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Optimal Foreign Borrowing in a Multisector Dynamic Equilibrium Model for Brazil

by

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MIT-EL 85-011 August 1985

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ABSTRACT

This paper shows how a dynamic multisector equilibrium model can be formulated to be able to analyze the optimal borrowing policy of a developing country. It also describes how a non-linear programming model with the proposed features was constructed for Brazil, and discusses the optimal solution of a base case scenario for the economy in the next 20 years. The sensitivity analysis emphasizes the response of the model to different interest rates on foreign borrowing, alternative export expansion and imports requirements scenarios, and different hypothesis with respect to future petroleum prices and domestic petroleum production. The main conclusion is that the optimal long run borrowing policy for Brazil is quite sensitive to the expected future interest rates, and may be different from some myopic strategies which are currently being suggested to handle the developing countries' foreign debt problems. The other important conclusion is that in the less favorable scenarios - protectionist foreign environment or higher petroleum prices - it is not optimal to postpone the required domestic adjustments by increased foreign borrowing. The usefulness of the model is not restricted to this set of simulations, since it can be readily adapted to address related issues such as foreign trade, investment and indirect taxation policies.

1. INTRODUCTION

In the wake of the recent international financial crisis, the need was felt to address several interconnected questions of long-range macroeconomic planning in Brazil. They are mainly related to government policy with respect to the foreign debt, the trade balance, and the intersectoral allocation of investment. The choice between high and low foreign indebtedness will have to be made in a context where borrowing is costly and can only be avoided by generating large trade surpluses which constrain the growth of domestic output and consumption. Efforts designed to generate these surpluses through reduced imports and increased exports will affect the size and sectoral composition of output, require shifts in the allocation of capital and labor in the economy, and lead to adjustments in the investment patterns.

These issues can be taken into account in an economy-wide dynamic optimization model, which can be specified to be able to evaluate the savings-consumption tradeoff, and include the restrictions in the foreign accounts and in the factor availabilities. The activity levels and capital stock in each sector, as well as the trade balance and net borrowing requirements can be calculated endogenously to maximize some specified utility function, which insures that the solution of the model has the desirable efficiency properties.

Planning models with similar objectives have been specified and implemented for a number of countries, as surveyed by Taylor [1975], and more recently by Dervis, de Melo and Robinson [1982]. The model described in this paper is similar in some respects to the one built by Blitzer and Eckaus [1983] for Mexico, but emphasizes the aspects that seemed most relevant for the analysis of the Brazilian situation[1]. The innovations of the model proposed here are a rather detailed representation of the foreign debt dynamics, the liberal use of non-linear relationships in the utility function and in the interest rate calculations, and a novel specification of the terminal utility term, all in the quest of attaining more realism in the intertemporal choice aspects of the problem.

Several economy-wide equilibrium models have been built for Brazil in the past, but none stressed the foreign debt problem and the intertemporal choice issues associated with it. Lysy and Taylor [1980] used a Johansen-type model to analyze income distribution issues in the '70s, with a medium-run perspective. Their model incorporates a detailed input-output representation of the productive sector, but does not include any formal utility maximization. Modiano [1983] linked a process representation of the energy system with a detailed econometric model of the rest of the economy, in a model where the market equilibrium for energy goods is found by maximizing consumers' plus producers' surplus. That model is solved forward in time, without dynamic optimization, and does not include a disaggregated representation of the intersectoral flows, as the one here. McCarthy [1983] has built a non-optimizing model for identity-based medium-run policy evaluation which includes the intersectoral flows, and also attempts to account for all the financial flows and budget requirements of the several actors of the economy.

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[1] The main differences are a more detailed representation of the borrowing costs, and the use of a more satisfactory formulation of the terminal conditions. In addition, the model presented here was solved with a non-linear programming algorithm which is apt to provide more precise results than the linear programming approximation used in the Mexico model.

This paper also demonstrates that it is now possible to easily solve numerically some of the simpler discrete time non-linear neoclassical optimal control problems that arise in models of economic growth. Thanks to MINOS, a program developed by Murtagh and Saunders [1983], optimization packages are now capable of handling a sizeable number of non-linear relationships, both in the objective function and in the restrictions (the latter at a somewhat higher cost), liberating the empirical model builder from the straight-jacket of linear programming or the purely static equilibrium models.

The plan of the paper is as follows. The next section presents the model formulation, addressing some of the possible extensions. Section 3 describes very briefly some aspects of the implementation, while section 4 presents the "base case" solution. Section 5 contains the sensitivity analysis, with the discussion of the main issues the model was meant to address. The conclusion is in section 6.

2. MODEL FORMULATION

Intertemporal choice problems can be treated consistently in the dynamic general equilibrium framework of optimal growth models. These can be extended by including foreign debt as another state variable, allowing the analysis of the joint determination of the time paths of savings, consumption and borrowing that maximize the discounted value of the stream of utility from future consumption. Two approaches can be used to analyze economies modelled in this way. One, taken by Blanchard [1983] is to work in continuous time and employ optimal control methods to derive analytically the system of differential equations to be satisfied by the optimal paths. The other, which is pursued here, is to solve numerically a discrete-time approximation to the original maximization problem. The tradeoffs are clear: the first allows a more systematic exploration of the underlying properties of the system, while the second permits the use of a more detailed multisectoral representation of the actual economy. The analytical approach does not render numerical optimization useless, because it turns out that the paths of the variables will in general depend very much on the initial conditions of the dynamic system, while on the other hand, the analytical solution is indispensable as a benchmark when implementing an empirical model. In short, the two approaches are highly complementary.

The discrete-time multisectoral model specified below chooses variables in each period such as sectoral production, sectoral investment, sectoral imports and exports, foreign borrowing, and consumption level and composition, subject to various constraints. These are the material balances, the foreign exchange balance, the labor supply constraint, and the dynamic equations for debt and capital accumulation[2].

The formalization of each of these aspects of this programming problem is in the next sub-sections, where the notation is as follows. In the equations, the symbols i and j are used as row and column indices for the vectors and matrices, denoting respectively goods and producing sectors. The parameters are generally denoted by lower-case letters, and exogenous variables by capital letters with bars under them. The indexes t and g denote time periods, all of length n years, and all the variables are specified in yearly terms. Matrix multiplication and internal products are denoted respectively by a star and a dot between the two arrays.

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2 Borrowing itself is not constrained, nor is the savings rate, since the model chooses these levels based on comparing costs and benefits at the margin.

2.1. Objective Function

The existence of a representative consumer is assumed, and the objective function of the planning problem is composed of two elements: the sum over the plan horizon of the total utility in each period properly discounted (at a rate δ), plus the discounted value of post-terminal utility. The yearly utility (U_t) and the terminal utility are specified in per-capita terms, so that they have to be multiplied by population ($\underline{N}_t$) to obtain total welfare.

$$(1) \qquad W = \Sigma_t \ (1+\delta)^{-t} \ n \ \underline{N}_t \ U_t + (1+\delta)^{-T} \ \underline{N}_T \ V$$

The post-terminal per-capita utility (V) includes a penalty for the accumulated foreign debt, and a premium for the level of capital stock[3], which exist at the end of the last period. It compensates for the truncation of the time horizon, assuming a steady state in the post-terminal period, and can be interpreted as fulfilling the role of the primal equilibrium approximation in Svoronos [1985] "squeezing" algorithm for infinite horizon convex programs[4]. The detailed equation with the formal specification will be presented later, after the relevant variables are defined.

A generalized logarithmic function was adopted to evaluate the utility of alternative consumption vectors in each period (C_t)[5], mainly because it gives rise to an extended linear expenditure system (ELES), which has often

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3 Terminal stocks are not exogenously specified as in other models in this tradition.

4 I thank Alan Manne for pointing this out to me.

5 The consumption vector includes non-competing imported consumption, in addition to the several other produced goods.

been used in planning models of this type to characterize consumer demand[6]. The parameters of this per-capita utility function are the vector of marginal expenditure shares (β) and the vector of minimum levels of consumption of each good (γ).

(2) $$U_t = \Sigma_i \beta_i \log (C_{i,t} / \underline{N}_t - \gamma_i)$$

This objective function has several desirable features like, for example, implying a declining marginal utility of consumption for each good, generating a full set of own and cross price elasticities, and internalizing the savings decision. For this functional form, the elasticity of substitution of expenditure between two consecutive time periods is smaller than unity[7], and is increasing with income level, which is consistent with empirical evidence regarding consumer demand in developing countries (see chapter 4 in LLuch, Powell and Williams [1977])). Rubinstein [1977] has also offered a host of arguments why a function of this type should be favored in finance models for analyzing intertemporal choice, particularly under uncertainty.

2.2. Material Balances

The material balance constraints insure that, for each good total supply

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[6] For a discussion of extended linear expenditure systems and their application to several countries, see Lluch, Powell and Williams [1977]. For a more formal treatment of linear expenditure systems in general, and the econometric procedures for their estimation, see Powell [1974]. Blitzer and Eckaus [1983] have used this function in a model for Mexico.

[7] In the limit, when the minimum consumption level for the several goods tends to zero (relative to actual consumption), the elasticity tends to that of the standard logarithmic function, which is unity.

is at least as great as total demand. Demands include the vector of intermediate deliveries to production (Z), and final demand vectors: private consumption (C), government consumption (G), investment (I), and exports (E). Supply includes the vectors of domestic production (X) and competitive imports (M)[8]. Dating each of these, the equation can be written as:

$$X_t + M_t \geq Z_t + C_t + \underline{G}_t + I_t + E_t \qquad \text{for all } t \tag{3}$$

Competitive imports are discretionary, and refer to goods which could be produced domestically although perhaps at higher cost. The other category of imports consists of goods which cannot be produced in the country, and are called non-competitive imports. They are demanded mostly for intermediate consumption, and do not appear in the balance above because they do not increase supply of the produced goods considered in the model. They are better thought of as another factor of production, in addition to skilled labor and capital.

All these variables are endogenous, except $\underline{G}_t$, which is forecast on the basis of an exogenous growth rate applied to the initial vector of government consumption.

2.3. Foreign Exchange Balances

The foreign exchange constraint guarantees that in each time period, export earnings plus gross foreign borrowing (B) meet the costs of competitive imports, the total expenditure in non-competitive imports (MN), interest

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[8] Note that because some goods are not traded, while others are not used for investment, the vectors M, E and I may have null elements.

payments (H), debt repayments (R) other foreign exchange transfers (F).

$$pm_t \cdot M_t + MN_t + R_t + H_t + F_t \leq B_t + pe_t \cdot E_t \qquad \text{for all } t \tag{4}$$

Since the levels of exports and imports are endogenous, this balance will allow us to shed some light on the issue of the appropriate level of openness for the country's economy[9].

The modelling of interest and amortization of foreign debt is described in section 2.4. For now it suffices to emphasize that, since repayments are included in the foreign exchange expenditures, the borrowing variable is defined in gross terms.

For simplicity, a linear formulation was adopted to calculate the export revenues of each sector. The vector of export prices at each point in time (pe_t) is exogenous and can be changed to trace the economy's supply curve in various scenarios for the foreign conditions. Maximum exports of each commodity in each period were however specified, implying that the market model underlying the export sector is competitive only up to that exogenous limit[10]. For the manufacturing sector these bounds may reflect limitations to market share increases which may be associated with protectionist measures or some degree of product differentiation within each product category. For the

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9 Equation (4) also highlights the potential use of the model for the analysis of foreign trade issues.

10 Unfortunately this specification may lead to some degree of "bang-bang" behavior, in that the model will in general specialize, exporting up to the limit in the more attractive sectors, and not al all (or only residually) in the remaining ones. This could have been avoided by incorporating into the model non-linear export revenue functions. From the mathematical and algorithmic point of view this would have been possible, but the functional specifications and estimates of the relevant parameters were not readily available, so that this extension could not be done reliably at the moment.

agricultural products this captures some of the effects of the declining demand curve in the markets where Brazil is a large competitor. In either case, historical performance provides an indication of the reasonable values for the maximum rates of growth.

Import costs have two components: competitive and non-competing imports. The expenditure in any of these is modelled as a linear function of the quantities imported, as exemplified in equation (4), where the price vector of the competitive imports is pm. Non-competing imports are required in the model for production (a vector MX), capital formation (a vector MK), consumption (a scalar MC) and government expenditures (<u>MG</u>). All are endogenous, except the last, and their prices are denoted respectively by px, pk, pc and pg in the equation (5).

$$(5) \qquad MN_t = px_t \cdot MX_t + pk_t \cdot MK_t + pc_t\, MC_t + pg_t\, \underline{MG}_t \qquad \text{all } t$$

Private consumption of non-competing imports is governed by the utility function, while the technology determines the other two categories.

Exogenously projected foreign exchange transfers for factor payments exclude interest payments, which are computed separately, but include remittances, dividends and (minus) foreign direct investments. Outflows for the payment of services other than factor services, are computed as service sector imports.

2.4. Technology and Input Demand

As in any modelling exercise, a compromise had to be struck between the points that we wanted to make, and the complexity and size of the model. Due to this tradeoff, the representation of the production function had to be as simplified as possible, to reduce the cost of running the model and allow the planned number of simulations to be performed. Therefore, a Leontief specification is used for each sector, with four categories of inputs: intermediate goods, non-competitive imports, capital, and labor. Their levels of usage are related to the level of activity of each sector through fixed coefficients.

