squire and van der Tak (1975), Little and Mirrlees (1974), and in particular, Gittinger (1982, pp. 246-51).

36 A typical 120,000 LPD autonomous distillery required an investment of about $8.3 million in prices and parity exchange rates of December 1980. This estimate is based on typical overall capital investment of $13 million in the most representative Centre/South regions (in December 1980 prices and offical exchange rates of cr$64/$) including distillery, ethanol storage facilities, 5-10 km access road, freight and agricultural equipment but excluding land. This $13 million is shadow priced at 36 per cent due to cruzeiro overvaluation in December 1980 - hence 8.3 million. Of this, 80 per cent - $6.65 million - was public investment in the form of a loan.

In addition, each of the above distilleries required an initial agricultural investment of about $3.3 million - $650 per ha - (also in December prices and above shadow exchange rate) including land clearing and preparation, first planting and initial cultivation (see Appendix B for details on ethanol-related investments). On average, 70 per cent of this - $2.3 million - was also subsidised public investment. Therefore, each autonomous 120,000 LPD distillery required an investment of about $11.6 million, including $9 million of public financing. For the production level of 1980, 194 of such distilleries would have been required, hence a total of $2,250 million investment, including $1,750 million of public funds. However, the 207 distilleries in commercial operation also included different scales - higher scales costing less, smaller scales costing more. Furthermore, 85 per cent of production in 1980 was based on annexed distilleries, which required up to 20 per cent lower industrial investments than autonomous ones. Furthermore, the 25 per cent share of molasses ethanol in total ethanol output in 1980 implied roughly 25 per cent lower agricultural investments than those estimated on the basis of autonomous distilleries. Taking these factors into account, the above investment figures would in fact have been about $1,800 million in total and $1,400 million in public investments, excluding investments in R and D, gasohol-mixing centres and other private and public investments in capital goods infrastructure, agricultural R and D and government services. Including these investments, the final figures may be estimated at $2,000 million and $1,500 respectively.

37 Government revenues per litre of ethanol will decrease as the share of hydrous ethanol increases. They may possibly also decrease, as projects become implemented under the new financing conditions established in 1981. This is because the private share in the industrial investment of an autonomous sugar-cane distillery of 120,000 LPD (20 per cent of the total) would have an internal rate of return of about 26-29 per cent under the financing conditions established before January 1981. This assumed a 20-year life at 50 per cent capacity by 1983, 90 per cent in 1984, and 100 per cent in 1985; biannual adjustments of ethanol prices to producers based on the general price index; location in the South-East states and an inflation rate of 80 per cent in 1982, and 60-70 per cent by 1985 and thereafter. Since inflation has remained much higher, and interest rates were only 2-6 per cent plus 40 per cent of the price index, the rate of return has been higher too. Under the new financing conditions, however, the rate of return would decrease to about 15-17 per cent, given the same assumptions (information collected from financial experts at Banco do Brasil). These rates of return also increase with inflation, but much less so than under the previous conditions. Furthermore, they are considered low by most private businesses in Brazil during periods of high inflation and financial instability including sharp fluctuations in exchange rates, as has been the case since late 1979. Hence, there is a good possibility that the Government may be forced to increase ethanol prices paid to the producers in real terms. Moreover, since consumer prices of

hydrous ethanol and taxes on hydrous-ethanol cars have decreased to encourage ethanol consumption, it is not certain what the change in the financing conditions implies for the Government's budget. It may eventually imply a transfer of government subsidies from investments to prices.

[38] Even assuming (a) the stricter financing conditions prevailing after January 1981, (b) a constant inflation rate of 90 per cent and (c) a general price index (ORTN) of 85 per cent, the public funds disbursed in 1980 for the industrial investment in each autonomous distillery of 120,000 LPD in the C/S macro-region would have a negative internal rate of return of about -27 per cent. This figure includes a government loan covering 80 per cent of the industrial investment at a fixed interest rate of 55 per cent in 1981, and a 5 per cent nominal rate added by 65 per cent of the ORTN variation in the following years - total of 12 years with a three-year grace period. The figure excludes the opportunity cost of the capital and the revenues from ethanol sales. Furthermore, it may be exaggerated by the assumption that inflation will remain high until 1995, but it gives a rough indication of the high direct cost of the public investments.

[39] This is more favourable than what the Government would annually have to pay for amounts of petrol equivalent to ethanol output in 1980. To import 21 m.bbl of petrol in 1980 (equivalent to 22.6 m.bbl of ethanol, taking into account the share of hydrous ethanol), the Government would have paid either $928 million (Rotterdam spot price c.i.f.) in cash, or $125 million in annual payments under the same borrowing conditions. Assumming 1980's output over 20 years, all of PNA's initial investments ($2,000 million) and annual production costs of ethanol ($35.3 x 22.6 m.bbl) would amount to $17,955 million compared with $18,560 million for the optional equivalent supply of petrol at the margin. Assuming total borrowing in either case of 1980 prices, the ethanol case would be more attractive - annual payments, at above financing conditions, would be roughly $2,440 million and $2,520 million, respectively.

[40] Montes and Gomes (1978) estimated these investments at about $50 (in 1978 prices) per cubic metre of capacity, using tanks of 30,000 cubic metres.

[41] This conversion factor takes into account 17-18 per cent fuel-efficiency loss, 5-9 per cent lower production cost and 6 per cent higher volume due to additional water content.

[42] The main problem in using a "standard" premium or a "standard" conversion factor for all traded or non-traded goods is that it is implicitly assumed that price distortions are the same for all these goods. Another problem is that the premium and conversion factors do not capture all distortions, particularly those which relate to foreign borrowing. For a comprehensive discussion see Gittinger (1982) and, in particular, Chapter 4 of Ray (1984).

CHAPTER 4

IMPACT ON OIL SUBSTITUTION AND BALANCE OF PAYMENTS

A simplified assessment of PNA's impact on the balance of payments can be made on the basis of information about the costs of ethanol and petrol. This method, which is normally used by government institutions in Brazil, credits a petrol-equivalent bbl of ethanol at c.i.f. prices of petrol and debits imported inputs to production. According to this methodological procedure, but also including annual payments on PNA's investment loans, ethanol production contributed some $557.8 million to the balance of payments in 1980.[1]

This method may, however, overestimate the balance-of-payments impact in certain fuel supply/demand conditions and underestimate it in others. It assumes perfect substitution of ethanol for petrol, while in fact only part of the total production of ethanol replaces petrol. The supply of ethanol in Brazil has had a combination of the following effects:

- direct substitution of petrol and petrochemicals;
- exports of ethanol and petrol; and
- increased output of naphtha and diesel (made possible by a decrease in the fraction of petrol and an increase in that of naphtha, part of which has been used for producing diesel).

Apart from the intended replacement of petrol and chemicals, these effects are mainly the result of imbalances between the consumption and the production of different fuels. In optimal conditions, the pattern of fuel supply (i.e., locally refined fuels plus fuel imports, taking into account storage, adjustments and losses) should change according to changes in the pattern of fuel consumption. This has not been possible, however, because of rigidities in the configuration of the oil-refining sector which provides nearly all the required supplies of fuels. As a result, the import-substitution effect of ethanol is mainly determined by the supply of petrol which depends on the consumption and production of other oil products.

Therefore, the assessment of the balance-of-payments impact requires an analysis of the effects of ethanol production on oil import substitution and exports of both oil products and ethanol. These considerations are discussed at length in the rest of the chapter.

1. Pattern of fuel consumption and supply

Most ethanol is used as fuel. Non-fuel consumption has been stable in volume terms, but declining as a proportion of total ethanol consumption - from 19 per cent in 1978 to 9 per cent in 1982. Fuel ethanol is used exclusively in road transport as a direct substitute for petrol. Petrol, gasohol and fuel hydrous ethanol have been consumed mainly by cars. Boats have consumed between 0.1 and 0.2 per cent of total gasohol. Aviation petrol, which is normally not mixed with anhydrous ethanol, is used exclusively by small aircraft; its consumption represented about 2.7 per cent of total petrol consumption in 1967, but only 0.7 per cent in 1978 and 1.4 per cent in 1980-82. The number of medium and light lorries and large vans running on petrol/gasohol had always been small, but has decreased in recent years due to the lower price of diesel. Some of these vehicles are now running on hydrous ethanol as a result of price and fiscal incentives adopted after 1982, but this is not expected to have a large impact on the demand for diesel under the current fuel-price structure.[2]

In Brazil, cars run exclusively on gasohol or fuel hydrous ethanol and are used mainly for private transport. Diesel oil is used mainly in freight and public transport and, thus, it is much more important than car fuels for generating output and income. This affects the relative domestic prices and consumption of diesel and car fuels. Before discussing this last point in more detail, some additional considerations about the pattern of fuel consumption need to be mentioned.

In 1978, some 72.6 per cent of all freight transport was carried by road and 16.8 per cent by rail;[3] the latter figure is as low as 7 per cent if rail transport of iron ore is excluded,[4] and it has remained roughly the same until at least 1983. The rail system accounted for only 1.2 per cent of total oil consumption (mainly diesel) in 1978. Most overland freight is carried by diesel-powered lorries. In 1979, heavy lorries and buses consumed 97 per cent (78 and 19 per cent, respectively) of all diesel used for road transport; the remaining 3 per cent was used by light and medium lorries and vans. Diesel consumed by the transport sector was 74 per cent of the total in 1978 and 73 per cent in 1982; furthermore, diesel used in road transport increased from 66 per cent in 1978 to 67 per cent in 1982. Thus, there has been virtually no change in the pattern of diesel consumption since 1978 (and this is mainly because of the very limited use of diesel in industry where most substitution options are).

Recent trends in consumption, which have important implications for the import-substitution effect of ethanol are these: the consumption of crude oil and fuel oil increased up to the second oil shock and began to decrease thereafter. Since 1979, consumption of fuel oil decreased more than that of crude oil, not only on account of the recession but also on account of conservation and substitution (fuel oil is used primarily in industry and can be replaced by several

other fuels). Consumption of car fuels also fell from 1979 to 1981, but began to increase slowly since 1982, mainly as a result of the government incentives to hydrous ethanol consumption and the fall in world oil prices. Consumption of naphtha and LPG increased steadily even after the second oil shock, whereas that of kerosene (including jet fuel) has remained practically stable since 1976. The consumption of diesel increased up until 1980, stabilised in 1981, but began to increase again thereafter.

Among these trends in the consumption of oil-derived fuels, which are shown in table 12 and figure 3, the high and increasing consumption of diesel is the main problem for Brazil's overall fuel balance. This problem has arisen because of the relative prices of gasohol (or petrol) and diesel and the lack of technically viable and economically competitive substitutes for diesel. The price ratio of gasohol to diesel was 1.2 in 1973, but up to 2.5 in 1980 and nearly 2 in 1981. This incouraged the use of light and medium vans running on diesel rather than on gasohol and therefore increased diesel consumption. In 1970, the ratio of gasohol/diesel consumption was 1.5 compared to 0.6 in 1981 and 0.5 in 1982.

Each unit of increase in diesel consumption causes an imbalance between fuel consumption and domestic fuel production, unless there is a similar increase in the consumption of other oil products or a change in the pattern of fuel supply. The latter option, however, is constrained by technological and economic factors which are discussed below. Thus, as figure 4 shows, there has been a slight deficit of LPG and a surplus of kerosene throughout the 1976-82 period, and significant surpluses of petrol and fuel oil, particularly after 1980. The large surpluses of diesel in 1978 and 1980 arose from adjustments in the oil-refining sector, which increased the diesel fraction in response to rising consumption. The surpluses of petrol and fuel oil are due partly to their substitution and partly to the increased consumption and production of diesel. Before discussing this issue and its implications in more detail, a few remarks on the oil-refining sector are in order.

Table 12: Oil product balances (1979-82) (Kilotonnes of oil equivalent - Ktoe)

a. Crude oil

Year	Production	Import	Export	Storage, adjust. and losses	Total Consumption
1979	8 262	50 049	-	-2 735	55 576
1980	9 083	43 485	60	1 810	54 318
1981	10 675	42 260	738	396	52 593
1982	12 984	39 856	1 103	292	52 029

Table 12 (cont.)

b. Diesel oil

Year	Production	Import	Export	Storage, adjust. and losses	Total Consumption
1979	14 868	137	338	46	14 713
1980	16 459	571	430	-792	15 808
1981	15 495	763	435	-316	15 507
1982	16 415	201	1 032	142	15 726

c. Petrol (automotive and aviation)

Year	Production	Import	Export	Storage, adjust. and losses	Total Consumption
1979	10 462	123	343	-200	10 042
1980	8 721	78	271	157	8 685
1981	8 980	67	1 090	308	8 265
1982	9 121	65	1 173	-102	7 911

d. Naphtha[1]

Year	Production A	Production B	Import	Export	Storage, adjust. and losses	Total Consumption A	Total Consumption B
1979	1 877	2 588	-	-	23	1 900	2 611
1980	2 035	2 881	-	-	-86	1 949	2 795
1981	2 257	3 189	-	7	-14	2 236	3 168
1982	2 429	3 408	1	-	426	2 856	3 835

[1] Column A excludes and column B includes naphtha used to produce diesel.

Table 12 (cont.)

e. Fuel oil

Year	Production	Import	Export	Storage, adjust. and losses	Total Consumption
1979	16 946	392	419	659	17 578
1980	16 428	1 131	802	439	17 196
1981	15 208	183	1 737	66	13 720
1982	13 551	2 033	2 390	-2 148	11 046

f. Kerosene (including jet fuel)

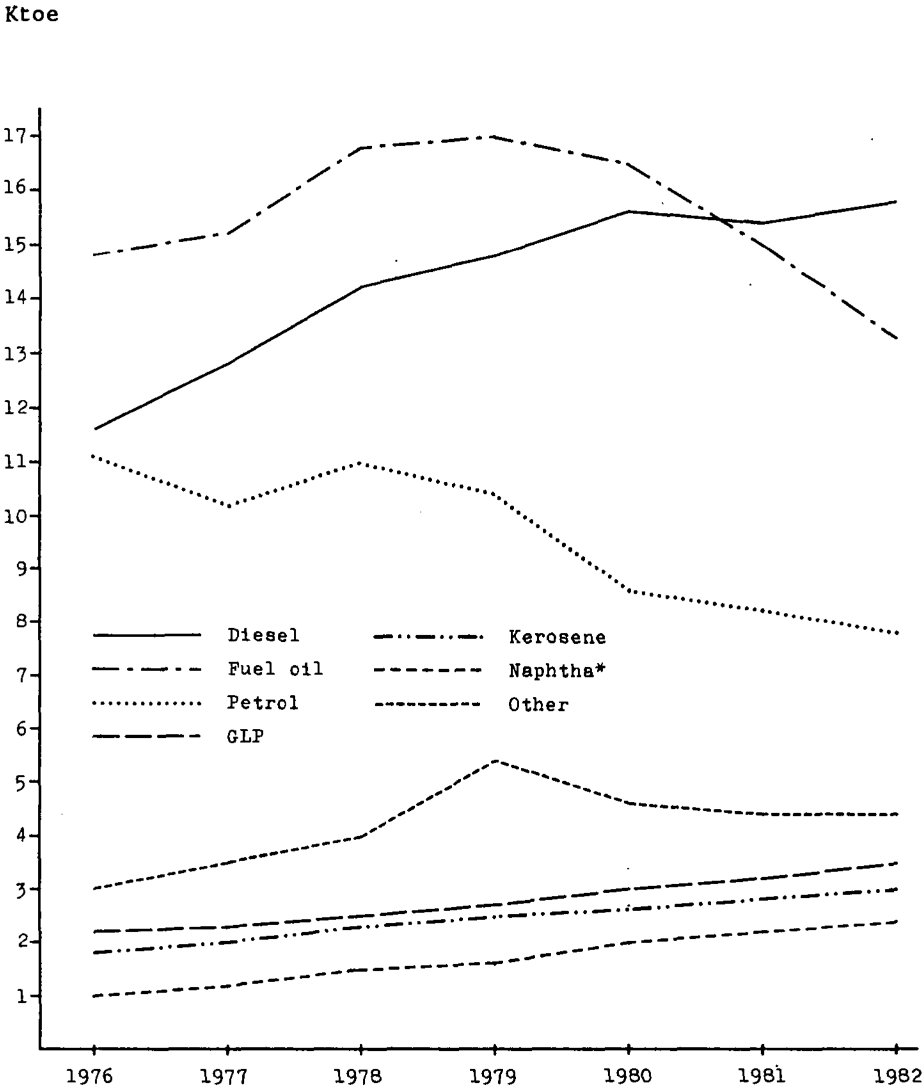
Year	Production	Import	Export	Storage, adjust. and losses	Total Consumption
1979	2 579	-	195	-85	2 299
1980	2 676	-	302	-226	2 148
1981	2 989	-	559	-121	2 309
1982	3 064	-	622	-117	2 325

g. LPG

Year	Production	Import	Export	Storage, adjust. and losses	Total Consumption
1979	2 639	75	36	85	2 763
1980	2 975	112	20	-63	3 004
1981	3 100	137	47	-30	3 160
1982	2 995	661	22	-204	3 430

Source: All data from the Brazilian Energy Balance - MME (1983).

Figure 3: Pattern of oil-product consumption



[1] Not including naphtha used to produce diesel (see table 12).

Source: Elaborated from the Brazilian Energy Balance - MME (1983).

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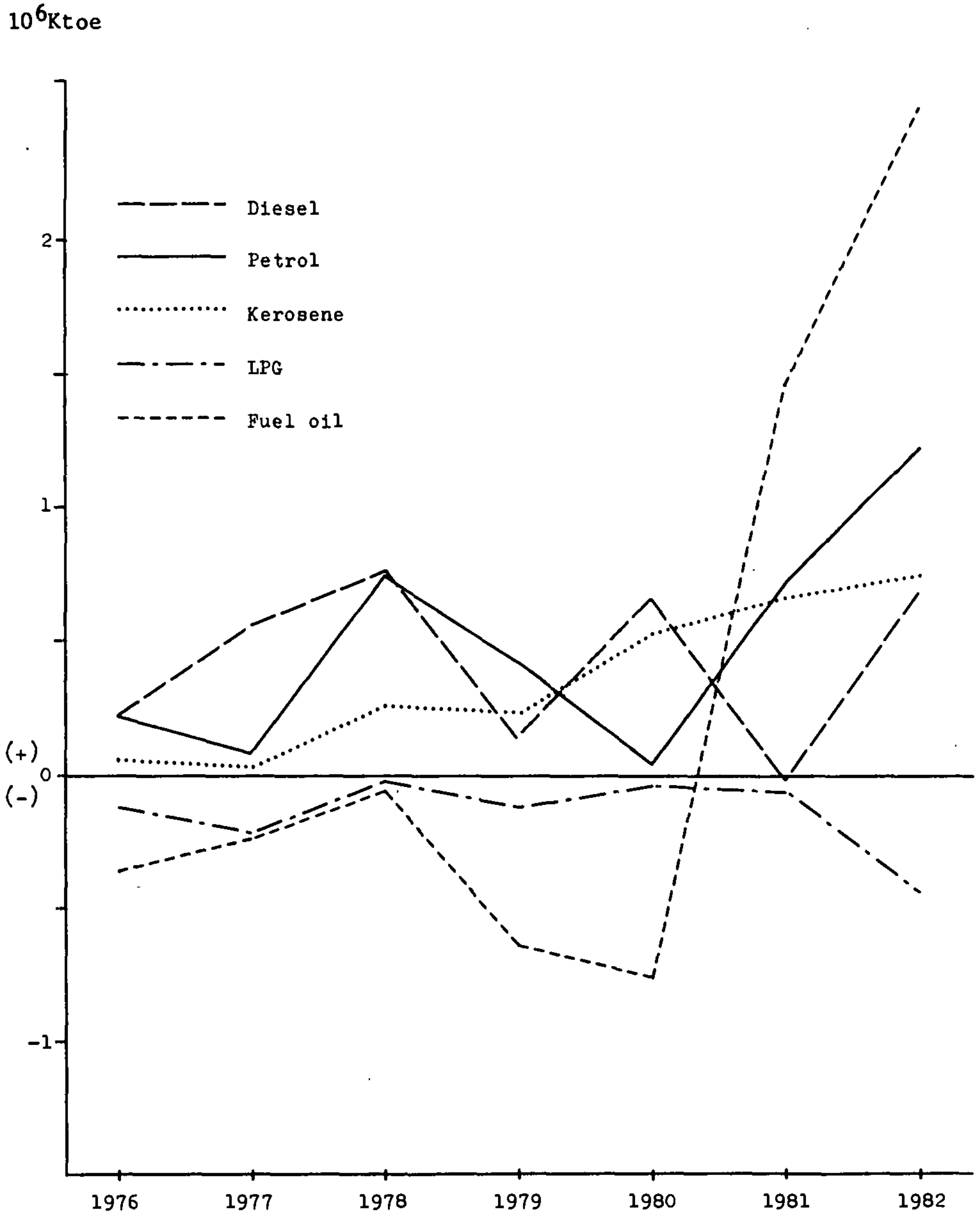
Figure 4: Surpluses (+) and deficits (-) of oil products (1975-82)



Source: Elaborated from Brazilian Energy Balance - MME (1983).

Brazil is self-sufficient in oil-refining capacity. In early 1979, its capacity amounted to 1,265,000 bbl per day of crude-oil throughput, which was roughly 10 per cent above the total consumption of oil products. The sector comprises twelve refineries. Ten of these are owned by PETROBRAS and shared 98.5 per cent of the total capacity in 1980, while the other two are privately owned. Over 90 per cent of the total capacity is distributed among seven relatively modern refineries with individual capacities of more than 75,000 bbl per day. Most of these refineries have "secondary" and "conversion" processing facilities with some flexibility to change the "crude slate". Brazil's oil-refining pattern between 1973 and 1982 is shown in table 13. The changes which have been made in the fuel fractions, however, have not matched the changes in fuel consumption. For example, fuel-oil consumption fell by 38 per cent between 1979 and 1982, but its production decreased by only 20 per cent. Petrol consumption also decreased, but the oil refineries have not been flexible enough to decrease the petrol fraction to a point where all fuel ethanol produced can replace equivalent amounts of petrol.

Up until 1980, consumption/production imbalances were not a major problem, because the consumption of both fuel oil and diesel (which together accounted for about 60 per cent of crude-oil consumption) was increasing along a similar growth path (figure 3). Crude-oil consumption had, until then, been increased primarily to satisfy the demand for these two fuels, even though a significant surplus of petrol had begun to appear in 1978 and 1979. Decreasing consumption of fuel oil, after 1979, meant that crude-oil consumption had to be reduced. The options were either to import separate supplies of diesel while maintaining the crude slate as it was, or to adjust it to the changes in the pattern of fuel consumption.

Table 13: Oil-refining pattern in percentages (1973-82)

Year	Petrol	Diesel oil	Fuel oil	Subtotal	Other[1]
1973	28.4	23.3	30.8	82.5	17.5
1975	26.9	23.4	28.9	79.2	20.8
1977	23.1	27.0	28.4	78.5	21.5
1979	22.9	29.4	30.2	82.5	17.5
1980	18.8	32.8	29.2	80.8	19.2
1981	18.9	34.8	26.4	80.1	19.9
1982	20.3	33.3	24.7	78.3	21.7

[1] Includes LPG, naphtha, kerosene, lubricants, solvents, paraffin, etc.

Source: PETROBRAS (1970-77), CNP (1980) and MME (1983).

The latter option was chosen, and two measures were taken to increase the diesel fraction beyond the 27-29.4 per cent obtained in 1977-79. First, the extra naphtha released, as a result of decreases in the petrol fraction, was mixed with fuel oil and added to diesel to produce a diesel with different, but acceptable, chemical properties. This procedure, however, could only provide a small increase in diesel supply and increased refining costs. Further modifications in the refining structure had to be made in 1981. These decreased the heavy fraction of fuel oil and increased output of diesel, but also increased the light fractions of petrol and/or naphtha. The petrol fraction fell from 22.9 per cent in 1979 to 18.8 per cent in 1980, but increased to 20.3 per cent in 1982.

Under the existing refining structure, more naphtha can, in principle, be released instead of more petrol. In practice, however, the feasibility of this depends on both the domestic demand for naphtha and the comparative export prices of petrol and naphtha. Excluding the amounts combined with fuel oil to produce diesel, the consumption of naphtha increased since 1976, but its supply has been totally met by increased domestic production; since crude-oil consumption decreased after 1979, the additional supply implies a shift from petrol to naphtha. No naphtha has been imported, nor has it been exported, since its world prices are generally lower than those of petrol.

