An Evaluation of the Use of Biomass as an Energy Source: The Brazilian Alcohol Programme

Léo da Rocha Ferreira and Octávio A.F. Tourinho[1]

Abstract: This paper discusses the preliminary results of Brazil's Economic and Social Planning Institute's BIOMASS linear programming model with emphasis on three aspects: temporal and spatial crop mix patterns along the analysis horizon; evaluation of the social cost of alcohol fuel; and the impact of alcohol production on the balance of payments. Brazil's national alcohol programme (PROÁLCOOL) increases domestic costs but its impact on the balance of payments is positive and substantial.

Introduction

The general objective of the research, the results of which are discussed in this paper, is an evaluation of Brazil's national alcohol programme (PROÁLCOOL) and its economic impact. PROÁLCOOL's main objective is to economize foreign reserves through the stimulation of ethyl alcohol production as an alternative to petroleum. To that end, the programme has set goals for substitution of part of gasoline demand by anhydrous and hydrated alcohol.[2] That substitution process has, on a national basis, direct costs associated with the alcohol production and opportunity costs due to the use of land for that purpose. The sum of those two components is referred to as the "social cost" of alcohol. Direct costs include the cost of the agricultural production of sugarcane, installation and operation of alcohol distilleries, and transport of the alcohol to the consumption centres. Opportunity costs are those caused by the use of land for sugarcane production and the consequent displacement of other crops, which leads to the increase of production and transport costs of domestic food crops, as well as to a reduction in the international competitiveness of exportable crops. Due to restrictions on the availability of farmland, the programme may also lead to a reduction in the volume of agricultural exports and a negative impact on the balance of trade.

A dynamic linear programming model, with time measured as a discrete variable, has been developed to analyze the above issues.[3] Mathematical programming was selected because it allows us to deal simultaneously with a large number of variables, and especially analysis of how the spatial and temporal distribution of agricultural production would take place if it were possible to plan it with the aim of reducing the system's overall costs. In addition, the linear programming technique allows us to incorporate (via restrictions on the model's formulation and limits on the values of the variables) the physical limitations on the reformulation of the agricultural production system, while still retaining some flexibility. The effect of programmes like PROÁLCOOL can thus be assessed and the export potential of the agricultural sector in the context of central planning can thus be evaluated. The realism of such modelling is assured by the number of details that can be included in the mathematical programming models. Finally, the model allows the derivations of sectoral product supply and factor demand functions, both of which are helpful in equilibrium studies of the respective markets.

Brazil was divided into 15 consumption regions associated with the major regional centres that concentrate the demand of the population located in their respective areas of influence. Those regions, which may or may not include ports for import or export trade, include one or more production regions within which agricultural technology is considered to be homogeneous. Twenty-nine production regions were defined, each of which carries out several of the 19 productive activities considered by the model with a technology specific to the region. Finally, the activities produce a total of 16 products whose demand is determined exogenously.

Methodology

The objective function maximized by the model is the present value of the flow of export revenues of agricultural products minus the cost of food imports, transport costs for agricultural products and alcohol among regions, production costs of annual and permanent crops, costs of sugarcane processed for alcohol and sugar production, and the cost of clearing new areas.

Import-export prices are the averages from 1974 to 1979 of the c.i.f. and f.o.b. prices actually observed for each product in Brazilian ports. Possible future variations in the world market prices of exportable goods were not, therefore, considered. For those products over which Brazil has the power to influence prices, the model allows for specification of an elastic international demand through stepwise discrete approximation.[4]

The main components of agricultural costs are labour, machinery, fertilizers, pesticides, depreciation, and interest payments, thus excluding land rent since it is a restrictive resource whose value is determined exogenously. Investments in the preparation of land for the cultivation of all products, including sugarcane, were annualized and included in the respective production cost. Sugarcane is the only product whose industrialization phase was considered in the model, with the inclusion in the objective function of a cost per processed metric ton, which includes the remuneration of capital invested in infrastructure.

The horizon of analysis was divided into eleven 2-year periods beginning with 1979-80, and the discount rate assumed was 10 percent per year. Maximization is subjected to two main groups of restrictions: demand and flexibility.

Demand restrictions are those that force the model to satisfy the domestic demand for food products and alcohol in the consumption centres through production in the production regions associated with each centre or through the transport of products from other centres. In both of the following scenarios, the calculation of the demand for agricultural products for domestic consumption assumes that the cross price elasticities of demand are nil. Only the effects over time of the growth of each region's income and population was considered.[5] In scenario *A*, demand for alcohol is compatible with recent evolution of the PROÁLCOOL. That scenario incorporates the lowest sugarcane production needed in those regions to supply existing distilleries and distillery projects already approved. In scenario *B*, demand for alcohol is restricted to alcohol's use in anhydrous form to produce gasohol, thus allowing the results to be interpreted as what would happen to the agricultural production system in the absence of the second phase of the PROÁCOOL programme. For all products, imports were also considered as an alternative way to satisfy demand.