Endogenous technological choice in production could have been easily included in the model, had the required data been available, by adding columns corresponding to the different alternative technologies, as was done by Blitzer and Eckaus [1983] in their model for Mexico. These vectors and their linear combinations can then be seen as approximating the isoquant for each sector, on which the model would select a point on the basis of implicit factor prices, taking into account the different input intensities of these approximating technologies. Alternatively, since the optimization algorithm allows non-linear restrictions, a truly neoclassical production function could have been specified, at least for some sectors. Neither of these alternatives were followed here due to the lack of readily available data, and because the present version of the model was designed to focus on the foreign debt aspects of the planning problem.

Demand for intermediate goods is calculated in the usual way with a matrix of input-output coefficients (a). The non-competitive imports demanded by the several sectors for current production are obtained by multiplication by a diagonal matrix (mxr) containing the sectoral requirements coefficients.

(6) $Z_t = a * X_t$ (7) $MX_t = mxr * X_t$ for all t

Only labor employed in the formal market is considered scarce and included in the formulation, but its supply ($\underline{L}$) is not modelled explicitly, being assumed to grow at an exogenously specified rate. The important problem of absorbing the large numbers of self-employed and sub-employed that exist in the Brazilian informal labor market is not addressed here[11]. As a consequence, the shadow price of labor in the informal sector is implicitly being assumed to be zero, which is an extreme assumption which probably overstates the leverage of capital and formal employment. The sectoral labor requirements follow the linear specification of the rest of the productive sector and are contained in a vector (lr). Labor-augmenting technical progress is handled in the usual way, specifying the labor supply constraint in equation (8) in terms of "efficiency" units:

$$lr_t \cdot X \leq \underline{L}_t \qquad \text{for all } t \tag{8}$$

The amount of capital which is available in each period is a vector indexed by sector which depends on the initial endowments (a vector $\underline{K}_0$), depreciation factors (a diagonal matrix d), and the investment decisions which the model has made for prior periods (a vector DKg). There are several vintages of capital used for production in each period, which are indexed by the period in which it is put in place (g). The total capital available in any period t is the sum of the depreciated value of these investments, which are denominated in yearly terms, and therefore need to be aggregated. This is done here by multiplying the depreciated investment vector by a diagonal

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11 For 1983, the approximate size of the "informal" market is 6.9 million rural and 9.6 million urban workers. This compares with 7.4 million rural and 23.9 million urban workers employed in the formal market.

matrix (f) that has all its elements equal to the number of years per period[12]. The demand for capital services in each sector is obtained by multiplying the gross output vector by a diagonal matrix of capital-output coefficients (k). The capital restriction can then be written as:

$$(9) \qquad k * X_t \leq d^t * \underline{K}_0 + f * \Sigma_{g \leq t} (d^{g-1} * DK_g) \qquad \text{for all } t$$

Demand for investment goods produced by a given sector (I) is determined applying a matrix of investment shares (b) to the required deliveries of new capacity (DK) to all sectors. This matrix reflects the composition, in terms of sector of origin, of sectoral capital formation. Demand for non-competing imports in investment also follows a linear specification, and is obtained by the multiplication of the capital formation vector by a diagonal matrix (mkr) whose elements are the import requirements of each sector.

$$(10) \qquad I_t = b * DK_t \qquad (11) \qquad MK_t = mkr * DK_t \qquad \text{for all } t$$

Since the distribution of initial year investment (I_0) by sector of destination was unknown, it was treated endogenously by using equation (10) (with the equality replaced by an inequality $\geq$) for the initial year, allowing the model to allocate initial investment efficiently.

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12 Since the level of investment is likely to be increasing in time, its effect on the capital stock in a sector will be dependent on its average gestation lag. These could have been approximately taken into account by adjusting the elements of f in a way similar to the one suggested by Blitzer in 1972 and used in Goreux [1977 chapter 10]. This would imply that the elements of the matrix would be slightly larger than n in the sectors with short gestation lag and high expected growth rate, and somewhat below n in the reverse situation.

2.5. Foreign Borrowing and Debt Service

Foreign borrowing is an important variable in the model. Making the time path of borrowing endogenous simulates actual policy choice and allows the economy to simultaneously adjust the level of domestic economic activities and of imports. However, there must be provision for payment of interest and repayment of principal either before or after the model's time horizon. A certain fraction of total debt comes due in each period, but it can be rolled over by contracting for additional borrowing, although perhaps at a higher interest rate. The choice of how much to borrow (B) and in which periods it will be repaid (R) is made endogenously by comparing the shadow value of foreign exchange and the marginal interest costs.

Foreign debt is modelled here using a vintage model in order to properly account for the effect of the situation of the foreign accounts on the total interest payments. To indicate this, let $D_{g,t}$ be the debt contracted in period g held at <u>start</u> of period t, where the index g runs from 0 to t-1. The following equation shows its dynamics, given repayment (R) and borrowing (B) flows, assuming that after an initial amount is borrowed in a period, it can only be repaid later[13]. Since these are both yearly flows, they are entered into the debt balance equation multiplied by the number of years per period. The second equation below defines next year's debt of one period of age as equal to the sum of the yearly flows of this period's borrowing.

(12) $$D_{g,t+1} = D_{g,t} - n\, R_{g,t} \qquad \text{for all t and } 0 \le g \le t-1$$

(13) $$D_{t,t+1} = n\, B_t \qquad \text{for all t}$$

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13 The repayment schedule ($R_{0,t}$) of initial year debt ($D_{0,1}$) is known, and is used in the recursion of equation (12).

The repayment schedule on any period's borrowing is assumed to be exogenously specified, and is independent of the period in which borrowing occurs. This implies that the fraction of the borrowing done in period g which is amortized in a later period t can be calculated as a function (r) of the difference between these two dates. This simple formulation does not consider changes in the repayment profile of the debt[14], which may however be a matter of policy choice for some countries. In the context of the model this issue is better addressed through sensitivity analysis, since changes in the maturity are usually associated with changes in the interest rates.

$$R_{g,t} = r_{t-g} \; B_g \qquad \text{for all g and t} \tag{14}$$

In order to calculate the interest cost, this model recognizes that a large fraction of the debt contracted in the international financial market by developing countries accrues interest on the basis of a floating rate (i.e. LIBOR) plus a spread, which supposedly reflects the country-specific risk. The debt of developing countries also usually has a fixed rate component associated with loans by foreign governments and official institutions, sometimes in preferential terms. Since the likelihood of large interest subsidies to Brazil through fixed-rate loans in the future is small, it was assumed that all of the debt is subject to the floating scheme. This is however only a simplification, since the model can be easily extended to allow for this other type of debt.

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14 This is true except for the changes that occur as a result of the gradual shift from the repayment profile of the initial debt to the one implied by the application of the repayment function specified above to future borrowing. To the extent that the function r is derived from the forecast repayment stream on initial debt, this change is small.

As with all other variables in this model, interest payments are calculated in real terms, excluding the effects of inflation of the currency in which the debt is denominated. If repayments for actual borrowing are given in nominal terms, higher inflation in the lending country decreases the real value[15] of the debt at any point in time. This effect of foreign inflation can be simulated in the model considering a faster repayment schedule on the real debt.

Therefore, in any given year, interest payments on total debt (H) have two components: the first is proportional to the real interest rate, which is exogenous and can change each period, and the second is a function of the spread rates contracted for in previous borrowing, which is fixed for the life of the loan. As shown in equation (15), the effective interest rate on debt is the sum of the real interest rate (h) and the endogenous spread rate (SH):

$$(15) \qquad H_{g,t} = (h_t + SH_g) \ D_{g,t} \qquad \text{for all t and g}$$

It was assumed here that these spread rates are a stationary linear function (with slope α), of the ratio of annual borrowing to an index of real income. This index is approximated by adding the sectoral value added, each calculated as the product of gross output and the initial year shares (a vector va)[16].

$$(16) \qquad SH_t = \alpha \ (B_t \ / \ Y_t) \qquad \text{for all t}$$

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[15] i.e. deflated by price index of the currency of denomination.

[16] Income as such is not available in the primal of model, since it depends on the shadow prices of the several goods. However, the index of gross domestic product at base year prices, which is used above, can always be constructed.

(17) $$Y_t = va \cdot X_t \qquad \text{for all } t$$

The rationale underlying equation (16) is the standard Capital Asset Pricing Model (CAPM) for financial markets[17], coupled with the assumption that higher values of gross borrowing (relative to income) are perceived by lenders as signals of higher volatility of future returns on their loans. This suggests that the spread rate contracted for loans taken out in a given year should be a function of the gross level of borrowing in that same year.

This formulation is cast in a long run perspective, and is offered only as a reasonable way to look at the cost of Eurobond funds from the borrower's point-of-view, and not as an analysis of the rational determination of spread rates in that market. Note also that this formulation allows the country to act somewhat like a monopsonist, since at the optimal solution the marginal costs of foreign borrowing are equated with its marginal productivity.

Alternative explanatory variables for the spread rate function were considered (see Appendix A), but the one adopted was preferred both due to its properties and satisfactory empirical fit. The use of net borrowing, instead of gross borrowing, in the spread rate function was avoided because the several equations that were estimated involving that variable had poor statistical results. This negative result can be rationalized if in the Eurobond market the lending decision is evaluated independently of the repayments of previous borrowing, which would be the case if in each period the lenders were not forced to refinance past loans, as seemed to happen until a few years ago.

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17 It states that securities with higher undiversifyable risk must command a higher interest premium over the riskless rate than the ones with lower risk.

The use of a specification involving debt as an explanatory variable for each period's spread was avoided because, being stock variable, debt is apt to change only slowly and not capture the dynamics of the rate if, for example, borrowing were drastically reduced. The debt service to export ratio, which is also a natural explanatory variable and does not suffer from this criticism, was abandoned because of an unsatisfactory empirical fit. However, an equation using the debt to income ratio as the independent variable fitted well the data, and was used to calculate the spread rate in the post-terminal period, as described in the next section.

The following equations define some variables already used above: total debt (D), amortization (R) and interest payments (H) in a period are the sum of the corresponding variables for the several maturities.

(18) $D_t = \Sigma_g D_{g,t}$ (19) $R_t = \Sigma_g R_{g,t}$ (20) $H_t = \Sigma_g H_{g,t}$ for all t

2.6. Terminal Stocks and Post-terminal Utility

It is straightforward to define terminal debt (DT) and terminal capital stock (KT) as in the equations below, where all the variables with a T subscript refer to the values in the beginning of last period.

(21) $$DT = D_T - n\ R_T + n\ B_T$$

(22) $$KT = d * K_T + n\ DK_T$$

Assuming that a stationary state prevails in the post-terminal period, the expression for the per-capita infinite horizon approximation term (V) can be derived by calculating the indirect utility function associated with the utility function in (1) and (2) at the terminal date. As in equation (23), it can be written as δ^{-1} times a generalized logarithmic function of terminal income, with total minimum expenditure equal to the sum of the minimum expenditures on the several goods (γ_i in (2))[18]. The intuition is clear: it is the present value of an infinite stream of single-period stationary utility (hence the term δ^{-1}) afforded by the supernumerary income flow.

The total terminal income is the sum of the labor income, plus the return (at a rate ρ) on the accumulated capital stock, less the interest cost of terminal debt. The terminal labor income (<u>YT</u>) and the yearly return on terminal capital stock (ρ) are considered here to be exogenous, but can be estimated on the basis of some preliminary runs. This exogeneity was maintained to avoid complicating too much the shadow-price structure of the model. Letting <u>NT</u> denote the population at the end of the last period, and recalling that V was specified in per-capita terms, the following equation displays the expression for the per-capita terminal utility.

$$(23) \qquad V = \delta^{-1} \log [(\underline{YT} + \rho\ KT - HT) / \underline{NT} - \Sigma_i \gamma_i]$$

The interest payment on the terminal debt in the equation above (HT) is calculated in (24), where the interest rate is assumed to be equal to the real LIBOR plus a spread rate which is calculated as a linear function (with slope σ) of the size of total debt relative to the index of real income defined previously[19]. This implies that the cost of terminal debt, which reduces the post-terminal supernumerary income, is a quadratic function of the debt.

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18 It is a bit tedious to show this. To do it, substitute the linear demand functions of ELES back into the objective, and integrate by parts.

19 The comments made in connection with equation (16) also apply here, in analogous form. Equation (24) also has a satisfactory empirical fit for the Brazilian data.

(24) $$HT = [h_T + \sigma (DT / \underline{YT})] DT$$

3. MODEL IMPLEMENTATION

The model was applied to Brazil with a horizon covering twenty-four years from 1984 to 2008, which is divided into 6 periods of 4 years. Endogenous variables and balances are estimated at the beginning of each period. The last period ends in 2008, the date at which the terminal condition term of the objective function is evaluated.[20]

A long horizon is necessary to allow enough time for the required changes in the economic structure to be accomplished through capital formation and labor reallocation. It is also needed to allow the correct evaluation of the investment decisions which are included in the model, and to minimize the distortions in the results for first few periods of the model's finite horizon[21]. The confidence that is accorded to the results for the last periods should however take into account the fact that some parameters of the real economy, which correspond to coefficients which are fixed in the model, may change over such a long time span.