The overall fuel balance in the 1980-82 period raises serious questions about the economic advantages of increasing diesel production against those of reducing crude-oil consumption and increasing separate imports of diesel, LPG and other fuels which might be in deficit. A further decrease in the fraction of fuel oil and an increase in that of diesel is desirable, but the necessary alterations which were being considered for this purpose in 1983-84 require large investments and would still not decrease the petrol fraction, given the limited consumption of naphtha. To decrease it, even greater investments seem to be required.[5] As world prices of diesel have been even higher than those of petrol since 1982, the Government is also considering blending part of the petrol surplus with diesel (and additives to correct the cetane index of these blends). While these options were being studied, more attention was also being paid to demand-side options, such as reducing the gasohol/diesel price ratio as to promote shifts from diesel-powered vehicles to those running on gasohol and hydrous ethanol, including vans, buses and light and medium lorries.[6] Other possible measures which have so far received limited study are the substitution of rail for road in freight traffic and a better management of inter-city freight transport.

Table 14: Consumption (cons.) and production (prod.) of ethanol and ethanol-related oil products in 1976-83 and effects of ethanol on oil-import substitutions and fuel exports in 1980-82 (m.bbl per year)*

	1976	1977	1978	1979	1980	1981	1982	1983
1. Total crude-oil cons.[1]	336	345	386	407	398	385	381	
2. Diesel cons.	86.5	92.8	101.3	110.3	118.5	116.3	117.9	
3. " prod.	88.0	96.9	107.1	111.5	123.4	116.2	123.1	
4. Naphtha cons.				20.9	22.4	25:3	30.6	
5. " prod.				20.7	23.0	25.5	27.3	
6. Additional naphtha cons. for diesel prod.[2]				5.7	6.8	7.5	7.8	
7. " " prod. " " "				5.7	6.8	7.5	8.7	
8. Ethanol cons. (total, 9+10+11)	3.3	6.9	11.8	18.0	19.9	18.4	25.6	34.7
9. Non-fuel ethanol cons.	2.0	2.5	2.3	2.1	3.0	2.5	2.4	2.5
10. Fuel-anhydrous ethanol cons.	1.3	4.4	9.5	13.9	14.2	7.2	12.7	13.7
11. Fuel-hydrous ethanol cons.	0	0	0	2.0	2.7	8.7	10.5	18.5
12. Fuel ethanol cons. (10+11)	1.3	4.4	9.5	15.9	16.9	15.9	23.2	32.2
13. Ethanol prod. (total, 14+15)	3.8	6.7	12.5	18.5	22.6	25.2	31.6	43.0
14. Anhydrous ethanol prod.	1.7	4.6	10.3	15.1	15.5	11.5	15.7	18.9
15. Hydrous ethanol prod.	2.1	2.1	2.2	3.4	7.1	13.7	15.9	24.1
16. Fuel ethanol prod. (13-9)	1.8	4.2	10.2	16.4	19.6	22.7	29.2	41.5
17. Petrol cons. (18+19)	91.9	85.0	86.8	84.8	73.3	69.8	66.8	
18. Aviation petrol cons.[3]	0.5	0.6	0.6	0.8	1.0	1.1	1.0	
19. Automotive petrol cons.	91.4	84.4	86.2	84.0	72.3	68.7	65.8	
20. Petrol prod.	93.7	85.8	93.1	88.4	73.7	75.9	77.1	
21. Gasohol cons. (19+10)	92.7	88.8	95.7	97.9	86.5	75.9	78.5	
22. Total cons. of gasohol and fuel-hydrous ethanol (21+11)	92.7	88.8	95.7	99.9	89.2	84.6	89.0	
23. Total prod. of gasohol and fuel-hydrous ethanol (20-18+16)	95.0	89.4	102.7	104.0	92.3	97.5	105.3	
24. % of anhydrous ethanol in gasohol (10/21)	1.4%	5%	10%	14%	16.4%	9.5%	16%	
25. Petrol prod. as % of gasohol cons. (20/21)	101%	96.6%	97.3%	90.3%	85.2%	100%	98%	
26. Petrol prod. as % of total cons. of gasohol and fuel hydrous ethanol (20/22)	101%	96.6	97.3%	88.5%	82.6%	89.7%	86.6%	
27. Total prod. of gasohol and fuel hydrous ethanol as % of its cons. (23/22)	102%	100%	107%	104%	103%	115%	118%	

Effects of ethanol on oil-import substitutions								
	Direct effects							
28.	Petrochemicals (part of non-fuel ethanol)[4]					1	1	1.2
29.	Petrol (22-(20-18))[5]					16.0	9.7	12.9
	Indirect effects[6]							
30.	Naphtha					2.3	0.3	0.6
31.	Diesel (6)					6.8	7.5	7.8
Effects of ethanol on fuel exports								
32.	Exportable surplus of petrol ((20-18)-(22-12))[7]	1.8	0.8	6.3	4.0	0.4	6.1	10.3
33.	Observed exports of petrol				2.9	2.3	9.2	9.9
34.	Exportable surplus of ethanol (8-13)	0.5	-0.2	0.7	0.5	2.7	6.8	6.0
35.	Observed exports of ethanol	0.12	0.03	0.09	0.69	2.1	2.2	2.1

Notes

1 Volume of crude oil consumed by domestic refineries to produce oil products.

2 The additional production of naphtha for producing diesel was equal to the additonal consumption except in 1982. The gap in 1982 was presumably because of storage and adjustments in 1981, when diesel production decreased, and probably because of the deficit of naphtha for petrochemical and fertiliser production.

3 Aviation petrol is consumed by small private aircraft, and it does not normally include fuel anhydrous ethanol.

4 In 1980, the ethanol-based capacity for petrochemicals (i.e., ethylene, acetaldehyde, ethyl acetate, octanol, butanol, ethylene glycols, ethyl chloride and ethyl ether) was 0.9-1.0 m.bbl according to experts at CENAL and Petroquisa (a subsidiary of PETROBRAS). Detailed time-series data have not been available in official publications, however.

Notes to table 14 (cont.)

[5] This is calculated by subtracting petrol production minus aviation petrol consumption from the gasohol consumption plus the petrol-equivalent amount of fuel hydrous ethanol.

[6] From 1979 to 1980, imports and total consumption of crude oil decreased and there were no naphtha imports. The increased production of naphtha (line 5) to meet the increase in consumption of the fertiliser and petrochemical sectors (line 4) was possible by virtue of the decrease in the fraction of petrol from 22.9 per cent of each bbl in 1979 to 18.8 per cent in 1980. This increased production can therefore be indirectly attributed to ethanol since its supply made it possible to avoid separate imports of naphtha or fertilisers and petrochemicals. By the same token, the increased production of diesel through additional naphtha production (line 7) turns out to be another indirect effect of ethanol, although this is strictly a consequence of the peculiar features of Brazil's fuel supply/demand balance and of ongoing adjustments in the oil-refining sector. In 1981-82, these effects were less evident judging from the data in this table and further information in the Appendix. The indirect substitution effect of ethanol for naphtha in 1982 is estimated as the difference between the increased production of naphtha from 1981 to 1982 and the increased production of petrol from 1981 to 1982 (i.e., 1.8 - 1.2 m.bbl = 0.6 m.bbl) - the same procedure was used for 1981. The logic of this method is this: had there been no shift from petrol to naphtha, the increased output of petrol and naphtha would have been the same. These indirect effects, however, should not be taken into account in the balance-of-payments analysis since, for a given level of ethanol supply, decreases or increases in petrol production (which affect the output of naphtha) are already directly reflected in decreased imports or increased exports of petrol, under the method used.

[7] The petrol surplus represents the amount of petrol available for automotive purposes minus the difference between total consumption of gasohol and fuel hydrous ethanol and total consumption of fuel ethanol. The same result is obtained the same if, instead, one subtracts fuel anhydrous ethanol from gasohol consumption. The logic of this calculation is this: as fuel-ethanol production increases faster than the consumption of fuel ethanol and automotive petrol, there is a reduced need for petrol to meet this consumption.

* For details of oil-product balances for 1979-82, see table 12. The consumption of oil products listed excludes exports and includes (i) imports and (ii) storage, adjustments and losses (notes on individual items are on the next page).

Source: Elaborated from official data by the National Petroleum Council, Ministry of Mines and Energy, Institute of Sugar and Alcohol and the Export Bureau of Banco do Brasil.

2. Effects of ethanol on oil import substitution and fuel exports

The available data on the consumption and production of fuels between 1976 and 1983 are summarised in table 14. It also includes data on the oil import substitution effects of ethanol in 1980-82, and figures on both exportable surpluses and actual exports of ethanol and petrol (there have been no exports of naphtha). The notes to this table provide detailed explanations which supplement the brief analysis below.

The direct substitution of ethanol for petrochemicals is straightforward. The amount is determined simply by the consumption of ethanol-based petrochemicals, or the additional naphtha which would be required to produce them. In 1980, this was roughly 1 m.bbl - 5 per cent of total ethanol consumption. According to STI experts, the amount may have increased slightly to 1.2 m.bbl in 1982, but it is expected to further increase to about 4.4 m.bbl in 1985, when some new ethanol-based petrochemical facilities will have begun production.

The amount of ethanol that can be directly substituted for petrol imports is determined from the total consumption of gasohol and fuel-hydrous ethanol minus the production of petrol available for the same uses (i.e., petrol production minus the consumption of aviation petrol). Part of the ethanol actually used in vehicles is reflected in import savings while the remaining is reflected in exports of petrol. The import substitution effect of ethanol is highest in years in which there are substantial decreases in the fraction of light distillates, due to changes in the crude slate, as in 1980. However, there have been also indirect substitution effects which require further analysis.

The indirect substitution of ethanol for naphtha can be estimated at 2.3, 0.3, and 0.6 m.bbl in 1980, 1981 and 1982, respectively. These estimates are based on the assumption that, for a given level of crude-oil consumption, the increase in output of petrol and naphtha will be about the same if there is no shift from petrol to naphtha. If the increase in naphtha output is higher than that of petrol, the shift from petrol to naphtha can be attributed to the substitution of ethanol for petrol. Similarly, the production of diesel from naphtha (added to diesel and crude oil) is also possible through the reduced demand for petrol, due to the supply of ethanol. The substitution of naphtha for diesel amounted to 6.8 m.bbl in 1980, 7.5 in 1981 and 7.8 in 1982.

These indirect effects can be particularly important whenever c.i.f. import costs of naphtha and diesel are higher than f.o.b. prices of petrol exports. This has recently been the case for diesel but not for naphtha. Nevertheless, these indirect effects cannot be credited in the balance of payments since, for a given level of ethanol supply, a decrease or increase in petrol production (which affects the domestic output of naphtha) is already directly reflected in decreased imports or increased exports of petrol.

To calculate the direct and indirect effects separately, it would be necessary to carry out two detailed analyses of oil product balances since 1975 (before ethanol production became considerable) to the present - one including ethanol, the other assuming no ethanol production. Each of these situations would be disaggregated into various scenarios of crude-oil throughput to determine which level of crude-oil consumption and oil product imports would have the lowest economic cost. This type of analysis would also determine the economic cost of the petrol surplus, which is critical in the estimation of PNA's impact on the balance of payments. This analysis cannot be done here, due to the lack of disaggregated data on oil product balances for the 1975-79 period.

3. Balance-of-payments impact

The following factors must be taken into account in the assessment of PNA's balance-of-payments impact:

(1) c.i.f. value of substitutions of ethanol for imports of fuels and petrochemicals (or their feedstocks, e.g., naphtha);
(2) c.i.f. value of imported production inputs;
(3) cost of imported capital (and/or equipment and technology whenever the case) for ethanol production as well as for investments in changes in the oil-refining structure due to increased ethanol supply;
(4) loss of export revenues from sugar (or manioc starch, or molasses, if these are used as raw materials) in situations where (a) sugar exports can be increased, and (b) f.o.b. export revenues per tonne of sugar-cane are higher than the c.i.f. import cost of petrol (in amounts equivalent to the output of ethanol per tonne of sugar-cane) but where a captive domestic market for ethanol restricts higher exports of sugar;
(5) f.o.b. value of ethanol exports;
(6) loss of ethanol export revenues in situations where the world prices of ethanol become higher than those of petrol, and where a captive domestic market for ethanol, such as that of hydrous-ethanol cars, does not allow a reverted substitution of petrol for ethanol;
(7) f.o.b. value of petrol exports, if any, made possible by the substitution of ethanol for petrol;

(8) c.i.f. import cost of the exportable surplus of petrol (or of its crude-oil equivalent), which is debited against the credited revenues from petrol exports (assuming these could only be possible, due to a surplus with direct or indirect implications for oil imports);

(9) foreign exchange losses derived from higher imports or lower exports of food crops, which are caused by the substitution of ethanol raw materials for these crops.

Any assessment of the balance-of-payments impact of ethanol production tends to be slightly distorted because most of the items listed above cannot be measured accurately. These are briefly discussed below with reference to the impact in 1980, which is summarised in table 15. Further considerations will then be made about the impact in 1982 (also given in table 15).

The c.i.f. value of imported inputs to industrial and agricultural production, and the costs of imported capital mentioned earlier, amounted to $170.4 million and $200 million (see footnote 1).

Losses in sugar export earnings were not evident even in 1980 and the beginning of 1981, when sugar prices reached their highest levels since 1974 and the ISA quota was temporarily suspended. This requires some brief explanations.

Brazil was able to export as much sugar over the 1970s as the ISA allowed. Variations in sugar production (table 24, Appendix A) were mainly caused by price fluctuations and supply restrictions rather than the expansion of sugar-cane production for ethanol. BANCO DO BRASIL's export accounts show that sugar exports rose from $39.5 million in January 1981 to $181 and $114.3 million f.o.b. in February and March. The March figure was roughly 100 per cent higher than sugar export earnings one year earlier, and the decrease from February to March 1981 was caused by the fall in sugar prices. In 1980, Brazil had a sugar-mill capacity of about 10-11 million tonnes but produced less than 8 million tonnes of sugar, having exported 2.5 million tonnes at $504 per tonne f.o.b. ($13,000 million). In principle, the ISA would have allowed a Brazilian export of 2.2 million tonnes, but the quota was suspended in February 1980, as world sugar prices surpassed $0.23 per pound ($480 per tonne).

This may lead one to think that Brazil may have been able to export more sugar in 1980, as in fact suggested by Islam (1980). But, even if this were true, the short-term marginal benefits from these additional exports would have pushed world sugar prices down and possibly reduced export revenues in following years. Furthermore, considerably higher exports in 1980 would have necessitated higher sugar output in 1979 and 1978 since there are time lags between demand and supply. Had this been the case, world prices might not have increased as much as they did in 1980. Indeed, it can be argued that Brazil's commitment to ethanol may sometimes contribute to higher sugar prices. There is also no reason to believe that there were

losses in exports of molasses, which accounted for 25 per cent of ethanol production in 1980. Exports increased from $10 million to $24 million and $29 million f.o.b. in the first three months of 1980, and from $16 million to $30 million to $41 million during the same months in 1981.

Provided that the ISA is able to maintain control over sugar supply, and that effective short-term forecasting of demand for molasses and sugar is continued, Brazil is unlikely to incur any considerable loss in export revenues from these commodities in the near future, because of the following factors. The country has a relatively large supply of petrol, and has the options of (a) increasing sugar production, (b) changing the relative share of molasses and sugar-cane in ethanol production and (c) reducing supply of anhydrous ethanol for gasohol blends. Moreover, there is a slight risk that the ISA may become less effective in the future if non-member OECD producers continue to increase their share in sugar supply. If this happens, world prices will probably drop considerably, and the opportunity cost of sugar-cane for ethanol will decrease as well.

It is difficult to ascertain the amounts of ethanol export revenues foregone because of fluctuations of world demand and prices. However, it is rather clear that no losses were incurred until at least 1983. Annual exports of ethanol have been much lower than the exportable surplus, as table 14 shows. Here again, there is the possibility of reducing the percentage of anhydrous ethanol in gasohol. In 1980, ethanol exports were 219 per cent higher than in 1979. The average price per bbl was $56 f.o.b. ($16 above the average price in 1979), which produced a total revenue of $117.6 million (for 2.1 m.bbl) compared to $26 million in 1978 and $3.5 million in 1979. Export losses may nevertheless be incurred in the future, due to (a) the necessity of providing sufficient supply of hydrous ethanol for cars running exclusively on this fuel, (b) the differentiated international demand for hydrous and anhydrous ethanol and (c) the constant fluctuations in the prices and the demand for these products. Although the average export price was $56 per bbl in 1980, prices reached $80 per bbl during short periods. During the first two months of 1981, prices rose to $79.5 per bbl, but by August 1981, the volume of exports was the lowest since early 1979 and prices decreased to less than $55 per bbl, having fluctuated within the $50 range at least until mid-1983.

Petrol surpluses have been rising substantially since 1980, but have easily been exported. For balance-of-payments analysis, one must take the exportable surplus into account rather than the exports which actually took place in a given year, since the latter are not necessarily all related to ethanol. Even in recent years, there have been some very minor imports of petrol, which may perhaps consist of high-octane petrol or may be a result of trade agreements. As discussed earlier, however, the real resource cost of petrol exports cannot be estimated without a detailed study of the oil-refining sector.

Table 15: PNA's impact on the balance of payments - 1980 and 1982 ($ millions)[1]

	1980				1982			
	Case A Credits	Debits	Case B Credits	Debits	Case A Credits	Debits	Case B Credits	Debits
1. Import substitution of [a]								
1.1 Petrochemicals	41		41		44.9		44.9	
1.2 Petrol	707.2		707.2		522.4		522.4	
2. Imported inputs								
2.1 Diesel		77.8		77.8		108.8		108.8
2.2 Fertilisers		57		57		79.7		79.7
2.3 Insecticides, herbicides and fungicides		27.8		27.8		38.9		38.9
2.4 Industrial inputs		7.8		7.8		10.9		10.9
3. Losses of sugar exports		0		0		0		0
4. Cost of imported capital for PNA's investments		200		200		279.6		279.6
5. Ethanol exports	117.6[b]		151.2[b]		117.6[b]		117.6[b]	
6. Losses of ethanol exports		0		0		0		0
7. Petrol exports	16.8		16.8		394.5		394.5	
8. Import cost of petrol exports		14.3[c]		0[c]		293.5[c]		0[c]
9. Cost of imported capital for oil-refining investments due to ethanol		Fc1		Fc1		Fc1		Fc1
10. Foreign-exchange losses from from crop substitutions		Fc2		Fc2		Fc2		Fc2
Total net balance	+497.9-(Fc1+Fc2)		+545.8-(Fc1+Fc2)		+268.0-(Fc1+Fc2)		+561.5-(Fc1+Fc2)	

Notes to table 15

[1] Oil-product import savings and imported inputs to production are valued in c.i.f prices, and exports in f.o.b prices. Oil product f.o.b. prices (per bbl) are annual averages (Rotterdam spot market as quoted monthly in the Petroleum Economist); for naphtha, diesel, and petrol, these were respectively $38.8, $41 and $42 in 1980, and $35.4, $38.6 and $38.3 in 1982. Petrochemicals are valued in c.i.f prices of naphtha which is their major feedstock. The c.i.f prices of these oil products are increased by a shipping cost of $2.2 in 1980 and an estimated $2.0 in 1982. Input prices are from UNCTAD's Yearbook of Trade Statistics. Data on import substitutions (line 1) and exports (lines 5 and 7) are in Table 14. Data on imported inputs (line 2) are in footnote 1. Other items are discussed in the text. The differences in assumptions in Cases A and B for 1980 and 1982 are stated briefly in notes (b) and (c) below and are also discussed in the text. Fc1 and Fc2 (lines 9 and 10) cannot be estimated on the basis of available data (see text). Ethanol production was 22.6 m.bbl in 1980 and 31.6 m.bbl in 1982.

(a) Indirect effects on import substitutions of naphtha and diesel (Table 14, lines 30 and 31) are not credited, since these are already reflected in petrol-import substitutions.

(b) For 1980, Case A includes actual exports that took place during the year (2.1 m.bbl), and Case B includes the exportable surplus (2.7 m.bbl). For 1982, both Cases A and B include observed exports only (also 2.1 m.bbl), since the exportable surplus in 1981 and 1982 was about three times higher than actual exports. Ethanol export prices were about the same in 1980 and 1982: $56/bbl.

(c) For both 1980 and 1982, Case A assumes this cost at the margin; it includes the c.i.f cost of crude oil ($32.2 f.o.b plus $2.2 shipping cost per bbl in 1980, and $25.5 f.o.b plus $2.0 in 1982), increased by the foreign-exchange component of the petrol-refining cost ($1.3 in 1980 and $1 in 1982 - at borrowing conditions assumed in Chapter 3, section 4 for domestic refining costs of $10 in 1980 and an estimated $8 in 1982 - see text and footnote 7), totalling $35.7 in 1980 and $28.5 in 1982. Case B values the import cost of petrol exports at zero, assuming the demand for different oil products made it economic to import the crude oil which produced the exportable surplus of petrol.

Source: See notes.

Two cases of the balance-of-payments impact are presented in table 15 for 1980 and 1982. Each of these is based on different assumptions as regards the import cost of petrol exports (line 8) and ethanol export revenues (line 5). Case A is less favourable than Case B. It values the import cost of petrol exports at the margin, under the assumption that it was economic for Brazil to import separate supplies of LPG and other oil products (i.e., diesel and possibly kerosene) - these would have been in deficit if crude-oil consumption had been decreased below the 1980 and 1982 levels (hence reducing surpluses of petrol and fuel oil). This import cost is calculated (per bbl) as the c.i.f. cost of crude oil (average Rotterdam spot f.o.b. price of $32.2 plus shipping cost of $2.2 in 1980, and $25.5 plus $2 in 1982), increased by the foreign exchange component of the refining cost of petrol,[7] totalling $35.7 in 1980 and $28.5 in 1982. In Case B, it is assumed that it was more economic to import crude oil than to import separate supplies of the above products, and no import cost is debited.

As regards ethanol exports, different sets of assumptions are made for 1980 and 1982. For 1980, Case A credits exports that had taken place in that year only (2.1 m.bbl, which were less than the exportable surplus) under the assumption that Brazil continued to experience difficulties in exporting ethanol (which was the case) and had to increase domestic ethanol consumption through further incentives to Sunday drivers. The increasing gap between the exportable surplus and the observed exports (table 14, lines 21 and 22) would justify this assumption even for more recent years. Case B assumes that the remaining surplus (0.6 m.bbl) was exported in 1981. For 1982, the observed ethanol exports (2.1 m.bbl) are credited in both Cases A and B, since it is evident that the remaining exportable surplus (3.9 m.bbl) could not have been exported in the following year (the remaining surplus in 1981 was even higher).

For 1980, the difference in PNA's net balance of payments based on either set of assumptions is not large: $497.9 million for Case A, and $545.8 million for Case B. In each case, the impact is quite positive, especially when considering the limited amount of investments which PNA required for infrastructure in its first five-year period.

This impact omits foreign exchange losses which may have been caused by substitutions of sugar-cane for food and export crops. Although these cannot be estimated on the basis of information available, their extent, if any, will have been minor and associated with short-term lags in crop relocations. It also omits costs of imported capital which may have been required for ethanol-related changes in the oil-refining sector in 1980-81. Nevertheless, these costs should not significantly alter the above findings, since modifications in the oil-refining structure relate not only to ethanol and petrol, but also to fuel oil, diesel and other products. Furthermore, ethanol production may also avoid investments in the oil-refining sector, under certain fuel supply/demand conditions.

PNA's balance-of-payments impact in 1980 was unusually favourable, however. As a result of changes made in the oil refineries, petrol production was at its lowest level since the early 1970s. This allowed a relatively high substitution of ethanol for oil imports, compared to 1981 and 1982.

On the basis of the data in table 14 and the assumptions made for 1980 regarding sugar exports and effects of crop substitutions, PNA's impact on the balance of payments in 1982 may be estimated at $268.0 million for case A and $561.5 million for case B. For this estimate, 1982 average Rotterdam spot prices of oil products were also used. Volumes of imported inputs were increased proportionately to the increase in ethanol output; their costs were calculated assuming no changes in their c.i.f. prices (except for diesel) from 1980 to 1982. For diesel, 1982 c.i.f. prices were used, since these were considerably lower than in 1980. Financial costs of imported capital were also increased proportionately. This method and assumptions for estimating costs of imported inputs may imply some distortions, but do not change final figures significantly.