The flexibility restrictions that limit the relative expansion and contraction of cultivated areas of a given crop between two consecutive periods are of the $X^t \leq (1+\alpha)X^{t-1}$ and $X^t \geq (1-\beta)X^{t-1}$ type, where X is the cultivated area in period t, and avoid the excessive specialization of the regions in the production of only a few products.[6] That specialization does not take place in the agricultural system due to the variation of productivity and costs both within and among the farms of a given production region. In addition, a natural inertia resists changes in the regional production system due to cultural and technological factors as well as to limitations in the availability of capital, machinery, equipment, and specialized labour. Another motive for resistance to specialization would be the need to diversify crops due to price risks or climatic factors. The flexibility coefficients thus summarize the end result of the above mentioned effects and can be derived empirically on the basis of past behaviour in the areas where the various crops are cultivated.[7] Factors that worked in the past to avoid excessively rapid expansions and contractions of the land occupied by a given crop were assumed to continue to have the same influence in the future.

The model also contains limitations on the rate of expansion of the country's total cultivated land area, which in the two scenarios was set at a rate of 3.6 percent per year. In the recently settled areas, where agricultural frontiers are expanding, the model applied the flexibility coefficient to the total cultivated land, and even so only after free expansion had reached a previously established limit. In the scenarios below, the rate was set at 7 percent per year.

Production technology in the model is characterized by the specification of productivity and typical costs for each of the crops in each production region. Except for sugarcane and livestock, only the predominant production technology for each crop in each region were considered.

The model's main decision variables are (for each period) the area occupied in each region by each agricultural activity, alcohol and sugar production, the volume transported of each product between regions, and the volume of imports and exports of the respective products.

The "Social Cost" of Alcohol

Conceptually, "social cost" is defined as the value of the dual of the demand variable and indicates how much the value of the objective function (described above) would change if demand were to increase by one unit in a given region in any given year on the horizon of analysis. For alcohol, exportables (soyabeans), and food crops (maize, rice, and beans), the shadow price for the scenario with PROÁLCOOL is higher than in the scenario that excludes it. The difference is proportional to the intensity of the particular crop's competition with sugarcane. That kind of effect is observed in all regions described in the model. In the same manner, the marginal "social cost" of alcohol can be assessed through its shadow price, since it takes into account both the direct and indirect effects of an increment in demand.

A comparison of the marginal cost of alcohol (for the 1987-96 period) with present consumer prices (US$0.342)[9] reveals the existence of an implicit marginal subsidy of US$0.104 to be socialized by means of fiscal mechanisms. The domestic cost of the programme thus includes the cost increase of all products (including alcohol) and the subsidy. Only as a reference, the estimated marginal cost of alcohol is around US$89 per equivalent barrel of gasoline.[10]

As was expected, comparison of prices in the various regions reveals the tendency of the model to equalize the marginal costs of alcohol in the consuming regions with the remaining differences accounted for by transport costs between regions. That equalization process is endogenous to the model and takes place mainly through adjustment of the shadow price of land, which on the horizon of the analysis reflects the purchase value of an additional unit of land. The results show a stable behaviour over time within each region and sharp differences among the regions, reflecting their different production potentials. Thus, for example, the value of land in the Ribeirão Preto region is approximately 13 times greater than in Recife and four times greater than in the Porto Alegre region in the scenario *A* simulation.

Balance of Trade

PROÁLCOOL's direct impact on Brazil's balance of trade has two aspects: the effect on agricultural imports and exports and the reduction in petroleum imports due to substitution of derivatives by alcohol. To evaluate those impacts, agricultural products were priced on the basis of average c.i.f. and f.o.b. prices from 1974-79, while anhydrous and hydrated alcohol were priced at US$0.22 and US$0.18, respectively. Estimation of those values took into account the fact that anhydrous alcohol is a perfect substitute for gasoline and that use of hydrated alcohol implies a 20 percent loss in volume yield. The world price of gasoline was assumed to be US$35 per barrel.

Table 1 displays the total effect of the above two factors and shows the agricultural surplus steadily increasing from US$9,200 million in 1981-82 to US$11,700 million in 1991-92.

Table 1—Simulation of the Balance of Trade for Agricultural Products and Substitution of Petroleum Derivatives in Scenario A

	1981-82	1983-84	1985-86	1987-88	1989-90	1991-92	Annual Rate of Growth (%)
			- - - Million 1984 US $ - - -				
Agricultural products:							
Exports	10,000	11,000	11,600	12,600	12,800	12,800	2.4
Imports	800	900	900	900	1,000	1,100	3.5
Balance	9,200	10,100	10,700	11,700	11,800	11,700	2.3
Substitution of petroleum derivatives by alcohol:							
Hydrated	300	600	800	1,000	1,200	1,500	16.4
Anhydrous	300	500	500	500	500	600	4.9
Subtotal	600	1,100	1,300	1,500	1,700	2,100	11.5
Total Balance	9,800	11,200	12,000	13,200	13,500	13,800	3.2

Agricultural exports are practically stable, with a growth of about 2.4 percent per year, while the substitution of petroleum derivatives makes a growing contribution to the surplus at a rate of 11.5 percent per year.