The economy is divided into nine producing sectors: (1) agriculture, (2) agro-processing, (3) construction, (4) manufacturing of capital goods, (5) other manufacturing, (6) petroleum, (7) utilities (electricity, water, gas), (8) transport and communication, (9) services. This classification is similar

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20 The accuracy of the infinite horizon approximation, evaluated by of extending the model to a larger number of periods, is discussed in the next section.

21 The adjustments made through the terminal conditions are only approximate.

to the one used in the Brazilian national accounts, but has the manufacturing sector broken up into its main components, and aggregates the several services sectors in a single class. The petroleum sector was separated because of its interactions with the foreign sector.

The model was implemented with the use of the GAMS matrix generator[22] and solved by the non-linear programming package MINOS[23]. It has 7 non-linear equations, and its coefficients matrix has 350 rows, 484 columns and 1685 non-zero elements. At the optimum, 48 non-linear variables are super-basic[24].

It should be emphasized that MINOS 5.0, being a non-linear programming package, cannot in general reach exact optimal solutions. Rather, it stops at an approximate optimal solution where the reduced gradient is zero up to some very small tolerance. The algorithm was always able to converge to the optimal solution, as long as the key parameters (discount rate, LIBOR rate, etc.) were in the range where the behavior of the dynamic system underlying the programming model was stable. On non-stable paths it failed in some instances to find a solution with the specified precision.

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22 The listing of the specification of the model in the GAMS language is presented in Appendix B. The author wishes to thank Sethu Palaniappan for providing several hints on how to implement the model with that software.

23 For an introduction to these programs, see respectively Kendrick and Meeraus [1985], and Murtagh and Saunders [1983].

24 Solution time from a "cold start" on a CYBER machine was 17 seconds, but the model can be run in an IBM PC with 640k and numeric co-processor in about 4 hours. The model was developed using the mainframe version of the software because of its faster turn-around time.

3.1 Data base construction[25]

Most of the data for implementing the model can be inferred from the intersectoral transactions and final demands table for 1983, which was constructed by updating the set of preliminary tables for 1975 obtained from the the Brazilian statistics institute (IBGE)[26]. The units for all the commodities and factors in the model are consistent with this table and are defined as the quantities that could be bought with one CR$ billion in 1983. Implicit in this definition is the hypothesis that the aggregation within each sector is on the basis of initial year prices. The other important data items for the model are shown in Table 3.1 and were obtained as follows.

Table 3.1
Parameters of utility and production functions

SECTORS/GOODS	Marginal consump. shares (%)	Minimum /total consump. 1983 (%)	Capital /gross output ratio	Depre-ciation (yearly) (%)	Labor /gross output ratio
Symbols	ε	$[\gamma_i/c_i]$	k	(d-1)	lr
Agriculture	2.41	70.8	2.600	1.6	0.1340
Agro-processing	7.63	70.8	1.520	3.7	0.0504
Construction	-	-	0.572	4.2	0.1607
Man. capital goods	5.01	28.4	1.092	4.0	0.0845
Man. other goods	16.46	30.2	1.278	3.6	0.0784
Petroleum	3.97	42.9	2.075	3.6	0.0341
Utilities	2.72	25.4	3.556	3.4	0.1866
Transport & commun.	7.09	22.6	0.935	4.5	0.2470
Services	37.72	46.8	2.354	3.9	0.1923
Non-compet. imports	0.79	52.0	-	-	-
Average			1.769		0.1226

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25 Appendix A contains detailed description of the data base construction.

26 Unfortunately it was not feasible, given the time available for the data collection, to simultaneously maintain the consistency of the 1975 table and attain an exact correspondence with the national accounts aggregates for 1983. The GNP in the updated table is 10% smaller than the value in the accounts, in part because a sizeable discrepancy already existed in the 1975 table.

The parameters of the utility function (the vectors β and γ) were calculated by constraining the linear expenditure system to reproduce the 1975 consumption vector, and using the income elasticities estimated by Williamson and McCarthy [1981]. These values imply an overall elasticity of substitution equal to 0.54 in 1983. The discount rate of 4% used in the utility function is consistent, given the marginal savings rate of .84 implied by the β's of Table 3.1, with an average net real yearly return on personal savings of 5%. This value is quite reasonable, given that the real coupon rate on indexed passbook savings in Brazil is 6%.

The capital-output and labor-output coefficients were derived from the respective factor shares making use of some depreciation and profit rates data contained in Lysy and Taylor [1980][27].

The slope of the function used to calculate the spread rate in each period (equation (16)) and of the post-terminal interest cost function (equation (24)) are respectively α = 29.69 and σ = 5.26, with the spread rate in percentage points. They were obtained from an analysis, using simple linear regression[28], of the real lending rates for Brazil in the Eurobond

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27 A warning is in order about the reliability of the data. Primary data on sectoral capital-output coefficients was not available, so they had to be estimated indirectly as described in the text. Very little information about the marginal investment shares matrix (b) exists in Brazil, so it had to be constructed piecing together information from several sources, and does not have much hard data to support it. A properly estimated linear expenditure system was also not available, but the elasticities that were used are not expected to be very far from the correct ones. Finally, the possibility that any of these parameters may not be stable through time may compound any errors in the estimation. Since no major data collection effort could be made for this project, we had to do our best with the data on hand, but it must be emphasized that further work to validate these coefficients is necessary.

28 The R^2 for the two equations were respectively .47 and .50 and both coefficients are significant at the 5% level.

market between 1974 and 1984. It was assumed that these behavioral relations will continue to hold in the future, in spite of the fact that there is no _a priori_ reason why this should be so. If the institutional arrangements for borrowing by developing countries change in the future, new rules to determine the interest cost of debt will have to be included into the model.

The yearly rate of growth of population and labor force were assumed to be 2.5% and 3% respectively, consistently with historical behavior and some recent projections done in Brazil[29]. The rate of labor-augmenting technical progress was assumed to be 2% yearly.

Government expenditures are assumed to grow at the same rate as population growth, which implies they are inelastic with respect to per-capita income. This is not the usual assumption in models for Brazil, but this parameter can be easily varied to check the sensitivity of the solution to it[30].

For the base case _scenario_[31], the following ad-hoc assumptions were made with regards to the values of the remaining parameters. The real LIBOR rate stabilizes at 5% yearly, slightly lower than the current level, and does not return to the very low levels of the early '70s. The maximum yearly growth rate of agricultural and manufactured exports is equal to 5% and 10% respectively, envisioning an yearly rate of increase of international commerce

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29 See Oliveira et all [1985].

30 Variations in the growth rate of government expenditures in the reasonable range are not expected to have any impact on the conclusions of the sensitivity analysis of section 5.

31 It cannot be emphasized enough that these are only scenarios for parameters whose future evolution we know very little about, and are not projections of the most likely course of events.

of 5% and market share increases for Brazilian manufactured goods. It is assumed that domestic petroleum production stabilizes at a level of 600 thousand bbl/day in accordance with recent forecasts, but that the gross output of the sector expands only to incorporate the value of the increased production. This implies a rather extreme assumption that the refining sub-sector does not expand above its base-year capacity, and that in the medium and long term the demand increases are supplied with imports of refined products[32]. The terms of trade are assumed stable at the 1983 level. Sensitivity analysis with respect to these parameters is shown in section 5.

Finally, due to the difficulties with finding a disaggregated estimate of capacity utilization appropriate to the framework of the model, full-employment was assumed to prevail in 1983, in spite of the fact that it was a recession year. In addition, since cyclical departures from full employment are difficult to handle in models of this type, experiments were not made to verify whether the inclusion of slacks in the resource constraints fo the initial period would lead to reasonable results. This assumption however does not seem to be overly problematic for the long-run calculations for which this model is suitable.

3.2 The adjustment of the terminal utility parameters

The post-terminal net return on capital (ρ) had to be estimated by insuring that the Ramsey equation be satisfied at the beginning of the model's post-terminal period. Working with a simplified version of a similar model,

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32 This may not have been a very good assumption, but it is not completely unreasonable economically in light of the large increases in Middle-Eastern refining capacity which are scheduled to occur in the next few years.

Goreux [1977] shows that the equilibrium condition reduces to expression (25)[33]. It can also be shown that the rate of decline of the per-capita marginal utility can be approximated locally by the rate of increase of per-capita consumption divided by the overall elasticity of substitution.

$$(25) \qquad \left|\begin{array}{l}\text{marginal rate}\\ \text{of capital}\\ \text{productivity}\end{array}\right| = \left|\begin{array}{l}\text{utility}\\ \text{discount}\\ \text{rate}\end{array}\right| + \left|\begin{array}{l}\text{rate of decline}\\ \text{of per-capita}\\ \text{marginal utility}\end{array}\right|$$

Recall that the base-case discount rate (δ) is 4%, and note that the maximum sustainable post-terminal rate of growth of per-capita consumption is the sum of the rate of labor-augmenting technical progress (2%) plus the rate of increase in the labor market participation rate (0.5%). The elasticity of substitution in the extended linear expenditure system, given the growth rates assumed above for population and per-capita income, would be average about 0.66 during the planning period[34]. Therefore, the approximate rate of decline of the per-capita marginal utility is 3.8%, and the discrete-time estimate of the return on capital for the post-terminal period (ρ) is 8.0%[35].

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33 Note the absence of the population growth rate from (25), due to the fact that in the objective function (1) the maximand is the sum of utility across all individuals.

34 In ELES the overall elasticity of substitution (φ) is equal to the supernumerary ratio, which would be about .8 in the first decade of the post-terminal period. The formula for the Frisch parameter (see Lluch, Powell and Williams [1977] is: $w = \mu/\varphi - (1-\mu)$, where μ is the marginal savings rate (0.16) and φ is the elasticity, and is about .9 in the beginning of the post-terminal period.

35 The use of the continuous time formula can lead to a slight numerical distortion, so the discrete-time version of (25) was used in estimating ρ (g_c is the growth rate of per-capita consumption, and ϵ is the overall elasticity of substitution):

$$(1 + \rho) = (1 + \delta)\,(1 + g_c)^{1/\epsilon}$$

The pos-terminal yearly net labor income, whose major role is to determine the slope of the terminal condition term in the utility function, was fixed at Cr$ 240 trillion (of 1983), assuming an average growth of per-capita income of 2.5% during the plan period.

Given these values for δ, ρ and YT, the initial runs (see the base case in the next section for an example) showed that the economy managed to attain an overall yearly growth rate of about 5%. Towards the last period of the model, the gross marginal productivity of capital was seen to be close to 12%, implying a net return of 8.2%, given that the average depreciation rate is 3.8%. The rate of decrease of the aggregate marginal utility also was very close to the predicted value of 6.5%, which was calculated by adding the rate of population growth to the rate of decrease of per-capita marginal utility.

The sensitivity analysis with respect to the net return on capital (ρ) in the neighborhood of 8% showed that the value 8.2% produces, for the range of simulations reported here, a smooth path for consumption, investment and borrowing. The latter value was then adopted for subsequent runs of the model.

The values for these indirectly estimated parameters were held constant in all the simulations reported in the next sections, in spite of the fact that in some cases some fine-tuning would had been in order.

The existence of a convex function for the cost of foreign borrowing generates another equilibrium condition for the model, which requires that the marginal return on capital be equal to the marginal cost of debt. This allows us to calculate the approximate value of the post-terminal debt to income ratio[36] as being equal to .3, which is somewhat smaller than the current .42, but very close to the ratio actually chosen by the model for the last periods of the horizon in these initial runs. This suggests there are no major inconsistencies between the parameters for the post-terminal period and the rest of the model.

Experiments with extending the horizon of the model to 7 and 8 periods showed that the formulation chosen for endogenizing the post-terminal period leads to stable behavior of most of the variables for the whole horizon. In the last period however, end effects are still present for some variables. This is exemplified in Table 3.2, which displays the small changes in consumption and debt, as well as the larger changes observed in the trade balance, when the number of periods is increased. The latter is one of the variables whose terminal behavior is most sensitive to the increase in the number of time periods[37], and shows that this model attempts to generate a large trade surplus near the end of the horizon, in order to be able to carry an artificially smaller debt to the post-terminal period[38]. As a consequence of these remaining end effects, the values of the foreign sector flows for the last 2 periods have to be interpreted with care. For the same reason, the last period is omitted from the tables in the following sections.

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[36] Note that the slope of (24) is $[h_T + 2\,(DT/YT)\,\sigma]$, where $h_T = 5\%$ is the post-terminal real LIBOR rate and $\sigma = 5.26$ is the slope of the terminal spread rate function.

[37] The current account is even more volatile in percentage terms.

[38] The reason for this behavior seems to be that by increasing exports in the last few periods, consumption is reduced only during the interval up to the end of the horizon, since the post-terminal labor income flow is exogenous. On the other hand, this secures an infinite stream of additional post-terminal income flow, via reduction of interest payments. In terms of discounted utility, this tradeoff favors the debt reduction.