In years in which there is a large petrol surplus as in 1982, the main item which makes a major difference to PNA's balance-of-payments impact is the import cost of the petrol surplus. Although neither this cost nor the overall economic cost of petrol had been determined by the Government until late 1983 (see footnote 5), it is imperative to do so in the light of recent trends in consumption and production of fuels. Unless these costs are known, it is impossible to reach firm conclusions about the net economic benefits of exporting petrol and, therefore, of having an increasingly large output of ethanol. For the same reason, the comparative benefits of the oil-sector options discussed earlier cannot be clearly assessed.

Given the increasing surpluses of car fuels, and also of fuel oil (which has been exported at 61-68 per cent of the f.o.b. price of crude oil, depending on sulphur content),[8] the assumption made about the petrol import cost in Case A is more likely to be correct than that in Case B. If so, it may be that ethanol output has grown beyond the economically optimal level. Table 14 shows car-fuel consumption lagging well behind production (line 27), in spite of the price and fiscal incentives given to ethanol and ethanol cars, particularly since 1981. Further incentives in 1982 and 1983 began to reduce the ethanol surplus after 1982, but the overall benefits of this sort of policy are questionable, since ethanol continues to be consumed primarily by cars for private use. Reducing the growth rate of ethanol output has not been among the options preferred by the Government, but it seems to deserve more attention.

In principle, PNA's balance-of-payments impact may improve in the future, as a result of increased direct substitution of ethanol for petrochemicals and shifts in consumption from diesel to gasohol and fuel hydrous ethanol. In practice, this will depend mainly on the production and the surplus of petrol and on the uncertain import costs

of this surplus. The planning link between the oil-refining sector and the transport sector is improving and inter-related projects in both sectors are under way, but so far there have been no promising short-term solutions for the petrol/diesel imbalance referred to earlier.

Notes

[1] A total of 22.6 m.bbl of ethanol (15.1 m.bbl of anhydrous ethanol and 7.1 m.bbl of hydrous ethanol) is equivalent to 21 m.bbl of petrol. Rotterdam spot prices (c.i.f.) are assumed ($44.2 per bbl) totalling $928.2 million. An estimated financial cost of imported capital of $200 million a year (Chapter 3, section 4) together with c.i.f. prices of inputs (imported at the margin), are then subtracted from this, namely (in $ millions) 77.8 of diesel, 57 of fertilisers, 27.8 of insecticides, herbicides and fungicides and 7.8 of industrial inputs. Data on diesel inputs are from Silva (1976), and on other inputs from CNPq (1978) and official data from PLANALSUCAR and IAA; input prices were based on UNCTAD (1983). Silva's coefficient of 311.7 litres of diesel per ha refers to the C/S macro-region. It takes into account manual cutting and mechanised loading during the harvest; an average distance of 10 km between the distillery and the farm; some transport of labourers by lorries as practised in Brazil, and other diesel-consuming operations in cultivation. Hence, 3,500 million litres divided by 70 litres per tonne equals 50 million tonnes of sugar-cane, which requires at least 0.93 million ha of harvested land. This multiplied by 311.7 litres per ha gives 286.7 million litres or 1.8 m.bbl of diesel. This is finally multiplied by $43.2, which is the c.i.f. price of diesel ($41 f.o.b. plus a $2.2 shipping cost), totalling $77.8 million. The fertiliser costs were based on PLANALSUCAR's recommendations for fertiliser consumption per ha, i.e., 99.5 kg (N), 141.2 kg (P) and 118.8 kg (K), totalling 359 kg of fertilisers per ha. Although about 57 per cent of fertiliser consumption was produced in Brazil in 1980, it is assumed here that PNA increases the demand for imported fertilisers due to insufficient domestic production 359 kg x 0.93 million ha = 333.9 million kg). It is estimated that the use of stillage may have replaced 10 per cent of the overall need for fertiliser. Therefore, 300,000 tonnes x $190 per tonne (1980 c.i.f. price for Brazil's imports) totals $57 million. The import cost of insecticides, herbicides and fungicides were also based on PLANALSUCAR's using the same accounting method. The final figures implied an import total of 4,510 tonnes multiplied by the average price of $3,700 per tonne (c.i.f.), which equals $27.8 million. Industrial inputs include sulphur (for the production of sulphuric acid), ammonia, diamonium sulphate, caustic soda and anti-foam, which are normally consumed in amounts of (kg per m^3 of ethanol) 2.4, 10.5, 3.7, 0.3 and 0.1, respectively. Enzymes are imported for the production of ethanol from manioc in amounts of about 5 kg per m^3 of ethanol. The minor enzyme requirements for the

output of the only manioc distillery operating in Brazil in 1980 were taken into account. Probable imports of steel used in industrial equipment were not included, due to the lack of information, although they would not be significant. The import cost of $7.8 million results from multiplying the amounts of inputs, which presumably had to be imported in 1980, by their c.i.f. prices.

[2] For a detailed analysis of Brazil's transport fleet and its policy implications, see Pinheiro (1983).

[3] It is noteworthy that in 1950, 38 per cent of all freight went by road and 29 per cent by rail (Kowarick, 1980, p. 48).

[4] ibid., p. 49.

[5] CENAL (1983) provides a detailed analysis of recent changes in the oil-refining structure, further options and their capital costs, but it does not assess the extent to which these changes and costs are due to ethanol supply. The study questions the benefits of the petrol surplus and exports, but it does not determine the import cost nor the overall economic cost of this surplus.

[6] See Pinheiro (1983), CENAL (1983), and Alvim da Silva et al. (1982).

[7] Given Brazil's foreign debt situation, it is assumed that refining additional supplies of petrol with domestic capital leads to borrowing at the margin. Hence, the petrol-refining cost of $10 per bbl in 1980 (table 2) implies an annual foreign exchange cost of about $1.3 at borrowing terms assumed in the previous chapter. For 1982, the petrol refining cost is estimated at $8 (using the same ratio between crude-oil price and refining cost in 1980 - see World Bank, 1980b, p. 38), and the foreign exchange cost of about $1.

[8] CENAL, 1983, p. 21.

CHAPTER 5

DIRECT EMPLOYMENT IMPACT

Ethanol production generates direct employment primarily in the operation of distilleries and in the cultivation and transport of sugar-cane. Indirect employment is created in the manufacture of equipment for ethanol and sugar-cane production; the installation and construction of distilleries and of adjacent infrastructure; the operation of gasohol mixing centres; the distribution of hydrous ethanol; R and D; government services and other activities. Direct employment can be estimated on the basis of surveys of distilleries and plantations, but indirect employment can hardly be assessed, because it includes mostly short-term jobs, and many of these are not exclusively tied to ethanol. For example, major manufacturers of distillery equipment also produce other types of equipment; jobs created in the manufacture of hydrous-ethanol cars or in the alcohol-chemical industry may be credited to PNA, but these jobs would have existed if petrol cars or petrochemicals were produced instead.

Therefore, this chapter focuses on direct employment only. It begins with an introductory discussion of ethanol-related activity and a general note on the methodology of employment assessment (section 1). This is followed by analyses of the direct employment created by individual ethanol distilleries (sections 2 and 3) and by total ethanol production at the end of the first five-year period (section 4). Finally, qualitative aspects of direct employment including social implications of labour seasonality are discussed (section 5). Appendix C analyses the choice of techniques in sugar-cane cultivation which concern ethanol production and employment.

To understand the quantitative and qualitative aspects of employment, one should bear in mind the basic characteristics of agricultural and agro-industrial production. As noted earlier, in Brazil, ethanol is produced directly from sugar-cane, but also indirectly from molasses in the case of annexed distilleries. Most distilleries operate for 150-180 days per year for 24 hours per day, in two 12-hour shifts during the harvest season. In the off-season (150 days), agro-industrial activities encompass equipment and vehicle maintenance, construction, etc., whereas agricultural activities include crop renewal and maintenance.[1]

The extent to which the number of workers in a given occupational group increases from the off-season to the harvest period depends on factors other than the work to be done. For example, because there is a shortage of well-trained lorry drivers, mechanics and farm machine operators, these are offered permanent employment in the majority of cases, although their activity is substantially reduced in

the off-season. On the other hand, almost all the additional unskilled workers in industry and agriculture required during the harvest season (for the extra 12-hour shift and additional agricultural activity, respectively) are employed on a seasonal basis.

During the off-season, the labour employed in agro-industrial operations consists largely of permanent workers. In agriculture, however, the mix of permanent and seasonal workers varies significantly from one plantation to another, even in the off-season. In a minority of plantations, over one-half of the total number of workers employed during the harvest have year-round jobs. In some of these cases, the agricultural labour force during the harvest period comprises the permanent workers, plus the seasonal ones. This implies a high degree of interchangeability of labour for different tasks (i.e., permanent workers perform different tasks throughout the year). Normally, however, the permanent labour force is considerably smaller than the seasonal one - around 32 per cent compared to 68 per cent according to estimates by CENAL in 1981.[2] Although seasonality of labour is largely caused by the seasonal nature of sugar-cane cultivation, variations among plantations in their compositions of permanent and seasonal labour in a given period are also caused by different labour and agricultural management techniques. Many year-round jobs are not filled by permanent workers, but by varying numbers of temporary ones. Many plantations hire labour indirectly through external contractors with a high turnover of workers. Annual variations in the demand for labour on a given plantation are also partly caused by the production cycle of sugar-cane, but they will vary among plantations depending on the techniques of crop renewal used.

The effects of the production cycle and the rate of crop renewal on employment deserve further discussion. There are basically two types of sugar-cane: the 12-month and the 18-month. The latter, which is the most common type in Brazil, takes 18 months to reach the first harvest period. Each plantation yields two or three further crops (also called ratoons) which take about 12 months to reach maturity and have progressively decreasing yields per ha.

Crop renewal - the replanting and cultivation of new sugar-cane - is normally not carried out all at once (every third or fourth cut) but staggered over a series of off-seasons. Not all sugar-cane producers follow the same crop-renewal techniques, although some of these are much more efficient than others in terms of both annual returns per ha and employment generated. There are various reasons why the best technique may not always be adopted. These include managerial deficiencies in the case of plantations owned by distilleries and sugar mills and unstable annual demand for crops in the case of external sugar-cane suppliers. In the latter case, the farmer may tend to make maximal use of his land by planting it all with sugar-cane in one year in order to maximise his crop return in the first harvest. However, he will have diminishing returns thereafter, while not being able to replant more sugar-cane in the second and third years to compensate for his increasing losses.

Table 16: Sugar-cane production cycle and alternative rates of crop renewal (P) - Brazil's case of 18-month canes - to meet the requirements of an autonomous distillery* of 120,000 LPD** (t - thousands of tonnes; os - off-season; hs - harvest season)

Months:	(os) 0	(hs) 6	(os) 12	(hs) 18	(os) 24	(hs) 30	(os) 36	(hs) 42	(os) 48	(hs) 54	(os) 60	(hs) 66	(os) 72
Alternative A													
Optimal rate of crop renewal to meet self-sufficiency every year	P(i) 2 500ha			1H(i) 257t		1R(i) 155t		2R(i) 125t		3R(i)[4] 105t			
		season	P(ii) 1 000ha		103t	1H(ii)	62t	1R(ii)	50t	2R(ii)	42t	3R(ii)[4]	
					P(iii) 680ha			1H(iii) 70t		1R(iii) 42t		2R(iii) 34t	
	a. Assuming 4 cuts (1 harvest (H) and 3 ratoons (R)); minimal area required: 4 760 ha.					P(iv)a 580ha or			1H(iv)a 60t		1R(iv)a 36t		
	b. Assuming 3 cuts (1 harvest (H) and 2 ratoons (R)); minimal area required: 5 780 ha.					P(iv)b[1] 1 600ha			165t	1H(iv)b	99t	1R(iv)b	
									P(i)b[2] 855ha			1H(i) 88t	
											P(i)a[3] 2 060ha		
Alternative B													
Irregular rate of crop renewal assuming 3 cuts	P(i) 2 500ha			1H(i) 257t		1R(i) 155t		2R(i) 125t (surplus)					
					P(ii) 2 500ha			1H(ii) 257t		1R(ii) 155t (deficit of 103t)		2R(ii) 125t (surplus)	
									P(iii) 2 500ha			1H(iii) 257t	

Notes to table 16

* Without production of ethanol from molasses, at an average yield of 70 litres per tonne.

** Assumes an annual requirement of 257 000 tonnes of sugar cane per year for a production of 18 million litres. The requirements of sugar cane and land area were calculated on the basis of yields supplied by Silva (1976) for the State of Sao Paulo: harvest cut (1H) 103 t/ha; first ratoon (1R) 62t/ha; second ratoon (2R) 50t/ha, and third ratoon (3R) 42t/ha

[1] P(iv)a takes place in the case of a four-cut system, whereas P(iv)b in a three-cut system.

[2] P(i)b takes place in the original P(i) area in the case of a three-cut system.

[3] P(i)a takes place in the original P(i) area in the case of a four-cut system.

[4] Takes place under a four-cut system only.

Source: Elaborated on the basis of information from IAA and PLANALSUCAR, and Silva (1976).

Typical plantations in the most productive areas of Brazil yield about 103 tonnes per ha in the first harvest, 62 in the first ratoon and 50 in the second. With the usual three or four cuts per planting, the most efficient technique for a distillery's plantation to follow is not to make full use of the land in the first planting period or in two separate periods only (table 16, alternative B), but rather to stagger the planting periods. Thus, the first planting will yield the necessary amount to meet the demand for raw material in the first harvest season, whereas the second and the third plantings will provide the additional supplies to compensate for the diminishing returns of the ratoons of the first planting (table 16, alternative A).

This optimal practice ensures a stable supply of raw material, and requires planting activities every year (although decreasing from the first planting to the third and increasing again thereafter). Furthermore, part of the land area may be used for the production of other crops under alternative integrated farming techniques, which would ensure additional returns per ha and more stable employment.

Non-optimal practices of crop renewal, on the other hand, will result in alternating surpluses and deficits of sugar-cane, as well as off-season periods without any planting activity. Cultivation and maintenance activities will create a year-round demand for labour,

but this will be much higher and more stable in plantations where the planting activities are evenly distributed. This means that the percentage of permanent workers can be considerably higher, depending on the substitutability between different types of labour for off-season and harvest-season tasks, as discussed in section 5.

1. Methodology for assessing direct employment

The data used are based partly on the author's field surveys,[4] supplemented by published information and interviews with public officials and managers of distilleries and plantations. In the survey, relevant data were collected concerning six occupational groups:

I. directors and top management;
II. skilled personnel, that is, agronomists, accountants, chemists and other professionals and technicians;
III. semi-skilled personnel employed in office services, that is, secretaries, maintenance employees, etc.;
IV. semi-skilled people in agro-industrial operations, that is, drivers, vehicle and equipment mechanics, work supervisors, etc.;
V. unskilled industrial workers; and
VI. unskilled agricultural workers and farm machine operators.

The information regarding each of these groups was divided into off-season and harvest season periods. Data on hours per week, weeks per period and salaries were collected for each of the occupational groups IV, V and VI.

Given the employment picture outlined earlier, employment in administrative/agro-industrial categories (occupational groups I-V), can be quantitatively assessed through a single survey at one point in time, since these groups remain virtually unchanged over an annual period and the seasonal variations are both minor and normally constant. However, the same cannot be done for agricultural workers (group VI) as a result of the sugar-cane production cycle and the rate of crop renewal.

Hence, it is necessary to assess direct employment separately for these two occupational groups in distilleries of different scales, before turning to total employment created under PNA.

2. Administrative/agro-industrial employment

Based on the author's survey, table 17 shows year-round and seasonal employment in individual autonomous distilleries of 90, 120 and 240 thousand LPD, according to occupational groups described above.

Seasonal employment occurs mainly in industrial unskilled labour (group V); much less so among agro-industrial, semi-skilled workers (group IV), and is non-existent in occupational groups I-III, although some professionals in group II (such as chemists, accountants,

Table 17: Administrative and agro-industrial employment in autonomous distilleries of 90,000, 120,000 and 240,000 LPD[1]

Nature of employment/ Occupational groups	Scale of distilleries (LPD) 90 000			120 000			240 000		
	No. of jobs	(%)	jobs/ m.1	No. of jobs	(%)	jobs/ m.1	No. of jobs	(%)	jobs/ m.1
Administrative/ agro-industrial[2]									
1. Year-round I and II	7			7			7		
2. Year-round III	10			10			11		
3. Year-round IV	27			30			40		
4. Seasonal IV (harvest season)	6			7			10		
5. Year-round V	27			30			50		
6. Seasonal V (harvest season)	22			24			40		
7. SUB-TOTAL year-round	71	72	5.2	77	71	4.3	108	68	3.0
8. SUB-TOTAL seasonal	28	28	2.1	31	29	1.7	50	32	1.4
9. TOTAL (7 and 8)	99	100	7.3	108	100	6.0	158	100	4.4

[1] These approximate figures are based on the author's survey (see section 1). Because of variations in scale, and in capacity utilisation (CU) in distilleries of the same scale, only 13 of the 28 autonomous distilleries surveyed could be taken into account. These included 8 units of 120,000 LPD, 2 of 90,000 LPD and 3 of 240,000 LPD. Even among these, the 120,000 LPD units had CU variations of 14 per cent; two of them with an output above 120,000 LPD. The standard deviations of the figures in line 9, first columns were as follows: 8.00 (90,000 LPD); 8.89 (120,000 LPD), and 13.88 (240,000 LPD).

[2] Occupational groups are described in section 1.

Source: Author's survey.

physicians) do not always have full-time jobs. In these administrative/agro-industrial categories, total employment (including year-round and seasonal jobs) amounts to 99 for an annual production level of 13.5 million litres (m.l); 108 for 18 m.l and 158 for 36 m.l. This shows the effect of scale on the amount of labour required. For example, a 120,000 LPD distillery generates about 4.3 year-round and 1.7 seasonal jobs per million litres, whereas a 240,000 LPD unit generates 3.0 and 1.4 jobs, in the same order; the percentages of year-round employment are 71 per cent and 68 per cent, respectively.

For each of the standard scales of distilleries, variations in capacity utilisation primarily affect the employment of lorry drivers and, in some cases, of unskilled workers in unloading operations[5] but the overall effect is negligible. Moreover, any distillery will normally reach full capacity by the second or third year of operation. The very small number of autonomous distilleries under 90,000 LPD does not permit an objective assessment of their administrative/agro-industrial employment. However, the smaller the scale, the higher this employment per million litres. The survey of some smaller-scale annexed distilleries with similar technology suggests that there is negligible difference in employment between distilleries of 60,000 LPD and 90,000 LPD.

Although annexed distilleries are predominant in Brazil (accounting for 82.5 per cent of total production in 1980-81), they cannot be used to estimate the employment effects of ethanol, because of overlaps between sugar- and ethanol-related operations, and because of their additional production of ethanol from molasses which does not require extra agricultural activity. The demand for labour in annexed distilleries of 120,000 LPD, compared with that in autonomous units of the same capacity, is about 20-30 per cent less in the administrative/agro-industrial categories, and lower by varying amounts in agriculture, depending on the share of production derived from molasses.

3. Agricultural employment

Table 18 shows the impact of individual autonomous distilleries of 90,000, 120,000 and 240,000 LPD on agricultural employment in the C/S macro-region. The data are based on labour coefficients periodically researched by COPERSUCAR[6] since 1976-77: 0.145 man-days/tonne in the off-season and 0.232 man-days/tonne in the harvest season. The coefficients refer to an average of situations involving three to four harvest cuts from each planting. Off-season operations are semi- mechanised, and harvest operations include mostly manual cutting and mechanised loading.[7] Appendix C provides a more elaborate discussion of the choice of techniques in sugar-cane agriculture in Brazil and other countries.

The impact of individual autonomous distilleries of 90,000, 120,000 and 240,000 LPD on agricultural employment (table 18) can hence be gauged from the following calculation: if, on average, one tonne of sugar-cane generates demand for labour of 0.145 man-days for off-season and 0.232 man-days for the harvest season operations, then a 120,000 LPD autonomous distillery (18 million litres per year, assuming 150 days of operation at full capacity and, hence, requiring 257,000 tonnes of sugar-cane) will provide 248 full-time jobs in the off-season and 397 in the harvest season. Hence, the demand for agricultural labour per million litres of ethanol can be estimated at 13.7 jobs in the off-season and 22 jobs in the harvest season, regardless of the distilleries' capacity. The partial use of farm machinery may possibly create some economies of scale, but there is no evidence of this. The labour-intensive harvesting of two ha of land will generally require twice as much labour as one ha, all other things being equal. One should note, however, that the number of seasonal jobs in the off-season and harvest season do not represent the number of workers actually employed, since the jobs may be done by different combinations of year-round and seasonal workers.

4. Direct employment in 1980 and projections for 1985

Total direct employment cannot be estimated with precision due to variations in demand for labour among different types and sizes of distilleries and regions. Nevertheless, employment is estimated here on the basis of earlier data on autonomous distilleries and on agricultural labour coefficients in the C/S macro-region. This method has some limitations and requires some explanations.

Although not all distilleries in operation in 1980 were of 120,000 LPD scale, this was the most representative; furthermore, the minor variations in labour/output coefficients among the different scales do not produce very large distortions in estimates of total employment. Considerable distortions result, however, from using autonomous distilleries and labour coefficients in the C/S. Gauging total employment on the basis of this type of distillery ignores the high share of annexed distilleries in total production and their lower demand for labour. This leads to an overestimation of total direct employment, particularly since it assumes implicitly that all ethanol is produced from sugar-cane. On the other hand, the use of agricultural labour coefficients for the C/S lead to an underestimation of overall agricultural employment, since the N/NE regions (15.8 per cent share in total production in 1980-81) have higher agricultural labour coefficients.[8] As it turns out, the net quantitative effect of these distortions is insignificant - about 2-4 per cent overestimation of total direct employment - when all relevant factors are taken into account.[9]

Table 18: Direct agricultural employment (unskilled workers and farm-machine operators) created by autonomous distilleries - Centre/South[1]

	Scale of distilleries (LPD)					
	90 000		120 000		240 000	
	jobs	jobs/ m.1	jobs	jobs/ m.1	jobs	jobs/ m.1
Harvest season (150-180 days)	298	22	397[2]	22	794	22
Off-season (150 days)	186	13.7	248[3]	13.7	496	13.7

[1] Employment data are based on labour coefficients (in man-days/tonne of sugar-cane) by COPERSUCAR, assuming a harvest operation of 150 days.

[2] 120,000 LPD x 150 days = 18 m.1 - 70 (litres per tonne - LPT) = 257,000 tonnes x 0.232 man-days = 59,642 man-days - 150 days = 397.

[3] 120,000 LPD x 150 days = 18 m.1 - 70 LPT = 257,000 tonnes x 0.145 man-days = 37,265 man-days - 150 days = 248.

Source: Elaborated from COPERSUCAR data.

The figures given in tables 17 and 18 can therefore be used for estimating PNA's employment impact. For the production of 3,500 million litres in 1980, total direct employment in the administrative/agro-industrial categories can be calculated by multiplying the number of jobs in each 120,000 LPD distillery by the 207 commercial units in operation. This leads to figures (not rounded to facilitate cross-references) of 15,939 year-round and 6,417 seasonal jobs. If, as expected, the production of 10,700 million litres is reached in 1985-86, the figures will increase to 48,728 year-round jobs and 19,618 seasonal jobs assuming no changes in technology (table 19).

Using the afore-mentioned labour coefficients for the 50 million tonnes of sugar-cane required in 1980 (assuming that all ethanol was produced from sugar-cane), agricultural employment is estimated at 48,333 jobs (of about 150 days) in the off-season, and 77,333 jobs

(150-180 days) in the harvest season (table 19). For 1985-86, the corresponding figures are 147,700 and 236,419 assuming the same yields, techniques and inter-regional distribution of production. The employment data for 1985 may be higher or lower than this estimate, depending on the net quantitative effect of two offsetting factors: increased mechanisation and the increasing share of the N/NE regions. The manner in which these figures are shown in table 19 is the most adequate way of stating employment under PNA. Extrapolations from these data in order to estimate PNA's total employment impact in terms of a single man-year number normally leads to errors. Further analysis is needed here.