The export composition during the period shows the stability of sugar and coffee exports (limited in the model by international agreements to which Brazil is a signatory),[11] the growth of soyabean, groundnut, and tobacco exports, and the accelerated reduction of orange and cotton exports.

The import composition shows an accelerated growth of milk and meat imports.[12] The growing deficit observed in livestock production in the model is probably a result of the combined effect of two factors: (1) the discrepancy between the rate of expansion of demand for milk and beef (4 percent) and the rate allowed by the flexibility restrictions for the expansion of the area occupied by livestock activities (3 percent);[13] and (2) the dislocation of livestock production to areas of lower productivity due to the expansion of sugarcane production. The combined effect of those two exogenous parameters condemns the model to import since the productivity coefficient is constant along the horizon of analysis due to the model's hypothesis of no technical progress.

Another factor is the lack of reliable data on livestock in Brazil (especially in terms of regional variations in productivity), land area actually occupied by the activity, type of exploration (technology), and type of herd (dairy, beef, or mixed).

Table 2 shows the model's balance of payment for scenario *B* and confirms the preceding indications that neither the mediocre performance of exports nor the large volume of imports in the model can be blamed on the effects of the PROÁLCOOL programme.

Both effects continue to appear *grosso modo* in the simulation that does not include the programme's demand for alcohol. Less pressure on the availability of land in scenario *B* simply diminishes the displacement of livestock observed in scenario *A* and increases exports of agricultural products by a value ranging from US$200 million in 1985-86 to US$500 million in 1991-92.

Table 2—Simulation of the Balance of Trade for Agricultural Products and Substitution of Petroleum Derivatives in Scenario B

	1981-82	1983-84	1985-86	1987-88	1989-90	1991-92	Annual Rate of Growth (%)
	- - - Million 1984 US $ - - -						
Agricultural products:							
Exports	9,800	11,000	11,900	12,800	13,200	13,400	2.8
Imports	700	900	900	1,000	1,000	1,100	3.1
Balance	9,100	10,100	11,000	11,800	12,200	12,300	2.8
Substitution of petroleum derivatives by alcohol:							
Hydrated	–	–	–	–	–	–	–
Anhydrous	600	600	600	700	800	800	3.0
Subtotal	600	600	600	700	800	800	3.0
Total Balance	9,700	10,700	11,600	12,500	13,000	13,100	2.8

Conclusion

The preliminary results of the model show a reasonable degree of coherence between the model's specifications and the actual experience of the 1982 and 1983 harvests. The PROÁLCOOL programme induces substantial domestic costs in the form of rising prices for agricultural products and for alcohol and the marginal cost of alcohol was estimated at US$89 per equivalent barrel of gasoline at the most. The impact on the balance of trade is positive and is around US$500 million annually.

Notes

[1]Instituto de Planejamento Econômico e Social and Universidade do Estado de Rio de Janeiro, respectively. The authors are grateful for the valuable criticism and suggestions of Michal Gartenkraut on a previous draft, for the help of Nuño Duarte da Costa Bittencourt in processing the scenarios, and to Carlos Augusto do Amaral Martins in preparing the tables.

[2]In Brazil, alcohol is used as a motor fuel in two forms: hydrated alcohol is burned in specially designed motors and gasohol (1:5 mixture of gasoline and anhydrous alcohol) is used in standard motors. The first and second phase of PROÁLCOOL involved the introduction of the former.

[3]For greater detail on the mathematical formulation and specification of the model, see Tourinho *et al.*, 1984.

[4]That recourse, however, was not used in processing the scenarios presented in this paper.

[5]The scenario assumed a per capita GDP growth rate of 3.72 percent per year. For further details, see Amaral *et al.*, 1983.

[6]See Tourinho *et al.*, 1984.

[7]The flexibility coefficients vary greatly among regions and from one crop to another. The highest values found are for the bean/maize consortium in the Salvador region (α = 44 percent and β = 40 percent per year). For livestock raised in the country as a whole, flexibility is much lower ($\alpha = \beta = 3.5$ percent per year).

[8]For more details see Tourinho *et al.*, 1984.

[9]Consumer price in November 1984 (Cr$890) converted at the exchange rate of Cr$2,600/US$1.00 (November 9, 1984).

[10]Assuming that the marginal litre of alcohol is used in its hydrated form.

[11]That, admittedly, is a precarious means of modelling the country's participation in those commodity markets.

[12]Those imports are merely the result of the model's simulations for scenario *A* and should not be interpreted as projections.

[13]As described above, the allowable growth rates were estimated on the basis of the past expansion rates of the area occupied by the particular activity, in all cases including livestock.

References

Amaral, C.M. *et al.*, "Pressões de Demanda sôbre Agricultura Brasileira," *Estudos Econômicos*, Vol. 13, No. 2, May/August 1983, pp. 309-322.

Tourinho, O.A.F., Ferreira, L.R., and Pimentel, R.F., *Agricultura e Produção de Energia: Uma Avaliação Econômica do PROÁLCOOL*, IPEA/INPES, Rio de Janeiro, November 1984.