Table 3.2
Sensitivity of the solution to the number of periods in the model
(% deviation from values of solution with 10 periods)

Item	# periods	1984	1988	1992	1996	2000
Aggregate	6	-0.08	-0.22	-0.43	-0.94	-1.19
consumption	7	-0.03	-0.04	-0.16	-0.23	-0.67
	8	0.00	0.01	-0.02	-0.05	0.01
Foreign	6	-	-0.18	-1.26	-4.69	-10.09
debt	7	-	-0.07	-0.46	-0.86	-4.72
	8	-	-0.01	-0.03	0.17	-1.23
Trade	6	0.94	8.13	24.19	24.76	55.28
balance	7	0.35	2.94	2.47	20.38	-13.41
	8	0.05	0.18	-1.60	7.95	-15.18

4.RESULTS FOR THE BASE CASE SCENARIO

Several important caveats are in order before we begin the discussion of the results. First, these solutions are driven by an optimization operation performed under conditions of perfect foresight, which implies that if the model can calculate that times will be better (or worse) in the future, it will make decisions today which will take that into account. To the extent that the model is a deterministic representation of a world which is actually stochastic, the solutions can only be interpreted in a rational expectations framework with identical penalties for over and under-shooting. Second, the model is normative in nature, so the solution should not be seen as a forecast. Third, the behavior of the variables within the periods is supposed to be smooth, which implies in particular that the values for 1984 should be interpreted as those that would produce an optimal path until 1988, rather then reflecting short-run contingencies that affected the economy in that year. Fourth, it is convenient to emphasize that the model's unit is <u>constant</u> 1983 CR$ billions[39], a fact that is particularly relevant when looking at the foreign accounts, where amortization and interest payments must be interpreted in real terms, and exclude the effects of US dollar inflation and exchange rate movements relative to third currencies.

Table 4.1
Economic aggregates for base case scenario
(evaluated at base year prices)

	1984[1] (Cr$ bil of 1983)	1984[1] (US$ bill)	Index 1984	1988	1992	1996	2000
Gross output	207777.8	360.1	1.0	1.206	1.462	1.771	2.145
Gross dom. income	111319.2	192.9	1.0	1.205	1.461	1.766	2.136
Consumption	76631.5	132.8	1.0	1.193	1.464	1.759	2.130
Investment	27392.1	47.5	1.0	1.286	1.508	1.831	2.222
Government consump.	4652.4	8.1	1.0	1.126	1.267	1.426	1.605
Exports	12927.5	22.4	1.0	1.212	1.704	2.352	3.094
Non-compet. imports	5918.7	10.3	1.0	1.206	1.484	1.819	2.244
Total imports	10284.4	17.8	1.0	1.302	1.826	2.474	3.277
Trade balance	2643.1	4.6	1.0	0.861	1.226	1.879	2.380
Regist. foreign debt	46385.8	80.4	1.0	1.157	1.391	1.601	1.704
Repayments	7596.1	13.2	1.0	0.964	0.940	1.284	1.358
Interest	3491.0	6.1	1.0	1.150	1.347	1.486	1.525
Transfers	973.7	1.7	1.0	1.000	1.000	1.000	1.000
Current Account	-1821.6	-3.2	1.0	1.489	1.337	0.656	0.004
Borrowing	9417.7	16.3	1.0	1.066	1.017	1.162	1.096
Capital stock	358294.8	620.9	1.0	1.191	1.445	1.739	2.097
Capital formation	28946.8	50.2	1.0	1.277	1.502	1.822	2.214
Population[2]	131.374		1.0	1.104	1.218	1.345	1.485
Employment[2]	31.999		1.0	1.113	1.250	1.398	1.565

Note: [1] These are the values calculated by the model for 1984.
[2] these variables are in millions of individuals.

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[39] The average exchange rate for 1983 was CR$ 577 per US$, according to International Financial Statistics [1984].

The main aggregates, all evaluated at initial year prices, are shown in Table 4.1. It is divided in four parts: the income accounts, the balance of payments, and the statistics for the capital and labor stocks. These are discussed in turn below[40].

Consumption at the year 2000 is about 2.13 times the current level, corresponding to an average yearly growth rate of 4.75%, while gross output grows slightly faster, at 4.91% per year. Per-capita consumption grows on average at 2.2% per year, a rate very close to its steady-state value equal to the rate of growth of labor productivity.

The shares in output do not change much throughout, with consumption, gross investment, government and net exports accounting on average for respectively 69%, 25%, 3.5% and 2.5% of income[41]. Since it was assumed that government expenditures would grow at the same rate as population, its share of income decreases steadily from 4.2% to 3.2%. The share of investment increases by one percentage point between the two extreme periods.

The trade surplus stays at about US$ 4.5 billion until 1992, and then grows at 9% per year. The larger actual surplus in 1984 (US$ 12.9 billion) can then almost surely be seen as excessive, from the long-run perspective of the model[42]. Accordingly, debt grows at 4% per year until 1996 and then stabilizes at a level of US$ 130 billion.

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40 For more detail about the results, the reader can resort to the solution reports for the base case, which are presented in Appendix C.

41 The government share differs from that in the national accounts (9%) because of the discrepancy in data sources alluded to in section 3.

42 Recall also it does not incorporate constraints in the level of borrowing.

The model chooses to let the real foreign debt grow, albeit much slower than income, in spite of its higher cost in the early years. This is reflected in the fifth row of Table 4.2, which shows that the average yearly real interest rate paid in each period is 7.5% until the end of the decade but then decreases steadily. Borrowing and interest rate on the debt are jointly determined, with the spread above real LIBOR being progressively reduced, as the approximately stable gross borrowing level (US$ 17.3 billion) declines with respect to growing income[43]. The relative level of gross borrowing depends in part (at each point in time) on the repayments on past borrowing, but its reduction decreases the total interest cost in two ways: by minimizing the size of the debt and by reducing the spread rate.

The current account shows that the inflow of "new" loans (there are no reserve variations) averages about US$ 4.5 billion annually until 1996, showing that the optimal strategy in this base case is to reach a situation of of balanced current account only toward the end of the horizon. The impact of requiring that it be equilibrated before then will be analyzed later.

Gross investment is on average 8.5% of the capital stock, sufficient to cover average depreciation of 3.8%, and provide a net growth of 4.7% required to support the gross output growth[44]. The share of labor force employed in the two manufacturing sectors goes from 12.5% in 1984 to 15.0% in 2000, showing some degree of labor reallocation.

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43 To see the reason for this, recall the equation for the determination of the spread rate.

44 Recall that in this version of the model there is no technological choice, and the production technology is pure Leontief.

The weighted average of the shadow-prices of the several commodities, with weights equal to the shares in the initial consumption bundle, is shown in the last part of the Table 4.2. It is a measure of the marginal utility of income at the several points in time, and is used as a numeraire to calculate the other prices in the economy. It declines because of the time discounting in the objective function, and because of the joint effect of income growth and concavity of the utility function.

Table 4.2
Shadow prices and implicit rates for the base case scenario
(in consumption units)

	1984	1988	1992	1996	2000
Prices Consumption	1.000	1.000	1.000	1.000	1.000
Labor	2.334	2.371	2.655	2.705	2.660
Foreign exchange	1.086	1.027	1.027	1.024	1.022
Marginal yearly rate of capital productivity[1]	0.168	0.148	0.129	0.125	0.127
Average yearly interest rate on foreign borrowing	0.075	0.075	0.073	0.070	0.067
Numeraire[2]	11.700	8.798	6.306	4.720	3.520

Note: [1] This rate is gross of depreciation
[2] See text for definition of the numeraire

The aggregate marginal productivity of capital in Table 4.2 is the average of the sectoral returns to investment, in terms of consumption units, over one year. The latter is the ratio the marginal utility of the rental one unit of capital and the marginal utility of consumption. The productivity is declining due to the increase of the capital to labor ratio in production. Since at the margin the economy can increase the capital stock by purchasing one additional unit of capital abroad, the level of borrowing adjusts so that its marginal interest cost is equal to the marginal productivity of capital, net of depreciation. The decrease in the marginal rate, which is followed by a reduction in the average rate shown in Table 4.2, is accomplished by a reduction in gross borrowing, relative to income.

In the model the shadow price of foreign exchange is close to unity in all periods except the first, indicating that no real depreciation would be needed to support the market equilibrium associated with this solution.

The sectoral rates of growth of output and investment, as well as the rates of growth of consumption and exports for each of the goods, are shown in Table 4.3. Consumption of agricultural and agro-processed goods grows slower than that of manufactured goods, while the rate of growth of services has an intermediary value. This reflects their differing income elasticities, which are built in the parameters of the objective function. The observed elasticities can be readily calculated, and range in value between 0.77 and 1.25.

Table 4.3
Average rates of growth of selected aggregates in the base case
(1984-2000, in %)

Sector / goods	Gross Output	Invest- ment	Consump- tion	Exports
Agriculture	4.4	3.9	4.4	5.0
Agro-processing	4.1	3.7	3.8	5.0
Construction	5.0	4.8	-	-
Man. capital goods	4.6	3.9	5.2	-6.0
Man. other goods	6.1	5.8	5.3	10.0
Petroleum	0.7	-	4.9	-
Utilities	5.2	5.0	5.2	-
Transp and commun.	4.7	4.4	4.9	-
Services	4.7	3.8	4.7	-

The behavior of gross output reflects also the strategy the model chooses with respect to exports: to expand at the maximum rate in the agricultural, agro-processed (except in 1988) and "other" manufacturing sectors, while reducing exports of capital goods. It seems that at the prices prevailing in 1983, which are held constant through the whole horizon in this simulation, the Brazilian industry is not very competitive in capital goods manufacturing.

The petroleum sector can only grow in accordance with the current forecast of domestic production, and is therefore stagnant. Consequently, imports grow at an yearly rate of 9.6%, absorbing essentially all the increase in demand. In interpreting this result it must be recalled that in this version of the model there are no substitution or conservation possibilities. It is hoped that in the future these can be included, if reliable data can be found.

Investment is more sluggish in the sectors which are growing at less than 4.9% and losing share in gross output.

The shadow price of labor can be used to calculate the implied sectoral wages, shown in Table 4.4 in terms of the number of minimum wages. The comparison with the level prevailing in the early '80s shows that the market wages are about 43% of the implied marginal value of labor. The explanation for this lies in part on the fact that in implementing the labor availability restriction only the formal employment was taken into account, with the vast "informal" sector (8 million rural and 7 million urban workers) having been ignored. It could also be due to taxation and other distortions, but the possibility of systematic underpricing of labor is not ruled out. No large discrepancies between market and model wages are observed in their sectoral distribution.

Table 4.4
Comparison of model and market sectoral wages
for formal employment in the base case in 1984
(in number of minimum wages)

	Agricul ture	Agropro cessing	Constr uction	Capital goods	Other goods	Petro leum	Util ities	Transp & comm	Servi ces
Market	1.00	4.69	1.73	4.02	3.57	5.82	3.20	2.20	2.50
Model	2.34	10.90	4.04	9.38	8.33	13.60	7.50	5.10	5.83

Table 4.5
Shadow price of commodities in the base case
(in consumption units)

	Agricul ture	Agropro cessing	Constr uction	Capital goods	Other goods	Petro leum	Utili ties	Transp & comm	Servi ces
1984	.71	.99	1.17	1.04	1.04	1.09	1.22	1.27	0.97
Average[1]	.94	1.01	1.09	1.02	1.00	1.02	1.20	1.31	0.95

Note: [1] This is the arithmetic average of the values from 1988 to 2004.

The comparison of the time average of normalized shadow prices of commodities in Table 4.5 with 1983 market prices (unity by definition) indicates that the only major changes that would be required for efficiency are increases of 20% and 30% in the prices of the utilities and transport & communications sectors[45]. The prices of traded goods tend to the international price, the only significant discrepancy being the price of agricultural products in the 1984-1988 period.

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45 It is also possible but unlikely that this is an indication that the technological coefficients in production overstated the true costs of these sectors. Alternatively, this could be signaling the need to have alternative production technologies in these sectors.

5. SENSITIVITY ANALYSIS

Five sets of sensitivity runs were performed to assess the response of the model to changes in the parameters characterizing the conditions affecting the foreign sector The first and second sub-sections trace the changes in the optimal solution due to changes in the discount rate and the cost of foreign borrowing, respectively. The third section tries to look at the effects of changes in the external markets environment, by varying the allowed growth of exports. The fourth evaluates the importance of the petroleum sector, by first hypothesizing higher levels of domestic petroleum production, and then looking at the effect of an increase in international oil prices. The last sub-section attempts to assess the impact of alternative assumptions about the value of the non-competitive imports requirements coefficients[46].

It should be clear that this is only a small selection of possible sensitivity runs that could be performed, but they will hopefully illustrate the power and flexibility of the model to analyze in a consistent manner a range of planning issues, especially those relating to the foreign debt[47].

5.1 Sensitivity to the discount rate

This section discusses the effects in the solution of alternative assumptions with respect to the discount rate for utility. Recalling the

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[46] Note that since the values for 1984 are calculated in the model, they change between the scenarios.

[47] Lack of space did not permit the inclusion of the complete results (see Appendix C for an example) for the scenarios, but Appendix D contains tables with the main macroeconomic aggregates for all the sensitivity runs.

discussion in section 3.2, the main dynamic relationship driving the model requires that along the optimal path the marginal cost of foreign debt be equal to the sum of the discount rate and the rate of decrease of the marginal utility.