What was the total workforce employed under PNA in late 1980 and early 1981? If all the year-round and seasonal jobs in all occupational categories (table 19) were added together, one would arrive at figures of 163,961 and 501,253 jobs in 1980 and 1985 respectively, but this would be incorrect because this total employment could not be quantified on the basis of a common denominator. In so far as the data allow, one may say that 15,939 man-year jobs and 6,417 seasonal jobs of 150 days have been created in administrative/ agro-industrial activities, but it is impossible to state how many year-round and seasonal jobs have been created in agriculture, unless one knows the percentage of permanent and seasonal workers during either the harvest season and/or the off-season. The data in table 19 are broken down for both periods of the year, but not all the workforce had seasonal jobs. As mentioned earlier, many of the workers employed in the off-season held year-round jobs, although the variations among the plantations did not allow an accurate estimation.

CENAL estimated that 68 per cent of the jobs in agriculture were seasonal and 32 per cent permanent. These percentages seem compatible with information gathered by the author in early 1981. Applying these figures to the number of jobs in table 19, it is possible to estimate that the total number of workers employed in year-round agricultural activities associated with ethanol production, was 24,746[10] in 1980. Moreover, since these would have also been employed during the off-season there would have been 23,587 seasonal workers in the off-season. The final estimate of the total workforce employed under PNA by the end of its first five-year period can then be seen in table 20, with a detailed breakdown of year-round (permanent) and seasonal (150 days) workers during both periods of the year. This amounts to about 40,000 and 82,000 permanent and seasonal workers, representing respectively 33 per cent and 67 per cent of the total.

These benefits should be considered in light of the employment implications of the substitution of sugar-cane for other crops and pastures. The net employment impact depends on the quantitative significance of these displacements and on the relative labour coefficients of the crops and pastures. Although reliable documentation was only available for some 65 per cent of the production areas, it is nevertheless possible to draw some conclusions. On the basis of the labour coefficients for the crops

and pastures displaced (excluding castor oil, for which no coefficient was found), it can be estimated that over 15,650 man-year jobs, or alternative compositions of year-round and seasonal jobs, were lost. This displacement implied a net gain of 24,450 man-years of employment. Sugar-cane is roughly seven times more labour-intensive than pastures and, among the displaced crops (rice, maize, cotton, manioc, beans, peanuts, oranges and castor oil), only cotton, peanuts and manioc have higher labour coefficients per ha (table 21). Moreover, as argued in Chapter 3, section 4, the displaced crops and pastures may have been relocated to other areas and created employment elsewhere.

Table 19: Direct employment impact of PNA in 1980 and 1985 (according to number of jobs in all occupational groups during the harvest season and the off-season)[1]

	1980	1985
1. Administrative/Agro-industrial[2]		
Harvest season	22 356	68 345
(Permanent jobs)	(15 939)	(48 728)
(Seasonal jobs)	(6 417)	(19 618)
Off-season	15 939	48 728
(Permanent jobs)	(15 939)	(48 728)
(Seasonal jobs)	(-0-)[4]	(-0-)
2. Agricultural[3]		
Harvest season	77 333	236 419
Off-season	48 333	147 761
3. Total	not applicable[5]	

[1] 1980 data are based on the calendar year's production of 3,500 million litres and yields of 50 tonnes/ha/yr. and 70 litres per tonne. 1985 data are based on a projected production of 10,700 million litres for 1985-86 and the same yields, labour coefficients and techniques registered in 1980-81. See section 1 for a description of the occupation groups.

[2] Based on the author's field survey (see section 1).

[3] Based on coefficients by COPERSUCAR for Brazil's C/S macro-region (see section 3).

Notes to table 19 (cont.)

[4] Normally the case, although a few distilleries surveyed employed some temporary labour in the off-season.

[5] See section 4.

Source: See notes.

Table 20: Total workforce actually employed under PNA in 1980[1]

	Harvest season	Off-season	Year
1. Administrative/Agro-industrial			
1.1 Year-round workers	15 939	15 939	15 939
1.2 Seasonal workers	6 417	-0-	6 417
2. Agricultural			
2.1 Year-round workers	24 746	24 746	24 746
2.2 Seasonal workers	52 587	23 587	76 174
3. Total year-round workers	40 685	40 685	40 685 (33%)
4. Total seasonal workers	59 004	23 587	82 591 (67%)
5. Total year-round and seasonal workers			123 276 (100%)

[1] Assuming a composition of 68 per cent seasonal and 32 per cent permanent agricultural workers during the harvest.

Source: See table 19.

Table 21: Employment effect of the displacement of crops and pastures in the State of Sao Paulo[1]

	Pastures	Rice	Maize	Cotton	Manioc	Beans	Peanuts	Oranges	Total employment displaced (man-years)[5]	Employment in sugar cane (man-years)	Net employment in displaced area (man-years)
Common worker man-days/ha/yr	4.8	25	6	60	60	13	41	19.1	-	28	-
Machine worker man-days/ha/yr	-	3	2.7	3	2.5	1.4	3	2.7	-	4	-
Total man-days/ha/yr[2]	4.8	28	8.7	63	62.5	14.4	44	21.8	-	32	-
Area displaced Thousands of ha[3]	245.1	46.5	44.7	18.2	7.9	4.8	2.1	0.7	-	-	-
Man-years displaced[4]	3 922	4 340	1 296	3 831	1 661	230	313	55	15 648	40 099[6]	24 451

1 The areas of the State reflecting the data in this table were responsible for roughly 65 per cent of national production (author's estimate based on the distribution of production in Brazil and in Sao Paulo).

2 Data from Instituto de Economia Agricola of Sao Paulo, and M. Zockun (1978).

3 Data from Instituto de Economia Agricola de Sao Paulo; see Table 8 in Chapter 3.

4 Accounting method: (total man-days/ha/yr) x (number of ha displaced) - (300 days).

5 Excluding castor oil (which was included in Table 8 but not here due to lack of data on labour inputs).

6 Accounting method: (32 man-days/ha/yr) x (375 928 ha).

Source: See notes.

5. Qualitative aspects of direct employment

The creation of permanent and seasonal employment for over 40,000 and 82,000 workers, respectively (table 20), is an undeniable social benefit of PNA. The figures reveal, nevertheless, a relatively high seasonality of labour, which deserves further analysis. The controversial case for maximising permanent employment while minimising seasonal jobs under PNA is discussed.

The author's field interviews revealed increasing signs of scarcity of unskilled agricultural labour in the 1980-81 harvest, in some areas of the major producing states in the N/NE. Some PLANALSUCAR officials believed this trend would become more evident as production of sugar-cane and ethanol increased. The continuing trend towards greater mechanisation in harvest operations - despite its technical and financial disadvantages compared to labour-intensive techniques until 1980-81 (see Appendix C) - may be another sign of the increasing difficulties of recruiting seasonal labour in some areas, although other factors are involved, such as managers' fear of labour disputes. Despite the sharp rise in urban unemployment and underemployment since 1979,[11] most of this recent labour surplus from the industrial sector is unlikely to compete for "back-breaking" rural tasks, such as manual sugar-cane cutting. Furthermore, the field surveys have shown that improvements in farm and labour management can substantially reduce the present level of seasonal labour, while increasing permanent employment. The social desirability of reducing seasonal work and migration of labour is generally controversial. In Brazil, however, seasonal work is regarded as a major social problem because of income considerations discussed below and the lack of access to social services, which the rootlessness of migrants implies.

In Brazil, and in some other countries, the seriousness of these aspects of seasonality and migration of labour depends on the types of seasonal workers concerned and their degree of underemployment.[12] Some of PNA's seasonal workers were once itinerant migrants who settled in certain communities, while working for one or more proprietors in the vicinity. These workers invariably have their "employment books" signed, receive legally-stipulated wages and benefits and are protected by labour laws regulating employer/worker relations. Another group of seasonal labourers comprises youngsters, women and older men who are not part of the regular workforce. These are not typical migrants either, since they usually live in nearby rural communities. Although some of them receive wages below the minimum rate, few of them seek permanent jobs, or depend on cash incomes alone for subsistence throughout the year. In the N/NE states, in particular, where ethanol production takes place mainly along the coast, a large part of the seasonal labour force during the harvest period consists of male workers who migrate temporarily from their minifundia in the hinterland, to which they return with some savings after the harvest. Another category of seasonal workers

comprises those who alternate between urban and rural jobs, although they are relatively few. Lastly, there is another group normally classified in Brazil as itinerant workers, with no fixed residence, who are hired mostly by labour contractors on a short-term basis. Most of these workers are not protected by labour legislation concerning employer/worker relations, including fringe benefits, although most of them earn at least the legal minimum wage. The emergence of labour contractors, operating as intermediaries for the plantations and normally without a social or economic interest in making optimal use of labour, has been a major factor preventing improvements in the standards of living for this last group of workers, who comprise a very large part of the workforce in the State of Sao Paulo.

The income-related disadvantages of itinerant workers, in particular, stem from their (a) job insecurity, (b) exclusive dependence on low wages and (c) inability to generate non-monetary income, often referred to as income "in kind", such as that provided indirectly by subsistence production of food and social assistance.[13] An increase in permanent jobs would tend to be more beneficial to these workers and, to a lesser extent, those who alternate between urban and rural jobs, rather than to other types of seasonal workers who have other sources of income.

At first sight, it might seem that a maximisation of permanent employment and a minimisation of seasonal jobs would reduce the net employment opportunities for jobseekers. But would this be necessarily the case? The above considerations suggest that employment could be increased, rather than reduced, through a more efficient use of land and labour resources. This is the same argument which was used earlier in an analysis of the implications of different techniques of crop renewal for employment. It was suggested that financial returns on agricultural investments might be higher and employment both higher and more stable, if the typical practice of monoculture in sugar-cane plantations were partially replaced by efficient crop-renewal techniques including some inter-cropping.

It might nevertheless be claimed that under certain circumstances it would be socially preferable to create two temporary jobs in the place of one permanent job, and indeed we have just seen that seasonal employment opportunities may be beneficial and desirable for some jobseekers. However, to the itinerant worker without a fixed residence or land for subsistence production, the seasonal or the very short-term job is desirable only in so far as better opportunities may not exist within easy reach. Generally, this type of worker seeks stable employment, but his attempts are often imperilled by the role of external labour contractors. This is particularly the case in the State of Sao Paulo which has a high influx of migrant labour, due to the attraction of the higher level of affluence as well as displacements of crops and labour.

Having, we hope, justified the case for maximising permanent jobs and minimising seasonal employment, we must now focus on the question of interchangeability among agricultural labourers between the harvest season and the off-season, in order to suggest means of changing the present composition of permanent and seasonal employment. The question can be put most concretely as follows: how could a manual harvest worker be given employment in the off-season in the activities of planting, cultivation and land maintenance?

The answer depends on the extent to which the seasonal and off-season activities overlap the level of skills required for each job and the willingness of a seasonal worker to accept different jobs and year-round employment. Local training facilities may also be important. It is unlikely that workers can be perfectly interchanged between harvest season and off-season tasks in sugar-cane production in Brazil. However, if one assumes an optimal rate of crop renewal, either in the distilleries' plantations or in those of external sugar-cane suppliers, the level of interchangeability is considerable in Brazil. First, the only activities which show a major overlap are those of maintenance, where the demand for labour is far lower than in any other off-season operation. Some cultivation may take place during the latter part of the harvest season, but the work involved is generally minor. Second, due to the high labour-intensity of agricultural activities in Brazil, only a limited number of specialised skills are required. A farm machine operator cannot be replaced by a manual harvester but the latter can easily replace, or be replaced by, a common worker in planting, cultivation or land conservation activities. Likewise, a tractor driver may be substituted for an operator of a mechanical harvester, provided that a minimal level of training is available locally. Moreover, since most semi-skilled workers in agriculture hold year-round jobs already, the argument for labour interchangeability (in the context of minimising seasonal employment and, in particular, the high turnover of workers during a given period) concerns mostly unskilled labour and tasks with a very low level of specialisation.

Bearing the above considerations in mind, the remaining part of this section will assess the employment implications of ethanol production in Brazil in 1980, assuming a hypothetical model of perfect interchangeability of agricultural labour between the off-season and the harvest season. The data base will be that used for the previous assessment of employment in administrative/agro-industrial and agricultural categories. While the employment of the former categories remains unchanged for reasons discussed in section 1, agricultural employment will change substantially, as far as the percentages of permanent and seasonal workers are concerned. As shown in table 18, an autonomous distillery with a capacity of 120,000 LPD will generate 248 agricultural jobs in the off-season and 397 in the harvest season. Although both labour requirements can be met by variable amounts of temporary workers (depending on their turnover), a maximisation of year-round employment would mean that roughly 248 workers employed during the off-season could also work in the harvest period. This amounts to some 62 per cent of the total agricultural

workforce in the harvest season, and would require 149 additional workers employed on a seasonal basis.

Table 22 shows PNA's total workforce as it would have been in 1980, assuming a perfect interchangeability of labour. A comparison of this scenario with the previous one (table 20), which reflected PNA's real impact, shows a much higher percentage of permanent employment both in agriculture (roughly 62 per cent, as against 32 per cent in the actual scenario)[14] and in employment as a whole (64 per cent as against 33 per cent).[15] There is also a drop of 47,174 in the annual number of seasonal workers. Roughly half of these would become permanent (compare figures in line 3), whereas the other half (representing 19 per cent of the total workforce actually employed in 1980) would, in principle, lose their seasonal jobs. However, the extent to which these losses in seasonal job opportunities (equivalent to fewer than 12,000 man-year jobs) would take place is significant only in so far as other sources of employment could not be created, either in the same plantations or elsewhere. Although a model of

Table 22: Total workforce directly employed under PNA in 1980 (a hypothetical model assuming a perfect interchangeability of labour between the off-season and the harvest season)[1]

	Harvest season	Off-season	Year
1. Administrative/Agro-industrial			
1.1 Year-round workers	15 939	15 939	15 939
1.2 Seasonal workers	6 417	-0-	6 417
2. Agricultural			
2.1 Year-round workers	48 333	48 333	48 333
2.2 Seasonal workers	29 000	-0-	29 000
3. Total year-round workers	64 272	64 272	64 272 (64%)
4. Total seasonal workers	35 417	-0-	35 417 (36%)
5. Total year-round and seasonal workers			99 689 (100%)

[1] Assuming a composition of 68 per cent seasonal and 32 per cent permanent agricultural workers during the harvest.

Source: See table 19.

perfect interchangeability is unlikely to be realised, an approximate alternative would be possible given Brazil's conditions, if legislative, policy and managerial efforts were made in this direction.

Notes

1 Ethanol production takes place during the harvest season. Normally, this is 150 days in the C/S macro-region and up to 180 days in the N/NE. Due to the large share of the C/S in total production (84.2 per cent in 1980), 150 days are used for the purpose of estimating employment. The off-season period varies slightly among distilleries and plantations, but in most cases there is a period of at least 30 days before the harvest, during which practically no activity takes place, due to holidays, etc.

2 Sis, 19 Mar. 1981.

3 This period varies with the sugar-cane species, climate and soil.

4 Seventy-two questionnaires were sent to the distilleries, and data were collected from 58 units (28 autonomous and 30 annexed), representing 28 per cent of the total number of distilleries in operation in 1980 and early 1981. Twenty distilleries were visited in the C/S State of Sao Paulo (14 annexed and six autonomous) and 14 in the N/NE States of Alagoas, Pernambuco and Paraiba (10 annexed and 4 autonomous units).

5 This depends on the body design of lorries. Some can unload the sugar-cane directly into the conveyer belts of the distillery.

6 COPERSUCAR is a consultancy co-operative of 71 industries of sugar and ethanol in the C/S macro-region offering technical assistance to its members.

7 Roughly 85-90 per cent of the sugar-cane cutting was done manually in 1980 and early 1981 in the C/S macro-region. The loading of sugar-cane into lorries is done mostly by machines with the assistance of labour, although the machine/labour ratio varies among plantations.

8 Sao Paulo has the highest yields in Brazil. The lower the yield in tonnes per ha, the higher the labour coefficients for harvesting activities.

9 The important factors are these: (a) 82.5 per cent of the total production of ethanol was based on distilleries with a 20-30 per cent lower demand for administrative/agro-industrial labour; (b) about 9 per cent of production took place in N/NE areas with labour coefficients twice and three times higher than in the C/S, respectively

in the off-season and the harvest season; (c) about 6.8 per cent of total production (the remaining share of the N/NE) had overall coefficients about 1.5 higher than those in the C/S and (d) 25 per cent of production was based on molasses, hence not creating ethanol-related employment in agriculture. However, it is best to ignore this insignificant overestimation because the effect of each of the above factors cannot be accurately disaggregated according to occupational categories and types of employment (permanent and seasonal). In addition, since these factors reflect Brazil's conditions only, the quantification of their effect would reduce the relevance of the data for other countries with limited production of sugar. While ignoring some of the above considerations some recent studies have overestimated PNA's employment; see Geller (1983) and COALBRA (1983).

10 32 per cent of the 77,333 jobs during the harvest season.

11 General "unemployment" was higher in 1980 than in 1979, with no better projections in mid-1981, 1982 and 1983. The six major cities in Brazil registered an average of 1.3 per cent growth of "unemployment" in 1980, followed by a slight decrease in the first months of 1981, and then by an increase since May, which continued throughout 1981. Although unemployment may have stabilised in 1982-83, its level has been the highest since the mid-1960s on a percentage of the labour force.

12 On this subject see, for example, Peek and Standing (1982); Graziano da Silva (1978 and 1980) and Goodman and Redclift (1977).

13 For a review of the concept of income "in kind", as distinguished from cash income, see, for example, Taylor et al. (1980).

14 See, respectively, tables 22 and 20, line 2.1.

15 See tables 22 and 20, line 3.

CHAPTER 6

IMPLICATIONS FOR PERSONAL INCOME DISTRIBUTION

Employment creation is undeniably a positive aspect of PNA, but it does not permit objective conclusions as regards income-related effects. This is because the bulk of PNA's employment is in agriculture and, in this sector, wages are not the only source of income. Rural incomes can be also a function of labour time and access to land. The more time one works for a given wage, the less time one has to generate income "in kind" or to have a second job. Furthermore, the overall income implications of technology choice, employment and wages depend primarily on the pattern of landownership on which crop production is based. Often considered controversial, this argument is nevertheless supported by a growing body of literature on the implications of agricultural modernisation programmes for income distribution. Appendix D provides some supplementary analysis of this issue with reference to sugar-cane agriculture.

This chapter examines income implications of the wages of PNA's workforce (section 1), and the impact of PNA on the pattern of landownership which has important implications for income distribution (section 2).

Some introductory remarks on the limitations of this analysis are in order. It is impossible to document, with precision, the impact that PNA has had on personal incomes, due to the lack of data on the previous incomes of the workers and any losses of income "in kind" they have suffered as a result of increased concentration of landownership and crop displacements. Similarly, the social effect of changes in personal incomes is even more difficult to assess, because there is very little data concerning the workers' previous marginal product and the net social cost of increased consumption or of reduced leisure.

The limited data that are available clearly suggest that, on the whole, PNA has promoted a concentration of personal incomes at the individual level. PNA's implications of PNA for inter-regional distribution of income were analysed in Chapter 3.

1. Income implications of wages

The data collected by the author in 1981 on wages of semi-skilled and unskilled workers, who account for about 95 per cent of PNA's workforce, suggest that the most significant improvements in incomes had taken place among semi-skilled agro-industrial and agricultural workers, such as lorry drivers, workers in vehicle and equipment maintenance, farm machine operators and other workers supervising industrial equipment. Persons in these occupations usually hold permanent jobs, although their work can scarcely be regarded as full time in the off-season. This allows many of them to have some

additional income-generating activities during this period. Their limited supply and skills have had a favourable effect on fringe benefits and wages. The wages of lorry drivers and farm-machine operators, for example, ranged from $145 to $250 per month (in May 1981, at the shadow exchange rate). Wages varied substantially within each region, but were generally higher than those of similar jobs in large urban centres. In many distilleries, workers in these two occupations received overtime earnings during the harvest season, when their working hours increase to 10-12 hours per day. Earnings also varied from one distillery to another. However, the income increase for this group of semi-skilled workers was not very representative of the general state of affairs, because there are not many of them.

Unskilled workers with permanent jobs in industry and agriculture may have benefited slightly, but more in terms of the security of their incomes and job stability rather than in terms of wage earnings. On average, their wages were about the same as those in comparable activities in other sectors (minimum salary of $50-63 per month in May 1981, at the shadow exchange rate). Overtime earnings during the harvest season may slightly improve incomes, but no consistent pattern was found in our survey.

For seasonal agricultural workers, still the largest group of employees, the findings are less encouraging. Most of these people worked 10-12 hours per day during the harvest, but earned average wages of about $63-70 per month (slightly above the minimum wage level, in May 1981, at the shadow exchange rate) and, in some cases, women and teenagers earned even less. These wages were a convenient source of extra income for rural families rooted in communities adjacent to sugar-cane plantations or for workers who migrate temporarily away from their family plots. But they were far too low (given Brazil's cost of living) for itinerant workers who depended exclusively on these wages to purchase food and other basic commodities. The fact that the latter workers earned little more than the legal minimum wage hardly suggested an improvement in their incomes, because many of them (their number is not known) had secured wage-employment in replacement of some or all of their income "in kind". In real terms, the minimum wage in Brazil decreased steadily from 1959 to 1974; increased by 3-5 per cent from 1974 to 1975, but began to decrease again until at least 1980.[1]

2. PNA's impact on landownership

The income implications of changes in the landholding structure and the organisation of production have been described by Pearse (1981), in the context of the Green Revolution in some Asian countries, as a process of "de-landing". Identifiable descriptions are found in Griffin (1972 and 1974), Ahmad (1972) and others. A similar trend has emerged in Brazil in recent years as a result of agricultural expansion and modernisation, which were intensified under the Second and the Third National Development Plans since the early seventies. These plans aimed explicitly at increasing productivity and exports.[2] In this context, ethanol farming has emerged as one of several major "de-landing" and income-concentrating factors, as a result of PNA's

financing policy and of the landholding structure. Before we focus on PNA's effects, however, it is appropriate to review the general trends in income distribution and landownership, which prevailed at the time PNA was planned and implemented.

Several studies on trends in income distribution, based on the 1970 Census of population and income (IBGE, 1971 and 1975), concluded that the income concentration was lower in agriculture than in non-agricultural sectors.[3] The 1980 Census reveals an opposite trend in the seventies, although poverty decreased in absolute terms.[4] Not only did incomes become more evenly distributed over this 10-year period, but the concentration of income became higher in rural than in urban areas. The top 1 per cent income bracket of "economically active" persons in rural areas increased its share in rural incomes from 10.5 per cent in 1970 to 29.3 per cent in 1980 - a 179 per cent increase. Over the same period, the top 5 and 10 per cent in rural areas increased their share by 86.5 per cent and 58 per cent, respectively. The corresponding increases for these income brackets in urban areas were 14.5 and 10.3 per cent. However, the poorest 20 per cent in rural areas saw its share fall by 26.9 per cent, while the share of its urban counterpart decreased by 12.5 per cent. For Brazil as a whole, the top 1 per cent, 5 cent and 10 per cent income groups of "economically active" persons increased their share of GDP by 15.1 per cent, 11.1 per cent and 9.0 per cent over the same period.[5]

The increased concentration of incomes in the rural sector at large is undoubtedly the consequence of financing policies adopted by the Government. In the late seventies, for example, loans were being offered for different types of agricultural production at typical nominal interest rates of 15 per cent, while the inflation rate rose from 40 per cent in 1977 to 160 per cent in 1983.

The overall trend in landownership could not be analysed over this period, but it has been highly and increasingly concentrated in a few hands. The IBGE (1975) revealed that farm units over 1,000 ha, though representing only 0.73 per cent of all units in 1970 and 0.84 per cent in 1975, accounted for 39 per cent and 42 per cent, respectively, of the total area under cultivation. Land units under 10 ha, with 51 per cent of the properties in 1970 and 52 per cent in 1975, accounted for only 3 per cent and 2.8 per cent of the total cultivated area.

In the case of sugar-cane farming in the States of Sao Paulo, Pernambuco and Alagoas, in 1972, 40 per cent, 47 per cent and 56 per cent of the sugar-cane, respectively, was produced in land units over 1,000 ha (INCRA, 1976). Silva (1979, p. 10) states that 71 per cent of all sugar-cane suppliers delivered less than 250 tonnes of sugar-cane per harvest from farm units of less than 5 ha. This concentration of landownership is part of an historical process tied to both the agrarian structure and all rural credit systems. An analysis by Pereira and Warkov (1980) of farm size, credit and output for the whole agricultural sector, based on Brazil's 1970 Census, concluded that units up to 10 ha received 5 per cent of the rural credit and accounted for 18 per cent of the total market value of production (0.27 ratio). Land units above 10,000 ha obtained 4 per cent of the credit available but shared only 1.8 per cent (2.22 ratio) of the total value of output.