Since the former is composed of the real LIBOR rate plus the marginal spread rate, and the latter is roughly constant, increases in the assumed rate of discount for utility will lead to higher levels of optimal borrowing, as the spread rate adjusts to satisfy the Euler equation. The optimal borrowing policy therefore depends essentially on the difference between the real LIBOR rate and the discount rate, through the marginal cost of borrowing. This is illustrated by Figure 5.1, which displays the variation in the total foreign debt as δ is increased to 5%, 6% and 8%, while holding the real LIBOR at the base case level (5%)[48].

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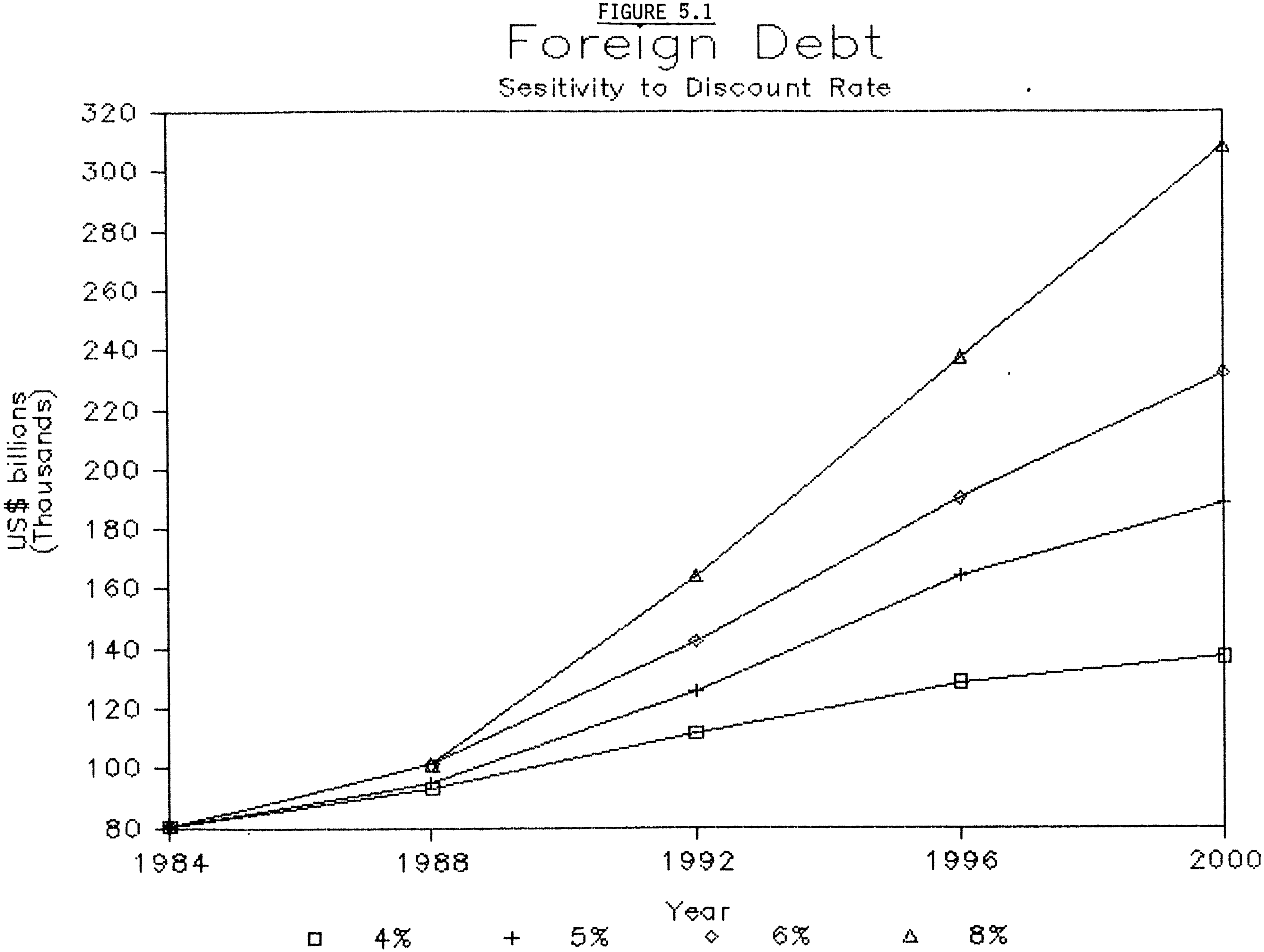
[48] The post-terminal return on capital (ρ) was adjusted to 9.2%, 10.2% and 12.2% respectively, as is required satisfy the Euler equation post-terminally.

FIGURE 5.1


Foreign Debt
Sesitivity to Discount Rate
320
300
280
260
240
220
200
180
160
140
120
100
80
US$ billions
(Thousands)
1984
1988
1992
1996
2000
Year
4%
5%
6%
8%

The convexity introduced in the formulation of the model by the endogenous borrowing cost allowed us not to have to specify the borrowing rate to be equal to the discount rate, to be able to avoid corner solutions. However, the fact that debt at each point in time is sharply increased[49] as the discount rate is raised, shows that this non-linear formulation can lead to unrealistically high marginal spreads if the difference between the two rates is large. This occurs because the specification (and the parameters) of the borrowing cost function in this model do not imply enough convexity to compensate for large discrepancies between them.

The shift in the intertemporal pattern of consumption towards earlier periods is the counterpart of the increase in indebtedness, and is illustrated in Table 5.1.

Table 5.1
Sensitivity of the yearly growth rate in consumption to changes in the discount rate for utility

Discount rate	1984/88	1988/92	1992/96	1996/2000
4%	4.50	5.26	4.70	4.89
5%	4.85	4.92	4.87	4.61
6%	5.06	4.61	4.50	4.64
8%	5.58	4.22	4.02	4.61

The message to be extracted from this section is that the study of the optimal borrowing policy in the model should center on the results of the sensitivity analysis, as is done in the following sections. The specific values for the foreign sector variables in base case solution have to be taken

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49 In fact, with [illegible]=8% the arbitrary limit on the terminal foreign debt (US$ 435 billion) was reached.

with a grain of salt, because they are depend quite a bit on the difference between the discount rate for utility, which is unobservable, and the future interest rate on foreign borrowing, which is unknown. Other variables however are not so sensitive, and their values in the base case are representative of the macro behavior of the model.

5.2. Variations in the fixed part of the interest cost

One would expect that the rational reaction to higher (lower) interest rates would be a reduction (increase) in the level of borrowing, in order to reduce the burden of the debt. This is indeed the response of the model, which can however also provide us with an estimate of the size of the changes involved. Table 5.2 summarizes the impact, on the main indicators of the foreign sector, of varying the real LIBOR rates in the range of 2% to 10%. In all these simulations the changes occur in the first time period and remain in effect until the end, so that they can be seen as "step" responses under perfect foresight.

As Table 5.2 shows, as the rate increases from 2% to 6%, the curve that describes the behavior of the current account shifts up by roughly US$ 8.5 billion[50]. This means that (in that range) an increase of one percentage point in the rate induces a reduction of US$ 2.1 billion in the current account deficit. This result must be interpreted in the optimizing framework in which the model operates, since this total derivative of the current account with respect to the interest rate on debt has the opposite sign of the partial derivative that corresponds to the strategy of not responding to the higher rates.

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[50] This is only strictly true between 1988 and 2000.

For the higher rates the net effect of a change in the real LIBOR is much smaller, as the alternatives for response are more limited, and are partly counter-balanced by the added cost of carrying the debt. This can be seen in the table by comparing the 8% and 10% rows for the trade balance, borrowing, and total debt, and noting that the small changes indicate that near maximum reduction of external exposure had already been triggered at the lower rates.

Table 5.2
Sensitivity of the main foreign sector aggregates
to the real LIBOR rate
(values in US$ billions of 1983)

ITEM	Rate	1984	1988	1992	1996	2000
Current Account	2%	-5.235	-11.580	-11.319	-8.482	-5.316
	4%	-2.970	-6.956	-6.747	-4.473	-1.971
	6%	-3.457	-3.423	-1.479	0.497	2.204
	8%	-3.564	-2.939	-1.492	2.863	12.204
	10%	-3.335	-3.382	-2.069	1.881	12.729
Trade Balance	2%	0.091	-5.123	-2.220	2.695	7.364
	4%	3.964	0.693	2.685	6.389	9.743
	6%	5.085	6.284	9.080	11.080	12.217
	8%	6.585	8.708	11.046	15.555	23.315
	10%	8.422	10.021	12.712	17.229	26.741
Borrowing	2%	18.400	25.104	27.407	32.640	34.224
	4%	16.135	19.575	19.944	23.307	23.248
	6%	16.621	16.236	13.486	14.899	12.597
	8%	16.729	15.795	13.355	12.381	1.591
	10%	16.500	16.146	14.004	13.659	1.878
Total debt	2%	80.391	101.332	147.651	192.929	226.856
	4%	80.391	92.271	120.096	147.085	164.975
	6%	80.391	94.218	107.908	113.825	111.859
	8%	80.391	94.649	106.406	112.372	100.920
	10%	80.391	93.733	107.260	115.536	108.012

FIGURE 5.2

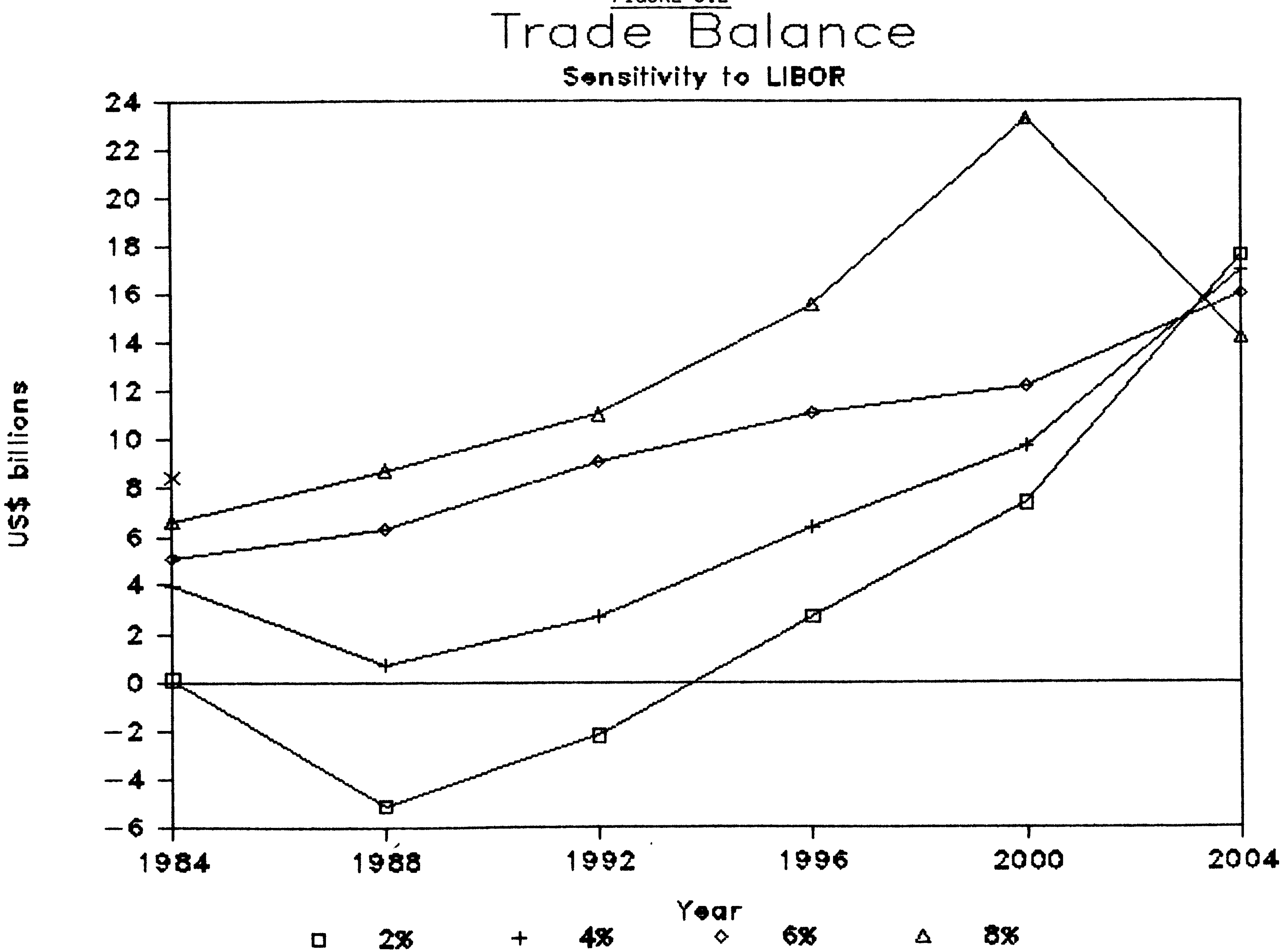
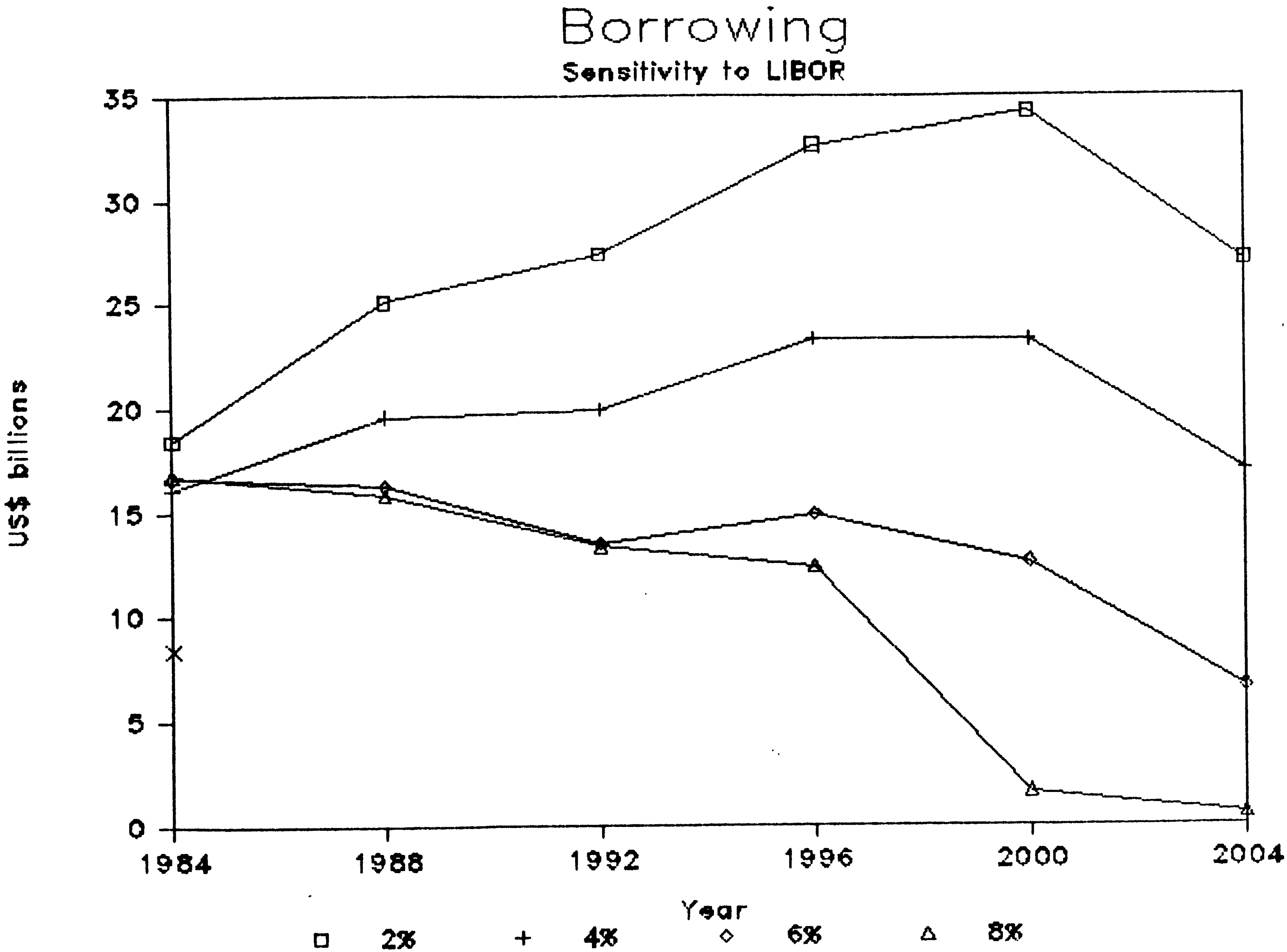

Trade Balance
Sensitivity to LIBOR
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
US$ billions
1984
1988
1992
1996
2000
2004
Year
2%
4%
6%
8%

FIGURE 5.3


Borrowing
Sensitivity to LIBOR
35
30
25
20
15
10
5
0
US$ billions
1984
1988
1992
1996
2000
2004
Year
2%
4%
6%
8%

As can be seen in Figure 5.2, the response of the trade balance to a change in rates is US$ 2.4 billion per percentage point, with most of the additional foreign exchange revenue being generated by the capital goods sector, which is the only one that had not reached the export limit in the base case.

Figure 5.3 shows that the level of gross borrowing is also only responsive to the interest rate in the range below 6%. Its scope of variation is larger the farther into the future is the period being considered, because the effect of higher (lower) level of borrowing in the early years is compounded in the form of larger (smaller) repayments later.

The optimal level of the total debt in the year 2000 can be anywhere between US$ 226 billion and US$ 100 billion (in real terms), depending on the level of interest rates. This highlights the point that the country's strategy with respect to the foreign debt should be cast in a long range framework of analysis, and that the discussion of the optimal policy with respect to the debt must consider explicitly the real rates which are expected to prevail in the future[51]. If they are expected to continue at high levels, it may not be optimal to try to pursue strategies that will lead to the continued increase of the debt.

Table 5.3 shows the average interest rate on debt at each point in time. An estimate of the average spread can be inferred from it by taking the difference between the actual rate and the real LIBOR. It can be seen that when the fixed rate is very low (2%) the model accepts average spreads of the

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51 This consideration seems sometimes to be missing in the negotiations to reschedule the Brazilian debt.

order of 3%, which are even larger than the highest levels observed in the past. In the first two periods there is not much variation in the average spread between the scenarios because those interest payments are dominated by the conditions on the initial debt. For higher LIBOR rates the lower levels of borrowing also allow a faster reduction of the average spread after the second period.

Table 5.3
Average interest rate on foreign debt
(in %)

Real LIBOR (%)	1984	1988	1992	1996	2000
2.0	4.5	4.7	5.1	4.9	4.8
4.0	6.5	6.5	6.4	6.2	6.1
6.0	8.5	8.5	8.2	7.8	7.5
8.0	10.5	10.5	10.2	9.8	9.3
10.0	12.5	12.5	12.2	11.8	11.4

The objective function changes by only 1% between the two extreme cases of the real LIBOR rate. The impact in the domestic side of the economy is further illustrated in Table 5.4, that shows how consumption (evaluated at 1983 prices) is affected by the changing rates. In general, as rates increase both initial and terminal aggregate consumption are reduced, falling by approximately 6% and 1% respectively when the two extreme cases are compared.

Table 5.4
Comparison of consumption in the first and last periods
for alternative real LIBOR scenarios
(% deviations from the base case)

Real LIBOR -->	2%	4%	6%	8%	10%
1984	+3.4	+0.7	-0.7	-1.9	-2.9
2000	+1.3	+0.4	-0.4	-3.3	-4.2

Summing up, while the optimal strategy with respect to the debt changes quite a bit with a change in interest rates, this economy seems to be flexible enough to absorb (in the long run) relatively large variations in them without much impact on welfare. It is interesting to note how limited is the long-term impact of widely different borrowing strategies, indicating that the real issues in the LDC borrowing problem must be more related to the short and medium term liquidity restrictions.

This last argument can be confirmed by Table 5.5, which compares the base case scenario with another where non-negative current account balance is imposed for the whole horizon. In this alternative scenario the real debt is not allowed to grow beyond the initial level, and the model responds to this by reducing consumption and increasing the net exports[52] in the early years. This loss of utility is compensated, in present value terms, by higher consumption towards the end of the horizon, when the required exports are much smaller. The impact therefore is very similar to that of a reduction of the discount rate, causing a reduction of about 2% in the yearly aggregate consumption level until 1992.

The shadow-price of foreign exchange displays a sharp increase of 70% in the first period, drops to a level 10% above the base cain the second, and stabilizes at the base case level by the end of the horizon.

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52 The increase in the trade balance is generated through petroleum imports reduction in 1984, and by an increase in agro-processed goods exports in the second period, each of about US$ 2.8 billion. The decrease in petroleum consumption associated with the imports reduction is accomplished through a sizeable relative shadow-price increase of 70%. The consumption shift required to free up agro-processed goods for export requires only a small relative price increase of 8%, because there already existed some slack in the export limit of this commodity in that year.

Table 5.5
Comparison of "base case" and "balanced current account" scenarios
(% deviations from base case)

ITEM	1984	1988	1992	1996	2000
Consumption	-2.5	-2.0	-0.1	+0.3	+2.1
Trade balance	+68.9	+88.9	+25.8	-21.3	-40.0

5.3. Export Markets

To evaluate the impact in the optimal solution of the conditions faced by Brazilian exports in penetrating foreign markets, two simulations were performed altering the rates at which manufactured and agricultural exports could grow[53]. In the protectionist scenario the maximum yearly rates of growth for agricultural and manufactured exports were set to 3% and 7.5% respectively. The optimistic scenario maintains the base case rate for the growth of agricultural goods exports (5%) and considers a rate of growth for manufactured exports (13.5%) that would lead to a doubling, by the end of the horizon, of the base case increase in the level of this type of exports[54]. Note that because these bounds are in terms of rates, no large departures from the base case can occur in either scenario in the early periods, since the different rates can only affect significantly the levels further out in the future.

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53 Recall from the model specification these rates apply cumulatively over the initial export level, and are not a restriction on the speed at which exports can grow at each point in time.

54 More optimistic scenarios than this do not affect much the results, as the model is not willing to reduce consumption to take advantage of them, as will be seen below.

Table 5.6 shows how the foreign sector aggregates respond to these different external conditions and exemplifies a situation where the forward-looking nature of the model produces some interesting results. In the optimistic scenario exports do not increase at all, relative to the base case, until the period starting in 1988 because, it will be recalled, the model was not using all its potential in that case. The solution does not display large trade surpluses until the last two periods, which indicates that the model prefers to increase imports at the higher rate of export growth, rather than use resources to reduce the debt. The level of post-terminal debt is however smaller in this case because of the large trade balance in the period starting in 2004.

Table 5.6
Comparison of foreign sector aggregates for protectionist, base and optimistic scenarios
(US$ billions)

Scenario	Item	1984	1988	1992	1996	2000
Protectionist	Exports	21.934	27.633	35.030	44.664	57.255
	Imports	16.165	21.736	30.209	40.921	54.077
	Trade balance	5.768	5.898	4.820	3.743	3.178
	Debt	80.391	88.269	97.407	112.193	134.193
Base	Exports	22.405	27.158	38.167	52.699	69.317
	Imports	17.824	23.212	32.553	44.092	58.415
	Trade balance	4.581	3.946	5.614	8.606	10.903
	Debt	80.391	93.019	111.818	128.703	136.984
Optimistic	Exports	22.856	27.191	41.832	64.031	99.711
	Imports	17.974	23.250	36.802	58.289	89.456
	Trade balance	4.882	3.941	5.029	5.742	10.255
	Debt	80.391	91.813	110.157	128.747	148.459

In the protectionist scenario the model knows that times will be difficult in the future and does not delay the adjustment by borrowing.

Rather, debt is smaller than in the base case until the next to last period, when it is allowed to grow, leading to a post-terminal value 80% larger than in the base case[55]. The surplus in the trade balance is however clearly decreasing, a trend opposite to the one in the base case. The relative effect on the primal of the smaller allowed export growth limit is not larger because the model was not strongly constrained by it in the base case.

The shadow-prices in table 5.7 show the exchange rate policy implied by the allocation above and tell different story: a real devaluation of 40% would be necessary to bring about the changes in consumption required to reduce imports in the protectionist case. If we were to measure real income in terms of the foreign currency, this reduction is an indication of the cost imposed on the economy by a more difficult external markets situation.

Table 5.7
Comparison of shadow-prices of foreign exchange
for the protectionist, base and optimistic scenarios

ITEM	1984	1988	1992	1996	2000
Protectionist	1.368	1.308	1.395	1.422	1.466
Base	1.086	1.027	1.027	1.024	1.022
Optimistic	1.075	1.018	1.024	1.041	1.013

5.4. Effect of assumptions about the petroleum sector

The model allows us to evaluate the impact on the optimal plan of a discovery today of a large (by Brazil's standards) oil field. This was

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55 This may be due to the approximations involved in the terminal utility term, and may not be very meaningful.

simulated by solving the model with hypothetical domestic petroleum production levels reaching 700, 800 1000 and 1200 thousand bbl/day in 1992, 1996, 2000 and 2004 respectively, rather than stabilizing at 600 thousand bbl/day as in the base case. In this simulation it was also assumed that the gross output of the whole sector (including refining) expands proportionately to this increase in domestic production. It should be emphasized however, that this scenario can only illustrate the effect of knowing <u>for sure</u> that future production can be higher. The resulting changes in aggregate consumption and income are reported in Table 5.8 in percentage terms, and show that this optimistic scenario would have a significant, but not overwhelming, impact in the growth of this economy.

The tilting of the time profile of consumption is quite interesting, and can be explained by looking at the last row of the table, and realizing that it is necessary to invest more in the petroleum sector (especially in the early periods) to support the higher production level. Consequently, the total terminal capital stock is also 6.2% higher than in the base case.

Table 5.8
Comparison of "base case" and "large oil finding" scenarios
(% deviation with respect to base case levels)

ITEM	1984	1988	1992	1996	2000
Income	-	+1.0	+2.4	+2.5	+3.0
Consumption	-1.4	-1.9	+1.0	+0.4	+1.2
Investment	+5.1	+11.1	+4.8	+8.2	+7.8

In this new scenario there are no major changes in the foreign sector, with borrowing, the current account, and the level of the debt having similar values in the two cases. The foreign exchange savings due to the reduction of petroleum imports is instead used to increase (dramatically) the imports of capital goods. This can be inferred from the sectoral gross output changes displayed in Table 5.9, which shows the growth of the petroleum and transportation sectors, and the shrinkage of the capital goods sector.