The ownership of land used to produce sugar-cane for ethanol is even more concentrated. Of a total of 83 projects approved by July 1978, 90 per cent had plots over 1,000 ha and 59 per cent over 5,000 ha (CNPq, 1978, pp. 118-121). In 1978-79, in Sao Paulo's largest sugar-cane districts (Piracicaba and Ribeirao Preto), the average planted area of each distillery was about 8,800 ha, while that of independent suppliers, producing 36 per cent of the sugar-cane, varied mostly between 12 and 45 ha (Veiga Filho et al., 1981, p. 72).

Prior to the launching of PNA, a revision of the Sugar-Cane Statute in 1965 determined that the plantations belonging to sugar and/or ethanol complexes could not supply more than 40 per cent of the raw material required for production, leaving 60 per cent to be provided by independent suppliers. This statutory law (Ato 4870, 1941) also included a clause granting 20 per cent of the total production of raw material to new sugar-cane suppliers who worked their land exclusively with family labour. With the advent of PNA, and partly as a result of the economic pressures to secure stable supplies of raw material and reduce costs, this law has been clearly disregarded both by the ethanol distilleries and by PNA's institutional network.[6] Subsequently, the distilleries have increased their share in sugar-cane supply through land purchases, either directly or indirectly through their shareholders.

The extent to which sugar-cane is derived from the distilleries' own lands cannot be estimated accurately because of the ambiguous role of lands owned separately by the distilleries' proprietors or shareholders. But some conclusions are possible. PLANALSUCAR's official data only distinguish between the distilleries' own lands and those of external suppliers. This classification is correct from the legal viewpoint, but distortive from a perspective of social policy because some of the external suppliers' lands are in fact owned by the distilleries' proprietors or shareholders. The questionnaires used in our field survey placed the raw material supplied by the distilleries' own lands and those of its proprietors or shareholders in the same category, but one cannot be sure about the accuracy of the answers in all cases. It may not have been in the entrepreneurs' interest to reveal patterns of landownership concentration, although the Sugar-Cane Statute had become overtly inoperable. Thus, the data below are likely to be conservative. Nevertheless, they serve as a broad indication of the increasing reliance of the distilleries on their own supplies of sugar-cane and therefore of the increasing concentration in landownership associated with ethanol production.

As table 23 shows, the annexed distilleries in Sao Paulo and Alagoas (which are the most representative states in each macro-region, producing 77 per cent of total production in 1980-81 between them) increased the supply of sugar-cane from their own lands by 3 per cent and 8 per cent from 1976-77 to 1980-81 respectively. PLANALSUCAR's data for Alagoas in 1981-82 suggest an increase from 50 per cent to 54 per cent in one year alone. For autonomous distilleries, the figures are 75 per cent in Sao Paulo, 79 per cent in Bahia, and a leap from 52 per cent to 65 per cent in just one year in Alagoas. The higher percentages of raw material supplied by the autonomous distilleries

themselves reflect the PNA's inability of PNA's to promote income redistribution, since such new projects were free to determine their locations and patterns of production.

The favourable loans and financing conditions for agricultural investments related to ethanol distilleries have been a major cause of landownership concentration, in so far as the distilleries and their proprietors or shareholders have had direct and privileged access to credit. Also, the general preference for distilleries of 120,000 LPD or more, (requiring at least 5,000 ha) has also led to landownership concentration. The high proportion of agricultural costs to total costs has meant that, the larger the distillery, the greater the pressure on it to control its supply and secure the raw material at the lowest possible cost. Raw material purchased from external suppliers also involves the risk of unstable supply.

The above factors explain but hardly justify PNA's contribution to an increased concentration of landownership. Indeed, there has been at least one major sugar-cane workers' strike, in the N/NE in 1979, and various threats of strikes on the part of independent raw material suppliers while bargaining for higher prices. These problems have nevertheless been partly resolved by the price policies. The Government's control over the prices of sugar-cane, sugar, ethanol and petrol has meant that production cost increases have been passed on to the consumers of sugar and car fuel. For non-proprietors who rent, sharecrop or hold land illicitly, however, there are no policies which can effectively compensate for income losses caused by a concentration of landownership. This concentration results in more monoculture at the expense of inter-cropping; it leads to increased seasonality and migration of labour, as well as to land-price inflation, and evictions of peasants who do not own their own plots. Silva (1981b, p. 5) throws light on this -

> The first reactions to the process of land ownership concentration, which is occurring as a consequence of PROALCOOL, are emerging as a result of the photogrammetric studies conducted in Sao Paulo and also through the perspicacity of some town mayors who have become shocked by the consequences that the distilleries may bring to their districts.
>
> As aerial photographs show and as the local mayors have already detected, the most striking cases are Iracemapolis, Sertaozinho, a green desert where 82 per cent of the municipality is occupied by sugar-cane and 50 per cent is in the hands of four families, and Guaira, where according to the mayor, the three approved projects to date will eliminate the traditional grain cultures and raise the workers' cost of living.

In Brazil, small farms inter-crop more than large farms and are more dedicated to basic food stuffs. In 1972, for example, of all farm units between 5 and 25 ha, more than 28 per cent cultivated beans and 25 per cent cultivated rice; of all larger farms between 2,000 and 5,000 ha, 0.01 per cent cultivated beans and 0.2 per cent cultivated rice (Barros, 1981). A large number of small farms producing staple foods are under non-proprietary forms of tenure. In 1975, the number

Table 23: Share in percentage of distilleries' own supply of sugar-cane in three producing states by type of distillery[1]

	Sao Paulo		Alagoas		Bahia	
Harvest	Annexed	Auton.	Annexed	Auton.	Annexed	Auton.
1974-75[1]	63	-	44	-	-	-
1975-76	67	-	46	-	-	-
1976-77	62	-	42	-	-	-
1977-78	63	-	-	-	-	-
1978-79	63	-	-	-	-	-
1979-80	-	-	-	-	-	-
1980-81	65[2]	75[3]	50[4]	52[5]	79	-
1981-82	-	-	54	65	79	79

[1] These states shared about 80 per cent in total ethanol production in 1980-81. Figures for Sao Paulo and Alagoas for 1980-81 are based on the author's survey (see Chapter 5, footnote 5), which included 17 annexed and 21 autonomous distilleries in Sao Paulo, and 10 annexed and 5 autonomous distilleries in Alagoas; distilleries which had figures with a deviation of 40 per cent or more from the mean of each grouping were excluded from the averages as mentioned in notes below.

[2] Average of 15 distilleries (2 other distilleries surveyed were excluded).

[3] Average of 17 distilleries (4 others were excluded).

[4] Average of 8 distilleries (2 others were excluded).

[5] Average of 4 distilleries (one additional distillery was excluded).

Source: Figures with notes are from the author's survey and all other data (also averages) without notes are from PLANALSUCAR.

of farm dwellings (not people) under such tenure comprised 36 per cent of the total number of dwellings (IBGE, 1981).

Of the 20 distilleries which we visited in the State of Sao Paulo and the 14 in the N/NE States of Alagoas, Pernambuco and Paraiba, none had crop rotations or consortia on their own lands. Furthermore, only two of those in Sao Paulo and one in Alagoas (which were annexed distilleries) reported having areas designated for the production of food for local needs, despite the existence of a decree of the early

1960s, known as the "Law of the Two Hectares", requiring plantations to have at least 2 ha of land for the workers' subsistence.

The trend towards monoculture under PNA is influenced by many factors, including the general belief that greater economies of scale are achieved as a result of a more uniform use of agricultural inputs and other factors of production, including farm machinery (see Appendix C). However, these factors deserve further research and policy attention. The practice of sugar-cane monoculture in Brazil is traditional and results from the lack of technical assistance and other incentives to change.

PNA's effect on the value of land is partly concealed by similar effects due to the expansion of some other export commodities and by the fact that sugar-cane is also used for sugar production. However, in so far as there have only been minor changes in sugar output in PNA's first five-year period, and there was in fact a decrease from 1977-78 to 1979-80, it is possible to show some conclusions at micro-regional level. This can be done by comparing average land prices at state or regional level with those in areas where sugar-cane production is most predominant. According to information collected at the Secretaria do Interior (Office of Internal Affairs) of Sao Paulo, for example, the State's land prices ranged from $1,130 to $2,000 per ha in April 1981 (at the official exchange rate). However, prices in the most sugar-cane-intensive districts of the State (Ribeirao Preto) ranged from $4,000 to $7,300 per ha according to PLANALSUCAR officials and distillery managers in the area. To some small proprietors in this micro-region, the increased valuation of land for sugar-cane cultivation is believed to have had a positive effect on their incomes, as they relocate to cheaper lands in the hinterland. However, land-price inflation and subsequent changes in landownership, leading to the substitution of sugar-cane monoculture for diversified agriculture, have negative implications for non-proprietors renting or share-cropping land, and possibly for food prices.[7]

The extent to which land evictions have occurred under PNA is not documented, although our interviews with various government officials and plantation managers, as well as a few recent publications, leave no doubt that this has occurred.[8] With the incentives given to sugar-cane production in recent years, it has become more attractive to develop plantations and hire landless workers on a wage basis than to allow them to cultivate small land plots under low rents and other marginal forms of tenure. It is clear from our field survey and recent literature that the "Law of the Two Hectares" and the "Sugar-Cane Statute" have not been enforced. Silva (1979, p. 10) confirms this -

> In Brazil, the forms of land tenure found in the sector are unjust as well as primitive - leasing, crop-sharing, illegal occupancies, etc. The tame laws that were created (the Sugar-Cane Statute...and the 'Two Hectare Decree'...to protect small landless producers have not been implemented, because of the power of the majority of the plant owners and sugar-cane suppliers.

Apart from the subsidies to PNA's investments, other factors have contributed to the concentration of landownership and incomes. These include the concessions given informally by some states to attract new

businesses and to stimulate economic growth. One particular case caught the eye of a well-known political economist in Sao Paulo who stated (Melo, 1981, pp. 6-7) -

> Recently, CENAL approved the first seven distillery projects at Correntina... in the South-West of Bahia. In an area of 600,000 ha of unexplored stunted land... Bahia's State Government is facilitating the installation of 40 distilleries... There are already 35 business groups involved in the project including some with project proposals under appraisal and in the elaboration stage. Among the major incentives offered at Correntina, the following stand out: the sale of lands directly by Bahia's Government at the price of cr$340 per ha... One can assess the magnitude of such transactions by examining the sale prices of local agricultural lands surveyed and published by Fundaçao Getulio Vargas. The prices quoted (per ha) for the second semester of 1980 were as follows: farming lands cr$11,732; pastures cr$9,605; brushlands cr$6,041, and fields cr$5,224. The average is around cr$8,151 per ha. Since the sale price was only cr$340 per ha, the transfer subsidy to the entrepreneurs comes to cr$9,400 million, not counting the future valuation which will certainly take place with the development of the infrastructure, also financed by the Government. That represents an initial sum of cr$230 million per business involved in Correntina's ethanol complex. Is it possible that other such projects are taking place in other areas of Brazil? While income concentration is occurring as a result of ethanol projects, newspaper stories about conflicts regarding land tenure in various parts of the country are becoming frequent. The area of 600,000 ha... would be enough to productively employ 6,000 families with 100 ha, who would probably dedicate themselves to the production of basic food needs.

This initiative by Bahia's State Government may be regarded as a positive rather than negative measure, since the opportunity value of these lands was apparently low. Furthermore, the above argument may overstate the problem, since there is other land available for basic food production or land re-distribution. However, the political controversy over social priorities emphasised in the argument cannot be ignored.

Income distribution among regions and persons can become increasingly more equitable in the future, but this will depend on policies concerning land use, land tenure and regulation of sugar-cane supply. Between 1977 and 1981, the fast growth of ethanol output resulted in an overconcentration of production in major sugar-producing areas of the States of Sao Paulo, Alagoas and Pernambuco. The reliance on annexed distilleries and on traditional sugar-cane growers unavoidably led to landownership concentration and to both displacement and relocation of food crops and pastures. Part of these distortions were a result of the disorganised planning for land use, which was to be expected. Since 1981 however, the Government had initiated detailed studies on land use in various states in order to identify areas where ethanol production would have the least effect on displacement of food crops and income distribution. As ethanol production increases in

poorer regions and states, the effect on inter-regional income distribution will improve, but this greater geographical dispersion of investments may not necessarily contribute to a more equitable distribution of personal incomes. Unlike in most southern states, the expansion of sugar-cane for ethanol in the NE region is more likely to displace crop land than pastures due to factors related to climate and land quality. Furthermore, since small land plots and non-proprietary forms of land tenure are also much more predominant in the NE, substitutions of sugar-cane monoculture for food crops may easily cause evictions of peasants and a greater concentration of landownership and income than in the C/S regions. CENAL officials are aware of these potential consequences, but to prevent them from happening it will be necessary to change the existing criteria for project approval (Chapter 3). Both project criteria and the existing financial incentives have certainly been ineffective in preventing concentration of incomes.

Notes

[1] See, for example, Wells and Drobny (1982).

[2] Over the period 1969-75, Brazil ranked as the world's fifth largest agribusiness exporter, moving up to third place in 1976. For an analysis of Brazil's agriculture in the 1970s, see, for example, Melo (1980) and Pereira (1978a).

[3] See, for example, Fishlow (1972) and Cupertino (1976).

[4] For a comprehensive review of this subject see Wells and Drobny (1982), Hopkins (1981), Taylor et al. (1980), Langoni (1973) and Fishlow (1972).

[5] Information obtained from IBGE officials in Rio de Janeiro on the basis of the 1980 Census data.

[6] At first glance, this statement may seem politically controversial, although there is no secrecy about this in Brazil. Moreover, the author's statement is based mostly on PLANALSUCAR's official data, which are available to the public, if requested, as mentioned in the text. Furthermore, some current literature confirms this. See, for example, Silva (1979), who is quoted in this chapter.

[7] The author's review of statistics on the monthly fluctuation of food prices at state and district levels did not suggest any clear correlation between the expansion of sugar-cane for ethanol and food prices.

[8] A well-known journal (Opiniao, 21 Mar. 1979, p. 11) published a copy of a letter addressed to Brazil's President Geisel on 16 Feb. 1979 from 50 non-proprietary families, comprising over 300 residents of two villages in the NE State of Paraiba. Describing their economic

situation, and the details of the eviction of one of the families, the farmers asked the President for help. The letter detailed the eviction process. Allegedly, armed policemen accompanied by some of the landlord's workers and farm machines arrived at the scene with the eviction order issued by a district court, and allowed the residents ten minutes to abandon the 2-ha plot. The family's belongings had been removed from the shack, which was allegedly destroyed afterwards, along with fruit trees and other planted crops, which were displaced by sugar-cane soon afterwards. The letter further stated that the evicted family was entitled to an indemnification of about $23. Land evictions of peasants associated with the expansion of sugar-cane cultivation for ethanol have been studied to some extent by Graziano da Silva (1980).

CHAPTER 7

CONCLUSIONS

This study has analysed the extent to which PNA's objectives were being achieved in its first five-year period, namely its contribution to (a) foreign currency savings, (b) employment creation and (c) income redistribution (Chapters 3 to 6). In addition, it reviewed the technological and economic aspects of ethanol production with interest for planning (Chapters 1 and 2). This chapter analyses the major findings on PNA's impacts and their policy implications (section 1) and discusses major considerations for the planning of ethanol programmes in other countries (section 2).

1. Analysis of PNA's impacts and policy implications

With a total of about $2,000 million in investments for the ethanol production capacity installed by 1980 (in mid-1980 prices, excluding land purchases), PNA had a positive balance of payments impact of about $520 million in 1980 alone, and created direct employment for 41,000 permanent and 83,000 seasonal workers. This implied investments of about $0.59 per litre and $15,000 per worker or $22,000 per job-year. Against these achievements, however, PNA may have contributed to a concentration in personal and inter-regional income distribution over its first five-year period (see summary of impacts in Chapter 3, section 3).

The positive impacts on employment and the balance of payments may well exceed the negative impact on income distribution, which cannot be rigorously assessed on the basis of available data. Whether the net benefits can be used to compensate for the negative effects is a broader socio-political question largely beyond the limited powers of PNA's policy-makers. Nevertheless, this study underlines a number of problems concerning ethanol production and related sectors which deserve attention.

The surplus of petrol that has occurred since 1978 and the widening gap between production and consumption of both fuel ethanol and petrol since 1980 suggest that ethanol production may have grown too fast. While the growing surpluses of petrol can be exported and fuel ethanol can be consumed through price and tax incentives, the economic benefits of both of these solutions are far from clear.

With regard to ethanol, one can well understand the Government's motives for promoting its consumption, given the dependence of car manufacturers on this, the low international prices of sugar, and the

limited external demand for ethanol. Though it avoids more difficult adjustments, this strategy overrates the oil import substitution value of ethanol. It requires government subsidies for private investments as well as price and fiscal incentives to the owners of hydrous-ethanol cars, which reduce government net revenues. It transfers national income to car owners and ethanol producers to the detriment of the needs of lower-income groups. Furthermore, since most fuel ethanol is consumed by private cars, its increased consumption has had very limited impact on overall economic growth.

Regarding the petrol surpluses, the benefits of exporting these depend on their real cost. As we saw in Chapter 4, in years in which petrol exports are significant, the balance-of-payments impact varies significantly according to different assumptions about the import cost of the exportable petrol surpluses. This cost, which also determines the economic advantage of producing fuel ethanol under the existing oil-refining structure, depends on whether, and how much, crude-oil consumption could have been, or can be, economically reduced to meet the overall demand for fuels. To know this, however, it is necessary to carry out a detailed analysis of crude-oil consumption, refinery throughput and detailed oil-product balances since 1975. Neither this nor the true cost of petrol exports had been assessed by government institutions in Brazil by the end of 1983, and cannot be estimated in this study due to the lack of data. Nevertheless, the huge surpluses of petrol and fuel oil (which is exported at much lower prices than crude oil), and the fact that only LPG has been in deficit, suggest that smaller imports of crude oil, together with larger imports of separate oil products and increased conservation of car fuel, would probably have been a more economic option at least after 1979. If so, the true cost of the petrol surplus may be perhaps anywhere from some 50 per cent to 100 per cent or more of its export value. Unless this cost is known, one cannot argue whether the fast growth of ethanol output has been economically wasteful or not. Nevertheless, it is likely that ethanol production has grown beyond the economically optimal level.

If the net economic benefits of exporting petrol surpluses are low, then it is necessary to increase the import-substitution effect of ethanol. This will require one or more of the following options: (a) further investments in the oil-refining sector to reduce the output of petrol and increase that of diesel; (b) decreases in crude-oil imports coupled with increases of separate imports of LPG, diesel, and possibly other oil derivatives; and (c) increased substitution of ethanol for diesel through changes in the structure of transport and engines.

Changes from road to rail in freight transport are long-term options which could also increase the import substitution value of ethanol, but they are constrained by their large investment requirements. The more immediate possibility of replacing diesel engines with spark-ignition engines in heavy lorries, buses, and even tractors deserves more attention than it has received so far. A

decrease in the gasohol/diesel price ratio could easily promote sales of vans, light lorries, buses and small tractors powered by gasohol or hydrous ethanol.

Reducing the growth rate of ethanol output does not seem to be an option preferred by the Government. Nevertheless, it should be considered, particularly if economically optimal adjustments in the oil-refining sector continue to yield a large surplus of petrol and its real economic cost is close to its export value. There is also a case for reducing production if the substitution of fuel ethanol for diesel in commercial and public vehicles remains constrained by difficulties in changing the relative prices of diesel, gasohol and fuel hydrous ethanol.

A lower growth strategy in earlier years would certainly have enabled more systematic planning which would have been required to prevent some unintended distortions, such as over-concentration of production in richer areas; increased concentration of landownership and; crop displacements which are also associated with a proletarisation of landless farmers who cultivated subsistence crops under rents and other marginal forms of land tenure.

Income distribution among regions and persons may increasingly improve in the future, but this will depend on policies concerning land use, land tenure, and regulation of sugar-cane supply. The fast growth of ethanol output between 1977 and 1981 led to a concentration of production in the major sugar-producing areas of the richest region and state. As ethanol production shifts increasingly to poorer N/NE states, its effect on inter-regional income distribution will improve, but a greater geographical dispersion of investments may not necessarily contribute to a more equitable distribution of personal incomes. Expansion of sugar-cane for ethanol in the NE region is more likely to displace crop land than pastures, because many of the areas which have climate and soil quality suitable for sugar-cane are cultivated with subsistence crops. Much of this cultivation is carried out by small farmers operating under partnerships, leases and even illicit occupancies. Furthermore, since small land plots and illicit forms of land tenure are also much more predominant in the NE than in the C/S regions, substitution of sugar-cane monoculture for food crops may easily cause eviction of peasants and a greater concentration of landownership and incomes than in the C/S regions. CENAL officials have become increasingly aware of these potential consequences but, to prevent them, it will be necessary to change the existing criteria for project approval. Both these criteria and financial incentives have been very ineffective in preventing concentration of income.

The partial findings on the displacement of crops and pastures suggest that this can easily happen even where land is not scarce. In Brazil, it has occurred for two main reasons, which were also responsible for the high concentration of investments in the richest state and region. First, the reliance on existing sugar-mills implied that annexed distilleries were built in locations

predetermined by the geographical and agrarian patterns of sugar production. Second, pressures to reduce raw material costs led to competition for good-quality soils which could produce higher yields. Sugar-cane has advantages over most food crops because it is more highly subsidised, is sold at higher prices and has a stable market.

There has been a lack of effective measures to prevent crop displacements. Strict land-use policies involve difficult and lengthy planning processes which were incompatible with the fast-growth strategy adopted in PNA's early years. More recently, however, detailed studies of land use have been carried out in some states and special areas have been designated for ethanol. Furthermore, CENAL can be increasingly selective in its choice of projects. Most of those accepted after 1981 are autonomous distilleries which, unlike those annexed to sugar-mills, can be located in areas where crop displacements will be minimal.

Given the lower demand for car fuel in poorer states, a greater regional spread of production may not promote significant income benefits for these states, unless emphasis is given to production based on many small-scale distilleries rather than on a few large-scale ones. In principle, this would seem a desirable option, since it would spread the number of investments and their economic linkages, and therefore decentralise the benefits as well. The feasibility of this option depends on factors, such as the financial aspects of small- versus large-scale production, and the implications of more decentralised gasohol-mixing centres for distribution costs. However, the costs of installation and operation of these centres are not significant, and savings in distribution costs may be possible in some areas, even in the case of anhydrous ethanol.

Small-scale distilleries (micro-distilleries up to 5,000 LPD, and mini-distilleries from 10,000 to 20,000 LPD) have not been able to compete financially with typical commercial-scale distilleries but this has been partly due to the lack of adequate policy incentives and of technological innovation. Micro-distillery proprietors are allowed to produce ethanol for their own consumption but do not qualify for subsidised investment loans. Mini-distilleries have been given slightly more favourable financing conditions than larger ones, but ethanol prices paid by the Government are the same irrespective of distillery scale. The two dominant equipment manufacturers in Brazil do not specialise in small-scale distilleries, and those which do, have been virtually unable to penetrate the market.

Investment decisions about small-scale distilleries, and particularly micro-distilleries, should not be determined by financial criteria alone. They have a number of advantages over large distilleries which make them more attractive for promoting rural development. These advantages include the possibility of making more productive use of distillery effluent (stillage) for direct irrigation and/or production of biogas. Small-scale distilleries could be strategically located in communities where by-products of stillage and

surplus bagasse could be used to meet local needs. This would spread the benefits of ethanol production and promote rural development. They are less likely to displace crops as their raw material requirements are much smaller and can be relatively more dispersed without significantly increasing transport costs.

Policies which could improve PNA's impact on both inter-regional and personal income distribution imply greater costs. The costs of ethanol production in the poorer regions are already higher, and a greater decentralisation of production through small-scale distilleries will involve greater investments per litre. However, the additional benefits in terms of employment and income and opportunities for rural settlement have not yet been assessed by PNA's policy-making network. These issues deserve much more emphasis than they have received so far.