Table 5.9
Comparison of sectoral gross output in year 2000 for "base case" and "large oil finding" scenarios
(% deviation with respect to base case levels)

Agric culture	Agropro cessing	Constr uction	Capital goods	Other goods	Petroleum	Util ities	Transp & comm	Serv ices
-1.6	-	+5.8	-47.6	-2.7	+158.0	-2.3	+9.2	-

To see how the model responds to an adverse shift in the terms of trade, a simulation was performed considering that the real petroleum price would be anticipated to grow at an yearly rate of 4%, instead of remaining stable through the whole horizon. Table 5.10 below summarizes the impacts of this scenario on the quantity index (weighted at initial year prices) of the main aggregates .

Higher petroleum prices have a very strong long run effect on consumption, relative to the other sensitivity analyses that were performed. The quantum of petroleum imports is reduced by 13% immediately, a margin which is extended to 17% by the end of the horizon. The <u>value</u> of <u>total</u> imports however, is 37% higher by the year 2000, due to the higher price. The trade balance surplus in 2000 drops from US$ 10 billion to US$ 2.7 billion, in spite of the sizeable increase in exports, which expand in all sectors at the maximum allowed rate[56]. It is this export drive that explains the stability

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[56] The reader will recall that the only sector where export expansion was not already at the maximum in the base case was the capital goods sector.

of gross output, shown in Table 5.10, on the face of smaller domestic demand (both relative to the base case). It is convenient to recall that the only substitution mechanism in this model works through output composition changes, which probably overstates the impact on consumption, and understates the import reduction and the elasticity of domestic demand with respect to prices[57].

Table 5.10
Comparison of real values of economic aggregates for the base case and high petroleum price scenarios
(% deviations from base case)

Gross output		Consumption		Imports		Exports	
1984	2000	1984	2000	1984	2000	1984	2000
-	+1.0	-1.4	-7.9	-6.7	-10.1	-	+20.0

Table 5.11
Comparison of the aggregate shadow prices for the base case and high petroleum price scenarios
(in consumption units)

Scenario	Foreign exch.		Labor		Capital rental	
	1984	1988-2000[1]	1984	1988-2000[1]	1984	1988-2000[1]
High petroleum	1.253	1.156	2.385	1.990	0.173	0.133
Basic case	1.086	1.024	2.334	2.647	0.168	0.128

Note: [1] These are arithmetic averages of the values from 1988 to 2004.

The impact of higher petroleum prices on the shadow prices can be seen

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57 The implied long-run price elasticity of demand is 0.3, about half of the consensus value of 0.6. Future versions of the model incorporating substitution within sectors may be able to generate more precise results.

in Table 5.11, which shows short and long run increases in the optimal foreign exchange rate of 25% and 15%, respectively. Domestic factor prices are also adversely affected, with a reduction of 25% in the long run average real wage and an increase of half a percentage point in the real interest rate.

The marginal utility of consumption falls slower in the high petroleum price scenario, and its ratio with respect to the consumption price index of the base case increases by 1% per year. This can be interpreted as the real inflationary (cost induced) pressure of the 4% yearly real growth of price of imported oil.

Table 5.12 shows the effect on the <u>relative</u> prices of the several goods of the adverse terms of trade situation[58]. In the case of faster growth of petroleum prices, economic efficiency would require a reduction in the relative price of all non-traded goods except transportation, which has higher costs in this case.

Table 5.12
Comparison of changes in average (1984 to 2000) relative prices for the base case and high petroleum price scenarios
(% deviations from base case)

Agric culture	Agropro cessing	Constr uction	Capital goods	Other goods	Petroleum	Util ities	Transp & comm	Serv ices
+12	-4	-1	+1	+3	+80	-6	+8	-8

The level of the foreign debt in the last period is virtually the same in the two cases which indicates that, given the other parameters of the base case, it is not optimal to borrow to defer adjustment to the higher prices.

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58 In each of the scenarios the shadow prices in consumption units were normalized by the respective marginal utility of consumption.

5.5 Sensitivity to the imports coefficients

This section will discuss the impact in the solution of considering values for the non-competitive imports coefficients 20% above and 20% below those in the base case. There is a dual motivation for these scenarios. One is the fact that imports requirements may change in the future, as a result of technological shocks and substitution, and the other is the possibility that the crude procedure used to calculate the coefficients may have led to a biased estimate of their true value.

The analysis of the effect on consumption in Table 5.13 shows that it is approximately symmetrical in the two cases and that, even in this model without technological choice, it is small. It is however of the same order of magnitude as the effects obtained in the previous sections, indicating that it is as important a factor as the others examined before. In the first period the relative change in consumption is approximately equal to the proportional change in income due to the change in imports, ceteris paribus. In the other periods it is double that amount.

After 1988, the effort of the model to compensate for the increased (decreased) import requirements by generating larger (smaller) trade balances and additional (less) borrowing is also illustrated in the table. In the first period there is less flexibility and apparently the model is not able to compensate for the direct impact on the trade balance, which induces it to make a larger adjustment in borrowing. This initial difficulty in handling the larger non-competitive imports coefficient is reflected in the change in the implicit exchange rate, which is larger in the first period.

Table 5.13
Sensitivity of the solution to the non-competitive imports coefficients
(% deviations from base case values)

	NCI Scenario	1984	1988	1992	1996
Consumption	-20%	0.6	1.7	1.2	1.3
	+20%	-0.6	-1.2	-1.3	-1.7
Trade balance	-20%	30.6	-5.6	-16.8	-8.5
	+20%	-29.8	1.6	10.1	12.9
Gross foreign borrowing	-20%	-8.6	-5.1	-2.9	-3.5
	+20%	8.4	5.9	5.9	3.9
Shadow price of foreign exchange	-20%	-4.7	-1.4	-1.6	-1.1
	+20%	5.3	2.7	2.3	0.9

5.6 Alternative spread rate function

It was pointed out in section 2.5 that the choice of functional form for the calculation of the spread rate on each period's foreign borrowing[59] was to some extent based on the notion that in the Eurobond market the flow effect of the volume of borrowing dominates the effect of the stock of debt. The truth of this hypothesis has not been verified, so this section shows the effect on some of the foregoing scenarios of making the alternative assumption.

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59 Recall however that, for simplicity, the formulation in terms of the stock of debt was chosen for the post-terminal period.

Table 5.14
Sensitivity to alternative specification of the spread rate function
(% deviations from values in the runs of the original model)

Scenario	Variable	1984	1988	1992	1996	2000
Base case	Consumption	0.5	1.7	0.0	0.5	0.9
	Foreign debt	0.0	1.2	13.0	13.6	16.8
	Current account	8.5	71.7	17.7	65.7	na
	Gross borrowing	1.6	20.0	13.3	17.8	81.8
High petroleum price	Consumption	0.3	0.0	0.0	0.1	-0.1
	Foreign debt	0.0	1.8	2.2	3.1	5.5
	Current account	17.7	10.5	15.3	22.7	13.3
	Gross borrowing	2.5	2.2	4.1	6.9	7.4
Protectionist export markets	Consumption	0.3	0.1	0.1	0.2	0.0
	Foreign debt	0.0	1.8	2.6	3.7	5.8
	Current account	20.2	10.1	11.2	16.6	13.6
	Gross borrowing	2.6	2.7	4.7	7.0	7.8

Table 5.14 shows the percentage changes that occur in the values of some key variables when the model is solved using equation (16′) instead of (16), to calculate the spread rate. In (16′) the slope c is the same as in the terminal interest cost function (24).

$$SH_t = c\ (D_t / Y_t) \qquad \text{for all } t \tag{16'}$$

The table shows that this alternative formulation does not affect consumption, except for an increase in the base case level in the period 1988 to 1992. Debt and borrowing at each point in time are slightly larger in this case, but do not change enough to affect the qualitative conclusions derived in the previous sections. When the alternative formulation is compared with the original one, the inflow of new loans in the two unfavorable scenarios is on average 15% higher.

Table 5.15 compares the two models in terms of the relative changes (with respect to the corresponding base case) that occur in the two scenarios above. It shows that the effects on the main aggregates are similar in both models. In particular, given the utility discount rate and the foreign interest rate of the base case, it is still not optimal to delay the required internal adjustments to adverse conditions in the foreign markets.

Table 5.15
Comparison of variables in standard and alternative[1] models in unfavorable scenarios
(% deviations from base case)

Scenario	Variable	Model	1984	1988	1992	1996	2000
High petroleum price	Consumption	Alternative	-1.6	-4.6	-3.0	-4.5	-8.8
		Standard	-1.4	-2.9	-3.1	-4.0	-7.9
	Foreign debt	Alternative	0.0	-3.5	-23.5	-28.3	-23.9
		Standard	0.0	-4.1	-15.4	-21.1	-15.7
	Borrowing	Alternative	-4.9	-33.2	-31.7	-17.5	-29.9
		Standard	-5.8	-21.5	-25.6	-9.1	18.7
Protectionist external markets	Consumption	Alternative	-1.3	-2.2	1.7	1.4	3.2
		Standard	-1.1	-0.6	1.6	1.8	4.0
	Foreign debt	Alternative	0.0	-4.5	-20.9	-20.4	-11.2
		Standard	0.0	-5.1	-12.9	-12.8	-2.0
	Borrowing	Alternative	-6.4	-28.6	-18.9	-2.5	-19.0
		Standard	-7.3	-16.6	-12.3	7.3	36.6

Note: [1] The alternative model uses equation (16′) instead of (16).

6. CONCLUSION

This paper has shown how a dynamic general equilibrium model can be formulated to be able to analyze a country's policy towards its foreign debt in the proper intertemporal framework. The utility function is non-linear, and the effects of the truncation of the model's horizon are reduced, but not completely eliminated, by including a term in the objective function which captures the post-terminal value of capital and cost of debt. The model also includes a detailed accounting of the debt dynamics by vintages, and recognizes that the interest rate charged on the foreign debt is dependent on the level of borrowing. The specification allows the model to behave as a monopsonist facing rising marginal borrowing costs in the market for foreign loans. A foreign exchange balancing equation incorporates the interaction between the capital account and the trade balance. The production function however, follows a standard dynamic Leontief specification.

The model was applied to Brazil to generate optimal scenarios for the next 20 years. A significant amount of data manipulation was required to assemble the database, which is valuable in itself, for allowing other economy-wide models for Brazil to be built more easily in the future. The model was implemented using an algebraic modeling system, and solved by a general purpose non-linear optimization package. It was observed that these programs, only recently available, greatly simplified the construction and solution of this economy-wide non-linear dynamic model.

The analysis of the sensitivity of the results to the number of time periods included in the horizon of the model showed that the formulation adopted for the terminal conditions performed satisfactorily, in spite of not being able to eliminate all the end effects.

In addition to the base case, several simulations were performed to evaluate the optimal responses of this long-run model of the Brazilian economy to perfectly anticipated "step" changes in some of the parameters. We have seen that while aggregate consumption may not be very sensitive to changes in the real LIBOR rate, the optimal borrowing policy certainly is, displaying a marked positive response when that rate falls below 5%. Above that level, the model tries to reduce debt as fast as possible. This response of the model shows that the attempt to devise new mechanisms of debt rescheduling which would in effect lead to high levels of net borrowing, may be a myopic policy from the long term perspective of the model, if interest rates are to continue at high levels.

It was seen that the impact of requiring current account balancing is akin to a reduction of the discount rate for utility, and would require a very large devaluation in the short run, relative to the base case.

The response of the model to relaxing the maximum future export levels is not very potent, probably due to the implicit costs, in terms of consumption, of larger trade balances. A protectionist scenario would however require a devaluation of 40% and lead to slightly lower debt until the last two periods, because the model foresees that times will be difficult in the future and does not delay the necessary adjustments.

The effects of petroleum discoveries that would double domestic production in the long run are an increase of 3% in yearly income and a tilting of the time profile of consumption, favoring later periods. Higher prices for petroleum (growth of 4% yearly, instead of being stable) lead to markedly lower consumption (reduction of 8% by 2000) and exploitation of all the export opportunities, but does not affect significantly the size of terminal debt. This seems to indicate that, given the model's assumptions, it is not optimal to borrow to delay adjustment of the economy to the higher prices.

A reduction of 20% in the non-competitive imports coefficients allows an average increase of 1.4% in the level of long run consumption, relative to the base case, while an increase of 20% has a symmetrical effect.

These sensitivity analyses are only a sample of the issues that can be addressed with a model such as this, but they will hopefully have made the point that in can provide interesting quantitative insights as to the relative importance of the several factors affecting a developing country's debt problems. Applications of the model are not limited to the analysis of the debt issue, since it can also be used as is, or with minor modifications, to tackle trade and investment policy questions.

Several possible extensions were suggested in the text, exploring the possibility of using a non-linear formulation in other parts of the model. For example, the production function could be reformulated to allow the inclusion of some measure of technological substitution and/or complementarity between capital and energy in some of the sectors, reducing the impact that adverse developments in the petroleum sector would have in the solution. Another possibility is to make the export revenue functions non-linear, to account for some degree of imperfect competition in export markets. None of these could be included in this version of the model due to time limits for this phase of the research project.