It is possible to improve the real income of wage earners, mainly through the creation of more stable employment. We found a significant variation in the composition of permanent and seasonal labour among distilleries' plantations. This is largely the result of different labour- and farm-management techniques. In principle, more permanent jobs will reduce the number of persons employed, but additional jobs on a more permanent basis can also be created while increasing financial returns on ethanol-related investments. This can be achieved, for example, by consorting sugar-cane and sweet sorghum for ethanol production. Ongoing research by government-backed institutions have concluded that this "consortium" is technologically feasible both from industrial and agricultural standpoints. Both crops require basically the same industrial equipment and have supplementary cultivation cycles. Their use can create more stable employment through extended cultivation and increased industrial production. The ethanol production period would increase from 150-180 days (when only sugar-cane is used) to about 300 days per year, and thus financial returns would increase as well. However, effective implementation of these objectives depends on the "demonstration effect" of ongoing research by government-backed institutions, on technical assistance, and on financial incentives.

A more equitable distribution of social benefits would also require policies aimed at increasing the number of small farmers who supply raw material. If this were supplemented by the effective enforcement of the "Sugar-Cane Statute", or similar legislation granting external suppliers a minimal share of supply, the trend towards increased concentration of landownership on the part of the distilleries and their proprietors could be partly avoided. These policies would increase the unit costs of ethanol because sugar-cane from external suppliers usually means higher raw material costs and risks for the distilleries. This, in turn, would imply higher retail prices of gasohol and/or fuel hydrous ethanol and/or a decrease in the distilleries' financial returns. Higher car-fuel prices would be more likely to occur, which would cause some decrease in consumption. This would have little effect on the economy because the use of cars is not very important for economic activity and

incomes in Brazil. It might have some short-term negative effects on employment, particularly in ethanol production (production and sale of gasohol or ethanol cars are normally not affected by small changes in fuel prices). But this effect would not be significant and would not provide any economic justification for maintaining or increasing car-fuel consumption. If this consumption decreases, other types of consumption or savings will increase, and the net effect of this on employment and income is likely to be positive. If there is a substantial increase in the number of commercial and public-utility vehicles which run on gasohol and fuel hydrous ethanol, it may be feasible to establish different prices for private cars and for commercial and public vehicles using a "coupon" system.

In addition, the enforcement of existing legislation requiring plantations to devote a certain amount of land for the workers' subsistence farming would be desirable because the wages of the vast majority of PNA's workers are extremely low.

The experience of PNA's first five-year period illustrates not only the sort of planning deficiencies which are likely to be inherent in new investments in alternative energy production, but also the virtues of initiatives in this risky policy area. Thus, PNA seems to inspire more praise than criticism, given the uncertain trends in oil prices and Brazil's heavy dependence on imported oil when it was launched.

2. Further considerations for planning in other countries

Although Brazil's experience should not be used as a blueprint for ethanol programmes in other countries, it does provide sufficient information for a number of general conclusions. These can be briefly stated as follows.

Ethanol is a renewable fuel with production costs that increase over time. It can provide foreign exchange and employment benefits, but also promote disparities of income and social conflicts associated with raw material production. There are clear trade-offs between cost efficiency and income redistribution which should be studied carefully before any large-scale ethanol programme is decided upon and production strategies are established. The impact of farming for ethanol production on income distribution depends primarily on the agrarian structure and related legislation. In countries where land is scarce and landlessness is high, the benefits of job creation may not necessarily be significant and overall impacts on income distribution may be negative. At existing levels of technology, large-scale programmes will tend to rely on crops which require prime-quality soils.[1] In the absence of effective land-use policies, this may conflict with food production even in countries with surpluses of arable land, such as Brazil.[2] In addition, the effect of fuel ethanol depends on the patterns of transport. Based

on the previous chapters, this final section focuses on the main issues affecting the decision to launch and design an ethanol programme.

Preconditions for commercial-scale programmes

Which countries could and should produce ethanol? The answer depends on many different factors, including the scale of production envisaged; the cost of ethanol and petrol; the importance given to market criteria in investment decisions; the surpluses of appropriate crops, the opportunity costs of these crops and of the land on which they can be produced; the supply and cost of other inputs, including their balance-of-payments implications. While these all require local assessment, there are two main issues which merit special attention: (a) the limitation of ethanol as a substitute for oil imports and (b) the choice between food and ethanol production.

The economic significance of ethanol programmes tends to be determined by patterns of fuel supply and consumption. Thus, a detailed analysis of these is necessary, taking into account oil-refining capacities where these exist. This is particularly important for countries whose crude il throughput is nearly equal to their overall consumption of oil products. For such countries, the most crucial task in planning an ethanol programme is to determine the optimal level of ethanol output and a most appropriate rate of its growth. This is difficult because it may be inadequate to rely on past trends of petrol consumption. It should be noted that the demand for ethanol can easily be overestimated, as it was in Brazil. Of course, the importance of this whole issue depends on the export value of petrol, on the economic costs of producing ethanol and petrol, and on export markets for ethanol.

Determining the need for ethanol and the optimal level of production is much less critical for countries with a small refining capacity and particularly for those which import large supplies of petrol and other refined oil-products. Even so, it may nevertheless be advisable to consider other options, such as fuel conservation and adjustments in the oil-refining and transport sectors. A small refining capacity might at some point justify an ambitious ethanol programme, to the extent that petrol imports could be decreased. The attractiveness of producing ethanol might change, however, if an increase in oil-refining capacity were to become more attractive than increasing imports of refined products.

The relative importance of this issue also depends on the scale and objectives of production. Even in some countries with a large oil-refining capacity and limited demand for fuel ethanol, the chemical sector may justify some production of ethanol. The substitution of ethanol-based chemicals for petrochemicals may become increasingly attractive if oil prices rise. The chemical sector (including beverages, cosmetics and pharmaceuticals) absorbed about 60

per cent of India's ethanol production in 1980[3] and most of Sri Lanka's production since the late 1970s. There may be potential for ethanol exports, but fluctuations in demand and prices make it unwise to aim production at the export market. If the export value of ethanol is greater than its value as a domestic substitute for oil products, any country producing fuel anhydrous ethanol for the domestic market could decrease the percentage in gasohol blends and export this type of ethanol, or liberate some distillery capacity for the production of hydrous ethanol for export.

The literature concerning the choice between food and ethanol tends to exaggerate the possible negative implications of commercial-scale ethanol programmes for food supply and prices. The most typical argument is that using land for ethanol in countries with scarce land resources would restrain or reduce the growth of food output. The real questions, however, are whether land used for ethanol would have been used for food production anyway; which factors account for increases or decreases of food output in the absence of competing land uses such as ethanol production; and whether this production can help stabilise supply and prices of agricultural commodities such as sugar, molasses, manioc, starch, etc. It is adequate then to consider some of the general points raised by other studies, as well as by the present one, before continuing the analysis.

Ramsay (1982, p. 27) summarised the above problem as follows:

> If we use grain for fuel alcohol, we cannot make bread out of it, or, more to the point in the United States, we cannot fatten cattle with the corn [maize] we burn as gasohol. While for individual farmers the gasohol idea may be a boon, in the national interest one must consider the question of the effects of the gasohol programme on the market for agricultural products and on the costs of land and labour factors that go into them. While this problem is rather complex and difficult to analyse, it is easy to see, even without going into the sometimes emotional question of using food crops for energy purposes, that using large quantities of land to grow alcohol will tend in future years to lead to higher prices even for the alcohol itself. That is the really basic reason that the already large costs for marginal amounts of alcohol are particularly worrying.

This view is perfectly logical. One tonne of sugar-cane or crop used for fuel cannot also be used for food. However, does this mean that crops grown for fuel would otherwise be used for food purposes? Similar questions could be raised about other uses of land resources, such as urban growth, and land speculation. Following on this line of thought, one is led to wonder why world famine has not yet been solved.[5] One problem with this view is the assumption that food and ethanol are substitutes for each other in terms of resource use. This is true in some cases, but it is also true that they can be complements as well. In some conditions, ethanol production will not

necessarily reduce food supply, due to a number of reasons which will be discussed below. FAO (1980b p.17) expressed the food-versus-fuel dilemma, from a global perspective:

> On a general level, agricultural growth will have to be accelerated to meet the dual demands for both more food and increasingly for energy feedstocks. The demands for agricultural self-sufficiency will make this growth effort more critical in agriculturally deficient countries. Much of the growth will have to be achieved through increased production on presently cultivated land, hence the challenge for research to increase productivity under minimum energy inputs, since historically this has been achieved principally with energy-intensive technology ... . In a broader sense, it seems increasingly apparent that countries must face a host of critical questions that relate to finding a balance between population growth and needs, and the provision of an adequate supply of domestically produced critical commodities of which food and energy are two of the most important.

Again, this view is also very coherent, but implicitly suggests an exaggerated effect of ethanol production on food supply without convincing evidence. Neither in this passage, nor anywhere in the FAO's study, is realistic reference made to the demand for ethanol; to the amount of the different raw materials to be produced with different implications for land use; or to location, growth and geographical spread of production over time. These are the major factors which determine whether ethanol farming will affect food supply both at national and world levels.

Brown (1980) argued that, as energy prices increase in relation to those of food, countries will face the food-versus-fuel dilemma, and will either have to allow market mechanisms to determine the choice, or to intervene with policies that favour either food or fuel. The author further warned that programmes based on cereals, as in the United States, could affect world food supply and prices. However, a more recent study by Ramsay and Jankowski Jr. (1982, p. 2) screened some of the most important literature on the subject, and concluded: "An alcohol programme in the United States, even of about 1,000 million (U.S.) gallons of alcohol a year, involves a relatively small percentage of our total corn [maize] crop, and therefore can be sensibly treated as a small perturbation of the existing market." Tyner and Buttom (1979, p. 176) also argued that the maize-based programme in the United States would not affect world food supply or prices. A similar argument can be made for Brazil. Because of ISA regulations, land surpluses, and sugar production capacity, there is no evidence that ethanol production has affected world sugar prices or reduced Brazil's sugar export revenues. Even if PNA or other sugar-based ethanol programmes reduced supply and increased prices of sugar-related products, it would be arguable, indeed, whether this

could be regarded as a negative event for either the terms of trade of poorer countries or world development.[6] Although PNA has displaced crops, and may have reduced food-export earnings and/or increased food imports, this could have been partly avoided by effective land-use policies. Some points raised by the World Bank (1980b, pp. 53-54) supplement the previous arguments-

> Basic considerations in assessing the extent of future competition for agricultural resources are the relative price movements for energy and food. As noted, on a global basis, a sharper increase in energy prices than in food or most other agricultural products is plausible, at least over the next decade. Assuming this occurs, the potential land use conflict between food, export and energy crops will increase as economic forces increasingly draw agricultural resources into energy production ... Where the biomass energy programme results in reduced food availability and higher food prices, the net distribution of benefits is likely to be unfavourable since increases in the price of basic foods impact much more adversely on the poor than on other consumers. Where potential competition in land use exists, the basic objective should be to pursue land use policies that maximise the per-hectare net benefits in 'social' terms - taking into account traditional measures of opportunity costs of the raw materials and economic efficiency criteria - as well as concerns with income distribution, impact on the environment, etc. The potential land use conflict may be more imaginary than real in those countries where abundant agricultural resources exist and new land can be brought into production at reasonable cost. Elsewhere, proper government policies may reduce possible competition between energy crops and production of food and other agricultural commodities.

A number of points can be added to the above analysis, based on the discussions in previous chapters.

First, the negative effects of ethanol farming on food supply and prices would normally occur where the ethanol industry can afford to pay higher prices per unit of crop-output of land than the food sector. Although subsidies can affect this situation, even the high oil prices in 1979-80 were too low to have promoted such an effect, except perhaps in some low-income countries. In most of these countries, the demand for ethanol would also be small. As some of the studies mentioned above note, the substitution of energy for food crops may take place in the future. In the meantime, however, the costs of ethanol production from conventional feedstocks will be increasing and countries can promote R and D to increase the attractiveness of less valuable raw materials (such as wood, manioc or even sweet sorghum) and establish medium-term plans for effective land use. To date, most large-scale ethanol production to date has been

based mainly on sugar-cane and molasses, except in the United States. Both the price and income elasticities of demand for sugar and molasses are low compared with those of other major raw materials. Moreover, in the light of the supply restrictions placed upon ISA member countries, one must distinguish between countries which can profitably increase their production of sugar and those which cannot. Being one of the latter countries, and having a surplus of arable land, Brazil's choice was not one of food-versus-fuel, but rather of food plus fuel, provided effective land-use policies were implemented. Although very few countries face comparable conditions, there are some which may produce significant amounts of ethanol for their needs, without seriously affecting food supply. Malawi's experience is worth mentioning: a 41,000 LPD distillery based on low opportunity cost of molasses[7] started production in 1982 with the aim of reaching an annual output of 7.5 million litres of ethanol. This alone is expected to provide a 13:87 ethanol-petrol blend for the whole country and ethanol will cost about 11.5 per cent less than imported petrol.[8] In Nicaragua, a new sugar/ethanol complex near Managua will begin production of ethanol from molasses in 1985 and will include some production of electricity from surplus bagasse and wood for the regional grid. In these cases, ethanol and food farming may be complements rather than substitutes.

Second, as Malawi's case may suggest, commercial-scale programmes do not necessarily have to be large. Brazil's experience suggests that it may be better to increase production slowly with adequate planning than to launch ambitious rushed programmes. Other country experiences also deserve attention in this respect. For example, the rationality of Kenya's ethanol programme has been questioned in terms of the patterns of supply and consumption of fuels, and the high opportunity cost of land and capital resources.[9] Costa Rica had made plans for an ambitious fuel-ethanol programme, which had to be reconsidered as a result of negative appraisals.[10] Also in Papua New Guinea, the Government has given emphasis to ethanol production as a substitute for petrol. A manioc distillery was under construction in 1982, and four additional projects had been planned. According to the World Bank (1982h, p. 11), however, a "published target in 1979 of 130 million litres per annum by 1990 has been recognised as unrealistic and has been reduced first to 36 million and more recently to 10 million; the Government should carefully review the economic justification of any further investment in ethanol projects".

Third, displacements of food crops may be avoided by consorting and rotating crops, provided R and D, technical assistance and financial incentives are implemented. Such techniques could increase output per ha, generate higher and more stable levels of employment and increase financial returns on ethanol-related investments.

Although this study is not meant to (and cannot) identify countries which should or should not develop ethanol programmes, it is clear from the analysis in this section that a general approach to the food-versus-fuel issue is inadequate. There may be many valid

reasons for land-scarce countries not to embark on large-scale ethanol programmes based on cultivated crops requiring good quality soils, especially if the economic costs of ethanol are considerably higher than those of competing oil products. Nevertheless, no sound policy on ethanol can be made without detailed analyses of supply and demand for fuels; supply and markets of alternative ethanol feedstocks for ethanol including molasses, wood and crop wastes (which need not affect food production) and; overall implications of ethanol production for the balance of payments, employment, income distribution and rural development.

The design of ethanol programmes

Given the constraints on the substitution of ethanol for oil derivatives and the dependence of most countries on these products, ethanol programmes have limited significance for energy self-reliance. This fact has two major implications for planning. First, such programmes need to be designed in the light of investments not only in oil-refining, but also in transport and agriculture. Second, the social objectives and strategies of ethanol programmes should be comparatively assessed.

Ethanol is a substitute for oil, but it can also be a catalyst for rural development. These two dimensions should be distinguished because they do not necessarily complement each other. Policies and resource-allocation criteria may emphasise one dimension more than the other and produce different social outcomes. Ethanol and other projects which are financially feasible from the private standpoint may be economically deficient from the standpoint of society, and incur high indirect costs in the medium or long term. Moreover, viable projects from the private and/or social viewpoints may be designed differently, and thus have different benefits and beneficiaries. Although these considerations are obvious in theory, they are often ignored in practice.[11]

It is possible to distinguish between two conceptually different strategies of ethanol programmes. One strategy primarily emphasises oil substitution and relies on fast growth with minor consideration given to employment, income distribution and ecological effects. The other emphasises not only oil substitution, but also social development in a broad sense, even though this usually implies a slower growth of production and possibly some short-term sacrifice in the oil-substitution effect, due to the more complex planning required and greater selectiveness of investments. Although the choice of strategy depends partly on the oil-substitution value of ethanol, it is nevertheless clear that the tendency to view ethanol programmes from an energy perspective alone is inappropriate for social development objectives of employment and income redistribution.

Whether the public sector acts as the ethanol producer or simply as the planner/controller, the latter role is crucial for the pursuit

and attainment of social development. The markets for ethanol and suitable raw materials require an efficient control over supply and prices. The food-versus-fuel problem requires effective land-use policies. An initial appraisal of ethanol projects and their socio-economic, financial and environmental implications is necessary to determine the optimal choice of (a) scale and location of distilleries, (b) raw materials to be used, (c) organisation of raw material supply and (d) techniques of production. It is also necessary to provide adequate credit arrangements based on detailed financial analysis. Furthermore, institutional mechanisms are needed for project appraisal and for enforcing the policies concerning credit, as well as the production and commercialisation of raw materials, ethanol and by-products.

If social benefits are to be optimised, local patterns of landownership must be assessed, and policies designed in such a way so as to avoid concentration of landownership and individual incomes. Projects should be guided to specific locations where by-products of ethanol can be used for irrigation and fertilisation, and eventually for biogas and/or electricity supply.

Once the need for ethanol has been assessed, a more operational level of planning is required. A relatively large-scale ethanol programme (assuming this is recommendable), with or without the co-production of food, involves many participants. Their roles, needs and interactions should be identified before the programme is designed.

The supply of information is important. Ethanol producers depend on information about agro-industrial processes, supply and market prices of factors of production and policies of the programme. Agricultural producers have similar needs. The manufacturers of equipment and other production inputs require information about the demand for their inputs, and perhaps incentives for R and D. This is especially true for less conventional equipment. The distribution sector needs specific guide-lines for operation, including details of the future trends and geographical distribution of supply of, and demand for, ethanol, etc. A minimum amount of R and D will also be required for improving the following: crop yields, crop integration and rotation and the choice of techniques concerning crop renewal and deployment of production factors, including machinery, etc.

Thus, although a government may have some idea about what it wants to achieve, a lot of fact-finding and operations research must be done to determine the overall needs of the programme and the people concerned. The objectives, strategies and targets of production of the programme must be defined on the basis of this research. Policies and institutional guidelines must then be formulated, in order for its implementation to be successful.

Notes

[1] At present, nearly all the ethanol production in the world is based on sugar-cane, molasses and maize. The first two are used in Brazil and in a number of countries of Africa and Asia (e.g., Kenya, the Philippines, Thailand, Zimbabwe, India, etc.), while maize is used in the United States. Both sugar-cane and maize require prime-quality lands, due to both agronomic and economic reasons. Molasses (used in Brazil, India, Sri Lanka, Malawi, Kenya and the Philippines) does not directly require land resources, but only major sugar-producing countries and/or countries with very small car-fuel markets such as Malawi (see World Bank, 1982i) could rely on this feedstock for large-scale commercial purposes.

[2] See also FAO (1980b), Brown (1980) and Ramsay and Jankowsky Jr. (1982).

[3] World Bank (1980b, p. 14).

[4] Koide et al. (1981, pp. 117-118).

[5] On this issue see, for example, Sen (1981).

[6] In a world of market imperfections between richer and poorer countries, the question of food supply and prices cannot be effectively separated from the question of the comparative benefits of trade.

[7] The low opportunity cost of molasses in this case is mainly a consequence of the remote location of the sugar mill, rather than oversupply (World Bank, 1982i, p. 45).

[8] In late 1981, the cost of ethanol was estimated at $52 per barrel compared to a c.i.f. cost of $58 per barrel for imported petrol (ibid., p. 45).

[9] See O'Keefe and Shakow (1981, pp. 212-217).

[10] See Celis et al. (1982).

[11] For a comprehensive review of this problem see, for example, Rosenstein-Rodan (1955), Stewart (1975) and Bhalla (1976 and 1981).

APPENDIX A

PNA: PATTERNS OF ETHANOL SUPPLY

Tables 24-30 illustrate the patterns of ethanol supply by type of ethanol, type and scale of distillery and geographical distribution of production in Brazil. Table 24 shows also land and raw material inputs.

Ethanol production has been reasonably stable, mainly because of the integrated price policy discussed in Chapter 3. Nevertheless, total output was about 10 per cent lower than IAA's established quotas in 1979-80 and 1980-81. This was caused by a combination of factors, including (a) IAA's liberation of the sugar quota in 1980 as world sugar prices increased beyond ISA provisions, (b) lags in pricing adjustments to meet rising agricultural costs, (c) the sugar-cane workers' strike in the NE in 1979 and, (d) the decrease in gasohol consumption after 1979.

As a result of the agreements between the Government and the car industry, the output of hydrous ethanol increased substantially after 1978-79, while that of anhydrous ethanol decreased after 1979-80 until at least 1982-83.

The annexed distilleries were responsible for the high growth rate of ethanol supply during the first five-year period, as most of them had begun production from molasses and then increased their output based on sugar-cane. Although the percentage of those using molasses has fallen from 98.9 per cent in 1975-76 to 72.2 per cent in 1980-81, most of them also produce ethanol directly from sugar-cane. The share of annexed distilleries in total production was over 90 per cent until 1979-80, and fell in 1980-81 only (table 26). Since 1979, the number of project proposals for new autonomous distilleries has increased more quickly than for new annexed ones because both the absolute number and the capacity of the latter are exhaustable.

Table 27 shows the rising share of the C/S macro-region in total production in the first five-year period in contradiction to PNA's objective of reducing regional income disparities. As shown also in this table, however, the share of the C/S will have decreased from 84.2 per cent in 1980-81 to about 66 per cent in 1984-85.

Table 24: Evolution of sugar and ethanol production; land and raw material requirements and by-production of stillage (1974-75 to 1981-82)

Harvest years	Area needed thous. ha	Sugar-cane m.tonnes	Sugar m.tonnes	Ethanol m.l.	Stillage m.l.
1974-75	1 490[1]	74.5[1]	6.7	625	7 500
1975-76	1 366[1]	68.3[1]	5.9	556	6 672
1976-77	1 756[1]	87.8[1]	7.2	664	7 968
1977-78	2 092	104.6	8.3	1 470	17 640
1978-79	2 194	109.7	7.3	2 491	29 892
1979-80	2 340	117.3	6.6	3 396	40 752
1980-81	-	-	8.2	3 786	45 000
1981-82	-	-	-	4 240	51 600

[1] For sugar production only; ethanol was being produced from molasses.

Source: IAA's official data.

Table 25: Production of anhydrous and hydrous ethanol per harvest year (in m.l.) and per calendar year (in m.bbl)[1]

Harvest and Calendar Years	Anhydrous CY m.bbl	HY m.l	annual incr. %	Hydrous CY m.bbl	HY m.l	annual incr. %	Total CY m.bbl	HY m.l	annual incr. %
1975-76	-	233	-	-	323	-	-	556	-
1976	1.7	-	-	2.1	-	3.8	-	-	
1976-77	-	300	29	-	364		-	664	19
1977	4.6	-	-	2.1	-	-	6.7	-	-
1977-78	-	1 177	292	-	293	-20	-	1 470	121
1978	10.3	-	-	2.2	-	-	12.5	-	-
1978-79	-	2 096	78	-	395	35	-	2 491	69
1979	15.1	-	-	3.4	-	-	18.5	-	-
1979-80	-	2 713	29	-	683	73	-	3 396	36
1980	15.5	-	-	7.1	-	-	22.6	-	-
1980-81	-	2 111	-19	-	1 575	131	-	3 786	11
1981	11.5	-	-	13.7	-	-	25.2	-	-
1981-82	-	1 453	-	-	2 787	-	-	4 240	-
1982	15.7	-	-	15.9	-	-	31.6	-	-
1982-83	-	3 550	-	-	2 273	-	-	5 823	-
1983	18.9	-	-	24.1	-	-	43.0	-	-
1983-84	-	2 468	-	-	5 399	-	-	7 867	-

Table 25 (cont.)

[1] Production in the 1980 calendar year (CY), for example, comprises part of the output in 1979-80 and part of that in 1980-81. The above figures for production in calendar years were calculated by taking the averages of two consecutive harvest years (HY). This procedure is required for accounting purposes based on calendar years. One bbl is equivalent to 159 litres.

Source: Elaborated from IAA's official data.

Table 26: Ethanol production by type of distillery (1975-76 to 1980-81)

Type	Annexed		Autonomous			Total	
Harvest year	No.	Production m.l.	No.	Production m.l.	% share annexed	No.	Production m.l.
1975-76	124	502.6	6	53.0	90.5	130	555.6
1976-77	121	619.1	7	44.9	93.2	128	664.0
1977-78	137	1 325.9	13	144.5	90.2	150	1 470.4
1978-79	150	2 261.7	22	228.9	90.8	172	2 490.6
1979-80	155	3 047.8	41	348.7	89.7	196	3 396.5
1980-81	158	3 127.1	49	659.3	82.5	207	3 786.4

Source: IBRASA, 1981.

Table 27: Major ethanol-producing states by macro-region: Relative share (in percentages) of production (1975-76 to 1980-81)

Macro-regions/states	1975-76	1979-80	1980-81	1984-85[1]
Centre/South (C/S)	83.1	83.2	84.2	65.8
Sao Paulo	65.2	72.9	70.8	
Parana	3.6	2.7	4.6	
Rio de Janeiro	9.9	4.1	3.9	
Minas Gerais	2.9	2.2	2.8	
Others	1.5	1.3	2.1	
North/North-East (N/NE)	16.9	16.8	15.8	34.2
Alagoas	4.9	6.7	6.3	
Pernambuco	11.6	6.9	5.5	
Others	0.4	3.2	4.0	
Brazil	100.0	100.0	100.0	100.0

[1] Assuming all projects approved by 14 January 1981 will be operating at full capacity by 1984-85.

Source: Elaborated from IAA's official data.

Table 28: Approved distillery projects by region, type of distillery, raw materials and production capacity (14 January 1981)

Region	Total of approved projects		Total capacity	Subtotal annexed capacity		Subtotal autonomous capacity		Annexed		Autonomous		Sugar-cane	Manioc	Other
	No.		(m.l.)	(m.l.)	%	(m.l.)	%	No.	%	No.	%	No.	No.	No.
C/S	228	258[1]	4 528.0	2 152.8	72	2 375.2	61	115	66.5	113	67.7	216	9	3
N/NE	112	121[1]	2 364.2	833.6	28	1 530.6	39	58	33.5	54	32.3	109	3	
Brazil	340	379[1]	6 892.2	2 986.4	100	3 905.8	100	173	100	167	-	325	12	
Sao Paulo	135	150[1]	2 718.9	1 679.8	56	1 039.1	27	82	47.4	53	31.7			
Pernambuco	27	28[1]	324.8	234.8	7.8	90.0	0.2	21	12	6	3.6			
Alagoas	36	36[1]	579.2	469.8	15	289.4	0.7	26	15	10	5.9			

[1] Position: 1 April 1981 (no change in overall trend).

Source: Elaborated from CENAL's official data.

Table 29: Evolution of the number of distilleries by scale and share (in percentages) in total production: 1975-76 to 1980-81

Scale of distillery (LPD)	1975/76		1976/77		1977/78		1978/79		1979/80		1980/81	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Up to 60 000	118	66.7	114	65.5	98	25.3	89	15.7	90	12.0	82	10.2
60-120 000	10	25.2	11	22.1	34	30.3	47	26.8	51	21.5	61	22.6
120-240 000	2	8.1	3	12.4	14	28.1	24	26.3	39	30.9	45	31.2
240-360 000	-	-	-	-	2	6.4	7	13.7	5	6.8	9	11.7
360 000 and over	-	-	-	-	2	9.9	5	17.5	11	28.8	10	24.3
Total	130		128		150		172		196		207	

Source: Elaborated from IAA's official data.

Table 30: Number of distilleries by scale of production approved until mid-September 1980

	Distilleries			
	Number		Capacity	
Production capacity (LPD)	Absolute	Relative (%)	Absolute (m.l.)	Relative (%)
Up to 60 000	55	18	500	6
60-120 000	133	43	2 400	31
120-240 000	88	29	2 800	36
240 000 and above	30	10	2 200	26
Total	306	100	7 700	100

Source: IBRASA (1981).

APPENDIX B

PNA: DISAGGREGATED PRODUCTION COSTS AND INVESTMENTS

1. Costs of anhydrous ethanol production

To supplement the analysis in Chapter 3 (section 4) this appendix disaggregates the costs of ethanol production, at market prices, by macro-region and type of distillery in Brazil. Costs expressed in dollars in this appendix have been converted at official exchange rates, except where noted, for illustration.

It is noteworthy that the poorer macro-region has higher raw material and per litre costs. This characteristic may or may not be peculiar to Brazil, but it should be borne in mind by planners in other countries, since there may be economic constraints to the distribution of investments in poor areas.

Table 31 illustrates the unit cost of sugar-cane production in Brazil's two macro-regions ($9/tonne in the C/S and $13.2/tonne in the N/NE) in December 1979, as researched by Fundacao Getulio Vargas (FGV) during the 1978-79 harvest. Regarding the composition of these unit costs by macro-region, table 31 shows that in the N/NE the considerably higher cost of agricultural labour contrasts with the lower costs of farm machinery and equipment, thus indicating a higher labour-intensity in ethanol-related agriculture than in the C/S.

The higher unit cost of raw material in the N/NE is not related to wages and incomes. Rather, it is caused by the lower yields of sugar-cane per ha (this being a consequence of factors relating to capital, technology and land), the higher irregularity of soils, the greater demand for agricultural labour and the somewhat questionable issue of the lower physical productivity of labour.[1] The regional variation in raw material cost is extremely important, since this cost as a percentage of total production costs has increased in recent years. The sugar-cane cost in large plantations under monoculture-based farming will be 65-70 per cent of the total per litre cost, but it can be higher, depending on the share of external suppliers' canes, which are purchased at a fixed price. Cutting, loading and transport operations represent, on average, about 40 per cent of the total sugar-cane cost, although regional differences in the choice of techniques may change this percentage slightly. In the N/NE, the higher agricultural cost is the major cause of the higher cost per litre of ethanol.

The FGV data (based on the 1978-79 harvest with prices adjusted for December 1979) revealed also that the N/NE distilleries' overall costs were 32 per cent higher than their counterparts in the C/S region, while on a national average, the per litre cost (excluding raw

material)[2] of the autonomous distilleries was 45 per cent higher than that of the annexed distilleries. The former gain only on "financial costs" (in consequence of higher subsidies), "ingredients and chemicals", and "conservation and repairs" (see table 32).

Table 31: Cost breakdown of one tonne of sugar cane produced in the plantations of distilleries of external suppliers in the 1978-79 harvest, by macro-region[1]

Cost items	C/S A $	%	N/NE B $	%	B/A[2]
Agricultural production cost	5.83	64.4	9.77	73.7	1.68
Operational labour	2.25	24.8	4.98	37.5	2.22
Fertilisers, insecticides etc.	1.68	18.4	2.48	18.7	1.48
Machines and equipment	1.05	11.6	0.66	5.0	0.63
Transport	0.44	4.9	0.82	6.2	1.86
Other costs	0.42	4.7	0.83	6.3	1.97
Insurance, taxes	0.09	1.0	0.13	1.0	1.44
Administrative costs	0.30	3.5	0.46	3.5	1.53
Financial costs	1.86	20.6	1.81	13.6	0.97
Total production cost	8.09	89.4	12.17	91.8	1.50
Cane transport cost	0.96	10.6	1.08	8.2	1.12
TOTAL	9.05	100.0	13.25	100.0	1.46

[1] Market prices and official exchange rate of December 1979 (cr$42.3/$, at parity with $).

[2] Ratio of cost in N/NE to cost in C/S.

Source: FGV.

Table 32: Cost breakdown of one litre of anhydrous ethanol by type of distillery (120,000 LPD) excluding raw material (December 1979; cr$ per litre)[1]

	120,000 LPD distillery				
	Autonomous A		Annexed B		A/B[2]
Cost items	Cr$/ litre	%	Cr$/ litre	%	
Manufacturing costs	2.4739	63.7	1.4661	54.7	1.69
Labour	0.3565	9.2	0.3265	12.2	1.09
Ingredients and chemicals	0.1212	3.1	0.1680	6.3	0.72
Fuels and lubricants	0.3156	8.1	0.0725	2.7	4.35
Light and power	0.1638	4.2	0.0642	2.4	2.55
Transport	0.0769	2.0	0.0308	1.1	2.49
Miscellaneous items	0.1305	3.3	0.0704	2.6	1.85
Maintenance	0.3065	7.9	0.3688	13.8	0.83
Depreciation	0.4325	11.1	0.2854	10.6	1.52
Other expenses	0.5704	14.8	0.0795	3.0	7.17
Taxes and insurance	0.0824	2.1	0.0251	0.9	2.33
Financial costs	0.9155	23.6	0.9575	35.7	0.96
Interest on work capital	0.2572	6.6	0.3864	14.4	0.66
Interest on investments	0.4889	12.6	0.4889	18.2	1.00
Amortisation	0.1694	4.4	0.0822	3.1	2.06
Administrative costs	0.4120	10.6	0.2324	8.7	1.77
TOTAL COST OF PRODUCTION	3.8838	100.0	2.6811	100.0	1.45

[1] $1 = 42.3 cr$; official rate at parity with $.

[2] Ratio of costs in autonomous distilleries to costs in annexed distilleries.

Source: FGV.

The production costs of anhydrous ethanol shown in table 33(a), (b) and (c) for December 1979, May 1980 and May 1981, were developed from basic data of the FGV[3] and the IAA.[4] The reasons for presenting data for more than one period are two-fold: to show the trend of rising unit costs and, second, to suggest the cost implications of different sources of raw material supply.

In December 1979, the simple-average cost of the two macro-regions, and the weighted-average cost (the latter reflecting the macro-regional distribution of production)[5] were USc22.8 and USc20.2 per litre (the same at the shadow exchange rate - see Chapter 3, section 4)), assuming that all the ethanol would have been derived from the distilleries' own supplies of sugar-cane.

For production costs in May 1980 and May 1981, a more realistic situation[6] was assumed, whereby distilleries would have purchased 50 per cent of the raw material at the price stipulated by IAA, with the remaining 50 per cent at production cost (calculated at 80 per cent of IAA's stipulated price). Assuming also real increases of 5 per cent and 15 per cent in dollar terms for all other costs, respectively from December 1979 to May 1980, and from May 1980 to May 1981, the weighted-average costs per litre in Brazil in these dates can be estimated at USc23.6 and USc30.5 at official exchange rates, or USc21.2 and USc21.4 at shadow exchange rates (see table 33).

Reliable data on per litre costs of manioc ethanol were not found. The only manioc distillery in operation until 1982-83 was probably not very typical, having had high production costs for reasons mentioned in Chapter 3.

The scale of the distillery has considerable effects on the costs of sugar-cane ethanol. Assuming a constant raw material cost and a base index of 100 for the litre cost of a 60,000 LPD distillery, research by COPERSUCAR (1980) during the 1978-79 harvest estimated index figures of 95, 88 and 85 for units of 90,000, 240,000 and 360,000 LPD (150 days/year). Also acccording to DEDINI's officials, and only regarding industrial operations, a 480,000 LPD has lower unit costs than a 240,000 LPD. However, the World Bank (1980b, p. 33) noted that "economies of scale diminish rapidly above 300,000 LPD". This conclusion takes into account raw material costs, including transport, which is the major factor accounting for diminishing returns beyond a certain radius of supplying lands.[7]

Table 33: Cost per litre of anhydrous ethanol from sugar cane in 120,000 LPD distilleries - Brazil, C/S and N/NE macro-regions and type of distilleries, December 1979; May 1980 and May 1981 (USc/litre)[1]

	Brazil			C/S	N/NE	Brazil	
	Annex. dist.	Auton. dist.	Simple average of A+B	Average	Average	Simple average of D+E	Weighted average of D+E
(a) Dec. 1979: Assuming 100% of sugar cane from distillery's own lands at cost ($9/tonne, C/S; $13.2/tonne, N/NE)							
	A	B	C	D	E	F	G
Raw material	15.8	15.8	15.8	12.8	18.8	15.8	-
Other costs	6.3	9.0	7.6	6.0	8.0	7.0	-
Total/ litre	22.1	24.8	23.4	18.8	26.8	22.8	20.2
Total/litre at shadow exchange rate[1]							20.2
(b) May 1980: Assuming 50% from external suppliers at stipulated price ($12/tonne, C/S; $20/tonne, N/NE) and 50% from distillery at cost (80% of stipulated price)							
	A	B	C	D	E	F	G
Raw material	20.5	20.5	20.5	15.4	25.7	20.5	-
Other costs	6.6	9.4	8.0	6.4	8.4	7.3	-
Total/ litre	27.1	29.9	28.5	21.7	34.1	27.8	23.6
Total/litre at shadow exchange rate[1]							21.2
(c) May 1981: Assuming 50% from external suppliers at stipulated price ($17/tonne, C/S; $24.5/tonne, N/NE) and 50% from distillery at cost (80% of stipulated price)							
	A	B	C	D	E	F	G
Raw material	26.6	26.6	26.6	21.8	31.5	26.6	-
Other costs	7.2	10.3	8.7	6.9	9.2	8.0	-
Total/litre	33.8	36.9	35.3	28.7	40.7	34.6	30.5
Total/litre at shadow exchange rate[1]							21.4

Notes to table 33

[1] Shadow exchange rate factors of 1, 1.1, and 1.3 were used for Dec. 1979, May 1980 and May 1981, respectively, to correct the over valuation of the cr$ in these months (see Chapter 3, section 4). The share of ethanol from molasses in total production implies that Brazil's average costs were actually lower than those above but, as production grows, this consideration becomes less and less significant.

C The figures in this column are illustrative. They are distorted by the bias of the national average of annexed and autonomous distilleries (columns A and B); they disregard the relative share of these in total production and their macro-regional distribution.

D/E Averages of annexed and autonomous distilleries in each macro-region.

F Simple average of both macro-regions, disregarding their share in total production.

G Weighted average litre, taking account of the macro-regional share in total production.

Source: Elaborated from FGV's costs in tables 31 and 32 and IAA's cane prices.

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2. Investments in ethanol production

Industrial investments

Table 34 summarises the industrial investment required for the most typical scales of sugar-cane autonomous distilleries. Columns 2 and 3 reveal some cost variations, caused by the inclusion of different items in the total cost structure. Earlier data from the CNPq (1978, pp. 193-97) on investments of various distilleries revealed variations of up to 90 per cent in the total investment for distilleries of the same capacity regardless of type. The causes of these variations were not clear, however.

ZANINI's figure for a 120,000 LPD distillery (column 3) is a normative one: it reflects what the investment costs ought to be, according to this company's vice-president. It includes some items which have been ignored by CENAL in its cost matrices (used for establishing maximal subsidised loans for each investment project approved). The $14.5 million, in contrast with PROQUIP's figure (which is similar to DEDINI's), include a 10 km access road to the distillery and other items described in note (c) in table 34. Personnel training was included because the distillery entrepreneurs usually need this service from the equipment suppliers, but it is often provided on an informal ad hoc basis at no extra cost to the distilleries.

Table 34: Industrial investments of sugar-cane ethanol distilleries ($ millions)

Litres per day (LPD)	(a)[1]	(b)	(c)
90 000	8.4		
120 000	10.2	11.5	14.5
150 000	11.8		
180 000	13.0		
240 000	17.3		
300 000	19.8		

(a) Data from IBRASA (1981), excluding ethanol storage facilities, land, access road, interest, working capital, but including freight and a 12 per cent contingency cost - Jan. 1981, at official exchange rate of cr$67/$ (overvalued 35.7 per cent).

(b) Data from PROQUIP, excluding freight, working capital, land, access road, and interest, but including storage facilities, December 1980 prices, at official rate of cr$64/$ (overvalued 36 per cent).

(c) Data from ZANINI, without freight, land, interest, working capital, but including 10 km access road, personnel training, laboratory - December 1980, at official rate of cr$64/$ (overvalued 36 per cent).

[1] See table 35 for a disaggregation of these costs.

Source: See notes.

Table 35: Breakdown of fixed industrial investments: autonomous sugar-cane distilleries ($ millions)[1]

	Scale of distilleries (LPD)					
Cost items	90 000	120 000	150 000	180 000	240 000	300 000
Machines and equipment	4.5	5.6	6.1	7.2	9.8	11.8
Stillage disposal	0.5	0.6	0.7	0.8	1.1	1.3
Civil works	1.05	1.3	1.8	1.5	1.7	1.8
Utilities	1.34	1.5	1.9	1.9	2.3	2.5
Sub-total	7.4	9.0	10.5	11.5	15.0	17.5
N/NE freight cost	0.2	0.3	0.3	0.3	0.5	0.6
12% contingency cost	0.9	1.1	1.2	1.4	1.8	2.1
N/NE TOTAL	8.5	10.4	12.0	13.2	17.3	20.2
C/S freight cost	0.09	0.1	0.1	0.1	0.2	0.2
12% contingency cost	0.9	1.1	1.2	1.4	1.8	2.1
C/S TOTAL	8.4	10.2	11.8	13.0	17.0	19.8

[1] At market prices and official exchange rate of January 1981 (cr$67/$ - overvalued 35.7 per cent), excluding storage facilities, land, working capital, access road, personnel training and financial costs.

Source: IBRASA (1981).

Table 36: Initial agricultural investment per hectare for creating a sugar-cane plantation: C/S macro-region, March 1981

Operations	$/ha
Preparing the area	237.80
- Brush-wood clearance	81.00
- Land clearance	54.00
- Ridging	27.00
- Burning	8.10
- Cleaning	13.50
- Other	54.00
Soil preparation	129.00
- Heavy levelling I	27.00
- Lime application	13.50
- Heavy levelling II	13.50
- Root extraction	8.10
- Harrowing	13.50
- Application of protectors	47.20
- Clearance and hauling	6.70
Planting	90.50
- Furrowing and fertilisation	27.00
- Cutting of seedlings	8.10
- Sanitary and thermic treatment	54.00
- Transport of seedlings	6.70
- Distribution, planting and covering	13.50
Cultivation	108.10
- Herbicide application	47.20
- Manual cultivation	24.30
- Roguing	13.50
- Fertilisation	10.80
Inputs	560.80
- Cane seedlings	202.00
- Cane freight	162.00
- Fertilisation	162.00
- Fungicides	10.80
- Insecticides	2.70
- Herbicides	40.50
Internal transport	20.20
- Fertilisers, seeds, water, etc.	20.20
General total[1]	1 135.00
General total at shadow exchange rate[2]	681.00

[1] Official exchange rate of cr$74/$.

[2] Using a shadow conversion factor of 1.4, to correct for the overvaluation of the cr$.

Source: IBRASA (1981).

Agricultural investments

On average, the total investment required for the establishment of one ha of sugar-cane in Brazil's C/S macro-region was estimated at $1,135 in March 1981 (about $680 at the real exchange rate); about 60 per cent of this cost was variable and 40 per cent was fixed (tables 31 and 36). A 120,000 LPD with a cultivated area of approximately 5,200 ha required an investment between $5.9 million, excluding machinery and construction works, and about $6.8 million if these items were included.

Notes

[1] Although this is often noted in Brazil as one cause of higher sugar-cane costs in the N/NE, it is nevertheless questionable, to the extent that it is difficult to distinguish between human and environmental variables affecting the physical productivity of labour. The former could only be tested if the latter remained constant.

[2] The exclusion of raw material is necessary in this case to show the comparative costs of annexed and autonomous distilleries. Not only regional variations in raw material costs, but also the varying use of molasses by the annexed distilleries would otherwise offset the relevance of these cost comparisons.

[3] See tables 31 and 32.

[4] Includes official information on the fixed prices of sugar-cane.

[5] This consideration is important in Brazil because the C/S macro-region with lower unit costs shared 84.2 per cent of production in 1980-81.

[6] Although some autonomous distilleries control 100 per cent of their required supplies of sugar-cane, they are nevertheless a minority.

[7] Beyond a certain scale of production, the economies of scale (of the total operation - agriculture and industry) diminish, because as the distillery requires a larger land area, the transport cost will increase to a point where it will offset the decrease in the marginal industrial cost. However, the point at which diseconomies of scale take place varies from case to case, depending on agricultural yields, price of raw material, etc.

APPENDIX C

CHOICE OF TECHNIQUES IN SUGAR-CANE PRODUCTION

This appendix to Chapter 5 analyses the choice of farm machines versus labour[1] in sugar-cane[2] cultivation for sugar and ethanol production. The comparative advantages of such options (in operations where a choice exists) should be analysed in a given situation, by taking into account (a) the direct comparative cost of labour and machines; (b) the indirect cost of differences in productivity, including the cost implications of the real operating time of machines per day, referred to as the "field rate"; (c) the supply of seasonal labour, level of unemployment and underemployment; (d) the indirect cost of added diesel consumption; (e) the effect of machinery on the improvement of the quality of work and workers' conditions, and possibly (f) the role of labour unions and their effect on wages and productivity. It is axiomatic, however, that the comparative advantages of techniques depend on different viewpoints (e.g., private versus social, wage worker versus landowner-operator) which are not always compatible.[3]

In Brazil, the supply and market prices of labour and farm machinery, as well as import restrictions,[4] have given labour-intensive techniques a financial advantage over machinery in sugar-cane harvesting operations. This is also because of their greater technical efficiency, which has cost implications. For example, research by Tambosco et al. (1978) in 1976-77[5], concluded that "dual-function" harvesters (cutting and loading)[6], with an average productivity of 36 tonnes per hour and with a "field rate" of 42 per cent (180 tonnes/day)[7], had an average "deficiency" rate (cane left in the field) of 14.9 tonnes/ha (21.6 per cent of the average productivity per ha in the State of Sao Paulo, and an average cost of $2.14/tonne.[8] This compared with $1.77/tonne (1976 prices) for the technique which combined manual cutting and mechanised loading and transport.

Another technical consideration, with indirect cost implications, concerns the comparative productivity of harvesting techniques, measured in litres of ethanol per tonne of transported cane, resulting from the efficiency of cutting and loading. Ripoli and Berto (1981) gathered information from Brazil and other countries, and compared the efficiency of alternative techniques in terms of the percentage of unusable scrap collected with the sugar-cane. As table 37 suggests, the combined method of manual cutting and mechanised loading is the most efficient in this respect. Furthermore, uneven terrain can also

reduce the productivity of the cutting machinery because it does not allow very low-level cuts, and the part of the cane with the highest sugar concentration is lost. The wide variation among the "dual-function" harvesters (table 37) is caused by ground conditions, and type of machine used, whereas the relatively high inefficiency of the Hawaiian harvester ("push-racker"), in terms of scrap collected, may also be an indirect result of the high opportunity cost of labour.[9]

PLANALSUCAR technicians consulted by us in Brazil argued that, because of both direct and indirect costs, the technique of manual cutting and mechanical loading was financially more attractive than "dual-function" harvesters even in 1980-81. They did mention, however, that the introduction of locally manufactured harvesters in 1980 could possibly reverse this situation, because of the lower investment and maintenance costs of these machines compared to imported models.

Methods of gathering sugar-cane in the field, and of loading and unloading lorries during the harvest, pose a further question. Santos (1981) compared the cost of transporting cut cane[10] versus whole cane in Brazil. He concluded that transporting cut cane was at least 10 per cent cheaper depending on the distance over which it was carried. This savings may not be important depending on the cutting technique, however. If it is done manually, the transport savings may not always compensate for the uncertain, but possibly considerable, increase in labour costs. It is particularly important if producers have to choose between manual and mechanical cutting or between different harvest machines. PLANALSUCAR officials interviewed in Sao Paulo suggested that the cut-cane method contributed to industrial efficiency (e.g. better flow in the reception at the distillery, easier preparation, and better crusher-feeding) but that the price of the necessary machines was also considerably higher than that of common equipment. Different designs of lorry racks also affect the efficiency of loading, transport and unloading operations, and possibly the number of workers needed for unloading sugar-cane at the distillery.

The alternative techniques of manual cutting and gathering have further effects on the demand for labour and its productivity. On rolling hills, where the loading machinery and lorries cannot operate, the sugar-cane must be cut, tied in bundles, and carried to the lorries, usually by hand or by animals. Even where the terrain is flat and where cutting, gathering and loading operations are carried out manually, the rate of productivity may vary substantially, depending on the cutting technique. According to experts at a PLANALSUCAR station in NE Brazil, the method of cutting is partly responsible for variations in labour productivity during the harvest, in areas where manual techniques are practised. The most efficient method is to cut the sugar-cane so that for every two cut rows there is one row of cut cane piles only, instead of two rows of inconsistent piles spread over the field.

Table 37: Percentage variations of waste material in harvested cane by alternative techniques in different countries[1]

Country or region	Harvesting technique	% of foreign material	Cane losses in the field
Sao Paulo (Brazil)	Manual cutting and mechanised loading	2-4.5	10-17 tonnes/ha depending on the equipment used in the loading operation
Rio de Janeiro (Brazil)	Manual cutting and mechanised loading	0.9-2	
Cuba	Dual-function harvester	4.2	
Trinidad	Dual-function harvester	5	
Mexico	Dual-function harvester	9-12	
Tucuman (Argentina)	Dual-function harvester	10	
Louisiana (USA)	Dual-function harvester	15	
Florida (USA)	Dual-function harvester	13	
Hawaii (USA)	"Push-racker"	35	

[1] These figures are not necessarily representative of those countries, but rather of given regions and cases where the techniques were surveyed. The data were largely based on earlier research by different authors on different countries and regions.

Source: Ripoli and Berto (1981).

The method of paying workers also affects the productivity of labour, in situations where the harvest worker is an employee. From the private standpoint, paying the workers according to individual output would be the most effective way of increasing productivity. This is difficult to implement on a plantation, since the quantity of production is normally assessed at the distillery on the basis of weight or sugar content per tonne. A few of the surveyed distilleries in Brazil employed some workers on a piece-work basis, but this was limited to cases where there seemed to be close contact between the agricultural managers and these workers. Some external labour contractors pay the labourers according to daily collective output.

The productivity of labour also seems to be affected by the use of some types of farm machinery. It has been argued, for example, that the speed of single-function harvesting machines (where these are used) commands the flow of the work and increases the productivity of workers tracking behind the machines in gathering and loading operations (Graziano da Silva, 1977, p. 10). This may, however, reduce the manager's interest in paying the workers according to their rate of productivity.

The available literature on effects of mechanisation on employment, labour productivity and incomes does not permit any standard conclusions. These effects depend on different variables, such as the type of crop (seasonal or permanent) farming technique (monoculture or intercropping), type of machines, and agrarian structure. However, unlike the more conventional wisdom tends to presume, there is evidence that mechanisation does not always reduce employment and labour incomes even in private farming systems. Sen (1975, pp. 155-56) synthesises the findings of some studies in India:

> Ashok Rudra (1971) reports that in his investigation of big farmers in Punjab, done jointly with Abdul Majid and B.D. Talib, it was found that tractors 'create demand for permanent servants and replace casual labour'. Rudra points out that 'the most frequently observed combination of permanent servants and casual labour is one permanent servant and between 100 and 200 man-days of casual labour for non-mechanised farms; zero permanent servants and between 100 and 200 man-days of casual labour for farms with pumps and tube-wells but no tractors; and 2 permanent servants and between 100 and 200 man-days of casual labour for tractorised farms'. Rudra's conclusions were drawn presumably after correction for size variations.
>
> Using data from Studies in the Economics of Farm Management relating to the Ferozepore District in the Punjab in 1968-69, Hanumantha Rao studies data for 150 farms and relates, among other things, employment to a number of variables, of which one is a dummy variable representing whether the farmer owns a tractor or not. The coefficient, close to zero, for tractorisation turns out to be not significant, and Hanumantha Rao seems inclined in the direction of regarding tractorisation

as not labour-displacing. He argues that 'the technological displacement of labour consequent on the use of tractor is roughly compensated by the rise in employment mainly as a result of the increase in yield associated with tractor-use'. He also notes that in view of the complementarity between tractorisation and irrigation and the use of high-yielding varieties, tractors may under certain circumstances expand employment.

Analysing the farm survey data of the Programme Evaluation Organisation of the Planning Commission of India for 1967-68, 1968-69 and 1969-70 relating to the wheat belt of the Indo-Gangetic plain, Brian Lockwood finds that 'tractors are associated with a slight increase in hired labour'. His prediction, however, is that 'this situation may not last' when other operations not yet mechanised are put under machines, which 'seems inevitable'.

In a pilot study done in Haryana, R. K. Sharma compares tractor farms and non-tractor farms carefully chosen to be similar in respect of land holding and irrigation facilities. He finds that while farms with tractors require a somewhat larger amount of total labour, the rate of utilisation (defined as labour used per cropped acre) is about 7 per cent higher for bullock farms than for tractor farms. There is greater labour use in tractor farms for harvesting, weeding and irrigation, but the labour requirement for ploughing is drastically cut by tractorisation.

It is unclear from the above examples whether it is the mechanisation or the increased output (generally associated with it) which affects employment. Whichever the correlation may be, such evidence deserves attention, since employment is a social objective only in so far as it contributes to improvements in income. Furthermore, the fact that research in Brazil indicates that some labour-intensive techniques are more efficient does not mean that these can be preferred simply for that reason, either in Brazil or elsewhere. For example, both the supply and costs of wage labour partly explain the adoption of manual harvesting in Brazil and of the "push-racker" harvester in Hawaii - the latter combining cutting, loading and soil preparation, but with a low efficiency in terms of cane collecting (table 37).

However, the choice of techniques in the production of sugar-cane and other seasonal crops may create a social dilemma in some societies. Labour-intensive techniques tend to generate higher employment in the short term, but also seasonality and migration of labour, and lower net output with longer-term implications for employment. Even in situations where factor costs favour labour-intensive techniques from the private standpoint, these may be inadequate for long-term improvements in rural incomes.

Indeed, a number of studies have suggested that the comparative social relevance and implications of choice of techniques in agriculture depend on alternative structures of land tenure.[11] As Griffin (1974, p. 18) so succintly suggested: "In rural areas, the most important means of production is land, and the only way to ensure access to it is to own it".

Notes

[1] Normally, one tends to refer to these terms as capital- and labour-intensive techniques. However, mechanisation and capital intensity are not synonyms in economic and financial terms. On this subject see, for example, Sen (1975) and Winston (1971).

[2] Sugar cane is selected for this analysis, because of the limited information on other ethanol crops.

[3] For a comprehensive review of these issues in different sectoral contexts see, for example, Rosenstein Rodan (1955); Bhalla (1981); and Griffin (1972 and 1974).

[4] In Brazil, the consumer price of most goods which can be imported has been about 100 per cent above the c.i.f price. Harvesters were not manufactured in Brazil until late 1980.

[5] This research took place at Usina da Barra, in the State of Sao Paulo during that harvest year. Similar data were developed by Santos (1978), from research conducted in the State of Rio de Janeiro.

[6] Four models of Brazilian-made machines were tested: Santal 115, Claas Libertadora 1400, Massey Ferguson 201 and Toft Robot 300 (the most efficient of the four).

[7] The figure is calculated as follows: 36 x (42 per cent of 12 hours) = 180 tonnes/day.

[8] Ranging from $1.70 to $3.30, including maintenance, fuel, oils, labour and financial costs.

[9] The "push-racker" combines three functions - cutting, loading and replanting - this being a consequence of the high wages in Hawaii (see Appendix D).

[10] With this technique, the sugar-cane is cut in two or three pieces before loading, thus increasing the density of the lorry load as much as 20 per cent.

[11] See, for example, Sen (1975), Pearce (1981) and Ghai et al. (1979).

APPENDIX D

COMPARATIVE CHARACTERISTICS AND IMPLICATIONS OF ALTERNATIVE AGRARIAN STRUCTURES

This appendix provides empirical and analytical support to the discussion in Chapter 6. It discusses the relative importance of agrarian structure in determining the income-distribution effects of sugar-cane agriculture for the production of ethanol or sugar.

Various authors have studied agrarian structures and forms of agricultural production.[1] In particular, the ILO series of country studies on this subject is noteworthy.[2] Among others, Griffin (1972 and 1974) provided a comprehensive analysis of different landlord-tenant relationships and their socio-economic implications. Klein (1977, pp. 50-56), with regard to Latin America, distinguished three "major forms of production", that is the "hacienda-type", the latifundium-minifundium complex, and the commercial-level agricultural enterprise. As Klein suggested, such a classification is neither exhaustive nor applicable to every country in the region, but it helps one to understand the relationship between agrarian structure and income-generating activity.

The "hacienda-type" is a traditional extension of early colonial societies, whereby the landlords allot peasants certain areas of the farm on which they can live and produce for subsistence and market purposes. In return, the peasants are obliged to work on land directly managed by the landlord, this work usually being seasonal. This is in some ways a more traditional form of share-cropping, the details of which have been described by Griffin (1974, pp. 19-30), and about NE Brazil, by Kutcher and Scandizzo (1976, pp. 343-45). Such an enclosed system is characterised by a low mobility of the peasants in social and economic terms, but also by full employment, in virtue of many "informal" unpaid activities and permanent family settlements, enjoying a variable quality and quantity of social services and other amenities provided by the system itself. In the latifundium-minifundium complex, the peasants hold land plots (sometimes their own) which are normally small and relatively near large plantations. They practice subsistence-level farming, and look for seasonal work on a plantation. Although the workers are paid wages, the manager-worker relations are often paternalistic and long-lasting. In the evening, or after the busiest crop season (depending on distance), the workers return to their land plots, where they invest their time and savings. This type of landholding system differs from the commercial-level agricultural enterprise, not only so

far as the level of technology and specialisation are concerned, but also in some other aspects. In the agricultural enterprise, workers are hired strictly on a salary basis, according to supply and demand, but some form of labour union may exist. The managers' attitudes differ substantially from the paternalistic relations in the two other systems discussed. The salaries tend to be higher than in these other cases, as Klein notes, but the demand for seasonal labour tends to be greater. Thus, the workforce is more variable in number and more mobile, depending on supply and the level and patterns of mechanisation. Beyond these three types of landholding and farming systems there are other intermediate types which deserve attention. For example, most sugar and/or ethanol plantations in Brazil and Hawaii could be classified as commercial-level agricultural enterprises. Nevertheless, there are substantial differences between the two in respect of landownership, factor inputs and technological choice, wages and labour organisation.

In Hawaii in 1977, "94 per cent of the sugar-cane production was controlled by the sugar industries" (Silva, 1979, p. 5), whereas the respective figure for the most representative state in Brazil was 63 per cent in the same year.[3] The wages of workers in Hawaii were then about 12-16 times higher (Silva, 1979, p. 5) than in Brazil, where mechanisation is relatively low. Seasonal labour has been practically eliminated in Hawaii,[4] but in Brazil the labour-intensive harvesting and semi-mechanised off-season operations depend on large amounts of seasonal labour and different levels of migration. Many seasonal workers earned slightly higher wages than permanent workers, but some of the latter (especially in the case of traditional sugar mills with annexed distilleries) enjoyed the security of the self-contained village next to the production unit. Some of these villages have a church, a post office, a general store, sometimes an improvised school, always a football field, and are reminiscent of a local variation of the traditional "hacienda" system. In the north-western part of the NE States of Alagoas and Pernambuco, where there is still a relatively high incidence of minifundia, one may loosely identify features of both the latifundium-minifundium system and the commercial-level agricultural enterprise.

Silva (1979) provided a "tentative" classification of the sugar-cane agro-industrial production systems, which he subdivided into the "Australian family unit system" (Australia); the "Asian system" (Bangladesh, India, Philippines, Indonesia, Fiji and China); and the plantation complex (Hawaii and Brazil). The characteristics of the systems in those nine countries[5] (accounting for about 40 per cent of the world's sugar production in 1978-79) were described as follows (Silva, 1979, p. 7):

> The Australian family unit is characterised by the use of its own family members first, and an eventual but minor use of salaried workers second. It uses modern technology and there is today 100 per cent mechanisation during the harvest.

The Asian system is also based on the family unit, but it is characterised by the micro-unit (0.1 ha in India to a maximum of 13.85 ha in the Philippines) and the technology is either primitive (Bangladesh, India, Philippines, Indonesia and China) or intermediate (Fiji).

In the plantation system, the salaried worker is predominant, while the land and the mill often belong to the same company.

Silva's data (table 38) show that among Asian countries, Indonesia and China, with smaller sugar-cane farms than the Philippines, have higher yields per ha. These findings do not rule out the possibility of correlations between productivity and farm size in some particular situations, all other variables being equal.[6] In contradiction to conventional wisdom in Brazil,

Table 38: Land size and sugar-cane producing farms in nine countries

Agricultural production system	Country	Area per family (ha)	Cane yield		Sugar yield	Average no. of cuts
			TCH	TCH(a)	TSH	
Family	Australia	49.70	84.38	77.95	11.52	4
Asian	Bangladesh	0.13	35.37	35.37	2.73	2
	India	0.13	56.40	56.40	5.40	2
	Philippines	13.85	52.54	52.54	5.62	3
	Indonesia	0.10	85.10	64.60	7.61	1
	Fiji	1.70	48.30	44.93	5.87	5
	China	0.08	84.78	84.78	-	2
Plantation	Hawaii	-	240.93	120.46	27.68	2(b)
	Brazil	-	56.12	49.90	4.53	4

TCH - Tonnes of cane per ha.

TSH - Tonnes of sugar per ha.

(a) The agricultural yield is adjusted to the annual cycle when the first cut takes longer than 12 months.

(b) A so-called "re-plant" is practically a new plantation due to the type of mechanical harvester or "push-racker". The yield was divided by two as the first cut is made after 24 months.

Source: Silva, 1979.

however, they suggest that (a) larger land units are not necessarily more productive than small ones; (b) the differences in productivity are accounted for by a series of integrated factors (e.g., soil quality, agrarian structure and type of labour used, deployment of machinery and fertilisers, and policy arrangements, and (c) productivity to scale correlations (which could possibly be used to justify concentrative trends in landownership) are difficult to sustain empirically, given the difficulty of controlling other variables. Silva (1979, pp. 9-10) compared some crucial differences between the countries surveyed -

> The main lesson to be learnt from present-day Australian sugar-cane production - which is modern and highly efficient - is the way it adapted to 'socialisation': in the countryside, present-day family properties have emerged from the old areas of company plantations and, in industry, various business firms have been increasingly substituted by co-operatives through purchasing ... The change has taken place more at the level of the agricultural production unit, with the elimination of the salaried worker and, more recently, with the tendency towards greater farmer participation in the control of plant domains. In fact, when a farmers' co-operative purchased three plants in New South Wales, in 1977, the position of the producers in the general control of the agro-industry was further strengthened.
>
> This structural evolution of the sector has gone in the opposite direction to that of the concentrative tendency seen in Brazil, where the sugar-cane plantations have increased in size, and industries are concentrated in big family complexes, be it sugar or ethanol production. In 1977, the average family property was 89.4 ha, of which 49.7 ha were planted with sugar-cane, producing an average of 3,287 tonnes per unit of production.

This evidence suggests that relatively equitable landholding systems, and/or co-operative efforts, are perhaps much more important in contributing to agricultural productivity and general improvements in the incomes of farmers and workers than any other factor. Cuba's experience is noteworthy in this respect. While the techniques of sugar-cane production have become increasingly mechanised, land reforms have deconcentrated the ownership and size of farms. Mechanised sugar-cane harvesting, which was not used at all in the late 1950s, increased to about 45 per cent in cutting operations by 1980, and to 98 per cent in loading by 1977 (Edquist, 1982, p. 66). MacEwan (1979, pp. 333-35) described the income changes in the world's second largest sugar exporter:

> Cuban agriculture, like agriculture in much of Latin America, had been dominated by large estates; more than 70 per cent of Cuba's 10 million ha of farm land was held in 10 per cent of the farms. The May 1959 Law proscribed estates of more than 400 ha; these lands had constituted 63 per cent of all agricultural holdings. Four years later, at the end of 1963, a second agrarian reform reduced the upper limit on land holdings to 67 ha, thus eliminating middle-level capitalist farms as well as the large estates.
>
> The private agricultural sector was not only reduced in size during this reform process, but it was also changed to an exclusively small farm agriculture. At the beginning of 1959, there had been 40-45,000 peasants owning farms of less than 67 ha The 1959 reform added about 110,000 peasants to this category by giving title on the lands they worked to renters, sharecroppers and squatters ... Thus, when the reforms were completed, there were roughly 160,000 private peasant farms in Cuba. ... Through the 1960s and 1970s, the Cuban agriculture would build on the dual basis of large-scale state farms and small peasant operations. ... On an economy-wide basis, unemployment, by conservative estimates, had run at annual rates of 12-16 per cent of the labour force. It had dropped to no more than 8 per cent by 1963 and continued downward thereafter. Also, the sharp seasonal fluctuations of employment had been substantially reduced by 1961.
>
> The cummulative impact of these and other redistributive measures was great. According to various estimates, the income of the working population rose by at least 25 per cent between 1958 and 1962, while national income was roughly the same in those two years. Some estimates place the increase in income of the poorest groups as high as 100 per cent in this period.

The major difference between Brazil and Cuba or Australia rests in the type of landholding structure, whereas the most striking difference between Hawaii and Brazil is perhaps in the supply of labour and the impact of labour unions on wages. MacEwan's evidence for the case of Cuba reinforces the earlier argument about the implications of agrarian structures for incomes. Cépède (1972, pp. 2-8) suggested that agrarian reform is an indispensable condition for the social effectiveness of green revolutions in private family systems. Ahmad (1972, pp. 10-35) who analysed the income-related impacts of the Green Revolution in Asian countries concluded that wage-labourers and share-croppers had not profited from it; the comparative gains tended to be proportional to the producers' land-holding size; and regional and individual income disparities had widened.

The implications of landownership and of access to credit for the incomes of small farmers creates a dilemma for the research and policy treatment of rural employment, since the linkage between this and

individual incomes is not always clear. As discussed earlier, the growth of wage employment in sugar-cane production for sugar or ethanol may be a misleading indicator of real improvements in workers' incomes. This can be true especially in situations where a rapid growth of production is promoted, and associated processes of landownership concentration, land eviction of peasants, crop and labour displacement and increased monoculture take place. The transformation of a subsistence producer, who may even have a small marketable surplus of production, into a wage-worker may lead to a decrease in real income, whenever the wages do not compensate for losses in non-monetary income.

The proletarisation of the peasantry, which had been discussed in Chapter 6 in the context of sugar-cane production for ethanol in Brazil, is not surprising or new, as Griffin (1972, pp. 69-70) has explained in his earlier analysis of agricultural modernisation in private farming systems -

> Commercialisation will tend to concentrate the function of entrepreneurship into a few hands. In the process, the peasantry will be destroyed. The quantity of goods produced may increase but the quality of life may decrease. As agriculture becomes more commercial and more profitable, the richness and variety of tenure arrangements which we described earlier will tend to disappear and be replaced by two basic types: owner-operators and agro-businesses. These changes in land tenure probably will lag behind changes in technology and income distribution, but they will be inexorable. Already there are reports from Celyon, India, Pakistan and the Philippines of landowners evicting tenants and taking over the land themselves. Sometimes the tenants are paid a small sum of money in compensation for being evicted, and sometimes they are not. But in either case, a tenant-entrepreneur is converted into a member of the proletariat and an absentee renter becomes a capitalist farmer.

In contrast with the above process, a small increase, or even a decrease, in wage employment, coupled with an increase in mechanisation, as in Australia and Cuba, need not lead to a drop in real per capita income if associated processes of land redistribution, development of co-operatives and crop diversification occur in family-based systems, for example. The following quote on the impacts of mechanisation on the pattern of employment in Australia, from a report by the Queensland Cane Growers Council, mentioned in Silva (1979, p. 23), underlines this:

> It is true to say that many of the communities along the coast of the Province of Queensland are based on, and owe their existence to, the sugar-cane industry. Despite the fact that the onset of the harvest marked a period of intense activity and attracted a lot of workers, the dramatic change to mechanised harvesting was not disastrous in terms of either commercial movement or population decline.

During the period of manual cutting, the flux of floating workers mainly consisted of men unaccompanied by their wives and families. Once the harvest ended they left for other cities.

Harvest mechanisation brought a much more stable and permanent situation to all the population and the classification of workers engaged in harvesting changed from a merely physical orientation to that of a condition of family life.

Although the sugar-cane industry is still based on the migration of some workers to areas where they are needed during the harvest, today the majority live on their own worksites. Qualified and semi-qualified personnel have increased dramatically as they work with cane harvesters and other auxiliary equipment. This stimulated the population to in-root themselves with sugar-cane communities and this in fact happened. Consequently, a purely seasonal industry has changed into a year-round permanent work activity.

The cane cutters from the past did a magnificent job, but they never identified themselves, as a rule, with the local communities and did not take advantage of any opportunities to become part of that society.

Community spirit in the sugar-cane localities (supported by the stronger and more active service clubs in these areas) has improved. The population has become aware that the sugar-cane industry is its way of life, and is more sensitive to the problems of the various groups engaged in this activity. This new attitude has helped the foundation of better understanding of the agro-industry's problems and of mutual respect for the role that each person plays so he or she can operate at maximum efficiency.

The conditions of Australia are obviously not comparable with those of many developing countries with higher supplies of labour and high rates of unemployment and underemployment, but it is noteworthy that increasing mechanisation in Australia and Cuba have, by and large, been consequences of changes in agrarian structures and of improvements in income conditions. Based on data from the Queensland Cane Growers Council, Silva (1979, p. 24) states that in 1958, there were 1,800 proprietors, classified in Australia as harvesters, for a production of 10 million tonnes. In 1968, the number of proprietors had increased to 5,750 for a total production of 17.5 million tonnes. This change represented more than a three-fold increase in proprietors for less than a two-fold increase in production, whereas the salaried workers decreased in the same ten-year period by a factor of 3.3. According to Roca (1976, p. 19) the number of manual harvesters in Cuba dropped from 370,000 in 1958 to 73,000 in 1971, whereas total unemployment decreased from about 14 per cent to 2.1 per cent of the Cuban labour force over the same period (Mesa-Lago, 1981, p. 122).

The above information underlines the importance of agrarian structures for trends in rural incomes. It further suggests that a re-distribution of landownership may be, in some cases, a prerequisite not only for a more equitable distribution of income, but also for a higher productivity of labour. However, this does not mean that agrarian reforms are a remedy for all ills, or that they are politically feasible, or equally adequate for all situations.

Earlier research, sponsored by the ILO under the World Employment Programme (Ghai et al., 1979), indicated that a given agrarian structure may generate widely different outcomes, thus implying that other factors may also play an important role. These case studies distinguish between landholding structures under different farming systems: (a) private, (b) communal and (c) intermediate. Using these classifications, it is concluded that in a private production system "the most important question is that of the distribution of ownership, while in a communal system it is the question of incentives ..." (Ghai et al, 1979, p. 202). The following excerpts summarise the major practices which, in general, seem most relevant of each category of agrarian structures mentioned (Ghai et al., 1979, p. 202):

> In a system of private farming, the most important condition of egalitarian growth is an equitable land reform and its continued reinforcement. In the present set of case studies, this is the characteristic that distinguishes South Korea from the other two cases (India and Bangladesh) of private agriculture, and largely explains its vastly different performance.
>
> The success of a collective agriculture (USSR, China and Cuba) depends crucially on the provision of a well-balanced system of incentives. As is evident from the experience of Cuba in the 1960s, and of China during the Great Leap Forward, an attempt to curb material incentives without proper development of the political and cultural consciousness of the population ... can have disastrous consequences for production efficiency.
>
> The most important fact about the cases in the intermediate category (Guyana, Tanzania and Egypt) is that they all represent different stages of transition from private farming toward some form of joint farming. Essential features of such transition are the continued predominance of private ownership and the attempt on the part of the state to promote some combination of co-operatives, collective, and state farming by gradualist (that is to say, non-revolutionary) means. These transitional characteristics define the basic conditions that need to be fulfilled if such a system is to succeed. Since private ownership predominates, an essential condition of egalitarian distribution of income is an egalitarian distribution of land and other means of production.

To many energy scientists, the issues discussed in this Appendix may seem only remotely related to commercial-scale ethanol programmes. Yet, such programmes are essentially agricultural and their effects on income distribution depend primarily on the landholding arrangements of raw material supply.

Notes

[1] See, for example, Shannin (1971), Lehmann (1976), Kautsky (1979) or Griffin (1974).

[2] See Ghai, et al. (1979). Also a special publication (ILO, 1971), includes agrarian reform case studies by Dorner and Felstehausen on Colombia, E. Clayton on Kenya and T. Misawa on Japan.

[3] This figure, for the State of Sao Paulo, may be conservative because of the role of the shareholders' lands (see Chapter 6).

[4] This is the consequence of the high level of mechanisation in Hawaii.

[5] Silva's survey included another country which cannot be mentioned in this study because of UN policy.

[6] Some recent studies suggest that farm scale has a very limited effect, if not a negative one, on agricultural productivity. For example, Griffin (1972, p. 62) argues that "the majority of technical changes that are associated with the Green Revolution are neutral to scale and therefore do not give the large landowner a cost advantage over the small peasant". Sen (1975, p. 147) analysed some of the findings by the Government of India in Farm Management Surveys in the mid-1950s, having not denied one of these, namely: "By and large, productivity per acre decreases with the size of holding". Ghose (1979) also confirmed this conclusion.

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