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APPENDIX A

DATABASE FOR A GENERAL EQUILIBRIUM PLANNING MODEL FOR BRAZIL

This appendix describes in detail the construction of the database which was utilized to implement the model described in the text. Most of the required data is summarized in the intersectoral transactions and final demand table for 1983 (Table A.1), which was constructed by updating, in the manner described in the following sections, a set of tables for 1975 obtained from the Brazilian statistics institute.

A.1 General methodology

The economy is divided into nine producing sectors by appropriate aggregation of the intersectoral transactions matrix. They are: (1) agriculture, (2) agro-processing, (3) construction, (4) manufacturing of capital goods, (5) other manufacturing, (6) petroleum, (7) utilities (electricity, water, gas), (8) transport and communication, (9) services. This classification is similar to the one used in the brazilian national accounts, but has the manufacturing sector broken up into its main components, and aggregates the several services sectors in a single class. The petroleum sector was separated because of its interactions with the foreign sector.

At the outset it had to be decided whether to try to adjust the input-output tables produced by Instituto Brasileiro de Geografia e Estatistica (IBGE) to reflect the specific values for the macroeconomic aggregates produced by Fundacao Getulio Vargas (FGV) for the 1983 National Accounts. Since the comparison of the absolute values, and of the shares, of the components of GNP in the two sources for 1975 showed several substantial discrepancies - and the reason for these was not readily apparent - it was decided not to attempt to make them compatible.

Instead, Table A.1 was constructed by updating the set of preliminary tables for 1975 obtained from IBGE[1], in a way that maintains its internal consistency as much as possible. As a consequence of this choice however, the updated table for 1983 shows a value for GNP which is 10% smaller than the FGV value. The lack of coincidence of the specific numerical values in the model with the values in the accounts is not a major problem since our concern is

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[1] The aggregated versions of these matrices is presented as Tables A.18 through A.20 at the end of this Appendix.

with the growth rates of the several macroeconomic aggregates in the future, and not with the specific levels.

To maintain the consistency of the 1975 input-output matrix, and still reflect the economic events between 1975 and 1983, the observed real rates of growth of the sectors, and of the price indices of the commodities they produce, were used to update the estimates of the values of flows in the intersectoral part. The rows of the 1975 matrix were scaled up according to the commodity price indexes from Conjuntura Economica, and the sectoral activity columns were multiplied by the growth factors associated with the respective sector obtained from the National Accounts. Since there is not an exact correspondence between the sectoral disaggregation in the model and either of these two sources, the indexes shown in Table A.2 had to be inferred from the available data by using the classifications that seemed to be closest to ours. The final demand columns were updated with a specific methodology in each case, as discussed in the following sections.

The matrix that resulted from the adjustments outlined in the paragraphs above was then balanced by distributing in succession (in the intersectoral part of the matrix), the excess demands to the rows, and the excess costs to the columns. The procedure was implemented in a spreadsheet program and repeated until convergence was attained to the value of gross output obtained from the scaling of the 1975 value according to the indexes in Table A.2.

TABLE A.1

SECTORAL TRANSACTIONS TABLE FOR BRAZIL IN 1983
(in CR$ billions)

SECTORS / PRODUCTS	Agriculture	Agro-process.	Construction	Manuf. cap.gds	Manuf. other	Petroleum	Utilities	Transp. & comm.	Other services	INTERMED DELIVERY *	*Private *consump.	Governmt consump.	Investment	Stock change	Exports	Imports	FINAL DEMAND *	GROSS DEMAND
Agriculture	2253.2	7196.1	15.4	412.6	2121.3	4.9	2.1	0.9	152.1	12158.6 *	3797.1	32.2	329.1	1211.9	1540.9	0.0	6911.3 *	19069.8
Agro-processing	602.8	3549.6	0.8	64.2	365.8	1.8	0.1	22.5	944.8	5552.3 *	12080.7	71.1	0.0	442.6	2973.5	0.0	15567.9 *	21120.2
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0 *	0.0	0.0	16629.9	0.0	0.0	0.0	16629.9 *	16629.9
Manuf. cap. goods	13.2	131.7	645.1	2610.6	2305.8	100.5	114.1	501.5	421.6	6844.1 *	3220.8	103.0	4737.0	132.2	1961.8	0.0	10154.8 *	16998.9
Manuf. other goods	1249.6	1335.3	5358.8	4275.0	12724.9	420.8	64.5	203.0	710.1	26341.8 *	11197.3	740.3	841.2	814.9	5481.3	0.0	19075.0 *	45416.8
Petroleum	507.6	167.6	1077.2	735.5	3184.0	7575.3	221.1	2411.0	1462.5	17341.8 *	3195.2	299.7	0.0	28.0	670.6	4534.7	-341.2 *	17000.6
Utilities	26.1	228.6	39.4	310.9	1000.5	68.1	645.1	41.4	704.0	3064.1 *	1677.6	81.0	0.0	0.0	0.0	0.0	1758.6 *	4822.6
Transport. & commun.	240.5	492.3	202.2	396.7	1127.8	1030.0	10.7	197.6	423.8	4121.7 *	4219.6	325.8	72.0	5.1	0.0	0.0	4622.4 *	8744.1
Other services	921.5	1181.8	2225.0	1539.9	3712.4	210.3	34.7	634.7	1158.8	11619.0 *	32598.6	2863.0	2081.8	116.7	0.0	0.0	37660.1 *	49279.1
Non-compet. imports	58.3	276.5	284.3	642.7	1591.0	0.0	16.5	420.5	242.9	3532.7 *	338.5	24.6	1267.3	59.3	0.0	5222.4	-3532.7 *	.0
TOTAL INTERMEDIATE	5872.8	14559.5	9848.3	10988.1	28133.5	9411.6	1108.8	4433.1	6220.4	90576.0 *	72325.4	4540.7	25958.3	2810.7	12628.1	9757.1	108506.0 *	199082.1
Indirect Taxes	-418.0	-864.5	1757.3	7.5	-379.6	256.7	111.2	487.4	1901.2	2859.2 *								
Wages	1960.7	1018.4	2137.6	1434.6	3533.7	579.7	900.0	1164.7	7703.9	20433.3 *								
Expenses w/labor	388.9	380.7	426.9	855.3	3362.9	215.4	258.8	59.4	2083.7	8031.9 *								
Auton. employment	595.3	45.9	534.2	1.8	24.9	.0	.0	995.4	1773.2	3970.8 *								
Return to capital	10670.3	5980.3	1925.5	3711.6	10741.5	6537.2	2443.8	1604.1	29596.6	73210.8 *								
VALUE ADDED	13197.1	6560.7	6781.6	6010.8	17283.4	7589.0	3713.8	4311.1	43058.6	108506.0 *								
GROSS PRODUCTION	19069.8	21120.2	16629.9	16998.9	45416.8	17000.6	4822.6	8744.1	49279.1	199082.1 *								

Table A.2
Price and activity level adjustment factors 1975-1983

Products and sectors	Price[1]	Activity
Agriculture	0.0983	1.325
Agro-processing	0.0989	1.325
Construction	0.0864	1.151
Manuf. capital goods	0.0774	1.254
Manuf. other goods	0.0844	1.254
Petroleum	0.1896	1.553
Utilities	0.0860	2.117
Transport & communication	0.0900	1.834
Other services	0.0884	1.248
Non-competitive imports	0.1375	0.000
Gross National Product	0.0897	1.337

Source: National Accounts and Conjuntura Economica.
Note: 1. The unit for the 1975 Matrix is Cr$ millions, while for 1983 it is Cr$ billions. Since prices increased 100-fold in the period, the adjustment factor is approximately 10%.

2. Consumption

To estimate the parameters of the utility function, note first that the extended linear expenditure system (ELES) can be derived from the following maximization problem, which has the same structure of the model we are proposing (see Lluch, Powell and Williams [1977]).[2]

$$(1) \qquad \max \quad e^{-\delta t} [\Sigma_i \beta_i \ln (c_i(t) - \gamma_i)]$$

subject to an intertemporal budget constraint, and to the condition that

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2 In this section the notation will be the same as in Lluch, Powell and Williams [1977].

$c_i(t) > \gamma_i$. The minimum consumption levels are assumed constant through time, as are the the marginal budget shares of each good (β_i). The parameters β_i are all positive and add to unity.

The solution of this problem leads to a system of demand equations of the following form, where the time subscripts are dropped for simplicity:

$$(2) \qquad v_i = p_i \, c_i = p_i \, \gamma_i + \beta_i^* \, (y - \Sigma_i \, p_i \, \gamma_i)$$

where v_i are the shares of expenditure in the good i, y is the income and $\beta_i{}^* = \mu\beta_i$. The parameter μ is defined by the equation $\mu = \delta/\rho$, where ρ is the instantaneous return on non-human wealth and δ is as before.

Since $\Sigma_i \, \beta_i = 1$, it follows that $\mu = \Sigma_i \, \beta_i{}^*$, and the marginal propensity to save is just $(1 - \mu)$. Noting that the derivative of v_i with respect to y is equal to $\beta_i{}^*$, these parameters can be calculated from information about the income elasticities of expenditure in each good (ϵ_i) as:

$$(3) \qquad \beta_i^* = (v_i \, / \, y) \, \epsilon_i$$

It is easy to see that summing all demand equations we can calculate the minimum total expenditure:

$$(4) \qquad \Sigma_i \, p_i \gamma_i = (\Sigma_i \, v_i - \mu y) \, / \, (1 - \mu)$$

With this constant we can substitute back in the demand equation for each good, and use the calculated marginal propensity to consume to obtain the minimum expenditure:

$$(5) \qquad p_i \, \gamma_i = v_i - \beta_i^* \, (y - \Sigma_i \, p_i \, \gamma_i)$$

To estimate the value of the parameters, the equation was fitted to the 1975 observed consumption vector, which corresponds to the following expenditure equation, where the dating is denoted by the superscript 0.

$$(6) \qquad p_i^o c_i^o = p_i^o \gamma_i + \beta_i^* (y^o - \Sigma_i p_i^o \gamma_i)$$

If estimates for β_i exist, the value $p_i \gamma_i$ can the be estimated as outlined above, since y^o is known. This calculation is shown in the left hand side of Table A.4. The minimum consumption of each good (γ_i) can be obtained by dividing the minimum expenditure by p_i^o, which are the 1975 prices relative to 1983 (which are unity), and are displayed in the second column of the right hand side of the Table A.4.

A properly estimated ELES for Brazil was not available, so the values of the marginal expenditure shares had to be adapted from related demand studies. The income elasticities which used here (Table A.3) were estimated by Williamson and McCarthy [1981] by fitting system of log linear demand equations to the data from a survey (ENDEF) conducted in 1975 by IBGE. There are other problems, in addition to the fact that it was estimated using a different econometric specification, with using this data in the model. One is that there are significant differences between the urban and rural demand patterns, which are not contemplated in the equations of the model, and had to be ignored by adopting the average value for the country. Other is that the product classification does not conform very well to the one adopted for the transactions matrix, and was circumvented by adopting the same elasticity value for more than one sector, when necessary. Finally, even taking into account the mismatch above, for some categories the expenditure shares in the survey are significantly different from those in the matrix.

In spite of the difficulties listed above, the true value of the elasticities is not expected to be much different from the ones which were adopted, since these tend not to be very sensitive with respect to the estimation procedure, and the values used were in the usual range. Is is hoped that in the future an ELES can be estimated for Brazil using the appropriate econometric techniques (see Powell [1974]), and the desired aggregation, to verify whether this is really true.

Table A.3
Expenditure shares in Brazil in 1975

Category	URBAN		RURAL		AVERAGE	
	Share	Elasticity	Share	Elasticity	Share	Elasticity
Food	34.24	0.49	57.21	0.53	43.43	0.5048
Manufactures	18.74	1.12	17.57	1.30	18.27	1.1920
Services	27.24	0.91	15.60	0.87	22.58	0.8932
Transportation	3.19	1.15	1.46	1.70	2.50	1.3700
Energy	3.15	1.22	1.68	1.41	2.56	1.2960
Taxes	4.68	1.27	1.58	1.80	3.44	1.4820
Savings & Investment	8.78	2.08	4.92	2.65	7.24	2.3080

Source: Willianson and McCarthy [1981]

The social rate of time preference (δ) is also implied by the parameters of ELES, once the real interest rate (ρ) that gave rise to the consumption vector is known. If the real average rate of return on non-human wealth in Brasil in 1975 can be approximated by the real interest rate on default-free federal indexed bonds (6%), $\delta = \rho\mu$ = 5%. The value actually used in the base case of the model was 4% because it produced a smoother time path for consumption.

The Frisch parameter, which measures the substitutability between consumption in two consecutive time periods, can be calculated from the above estimates by using the formula $w^* = \mu w - (1-\mu)$. The parameter w is the expenditure elasticity of the marginal utility of expenditure, and is equal to the inverse of the supernumerary ratio, which is defined as the negative of the ratio of total expenditure to supranumerary expenditure:

$$(7) \qquad w = 1/\varphi = [\Sigma_i \; p_i \; c_i] \; / \; -[\Sigma_i \; (p_i \; c_i \; - \; p_i \; \gamma_i)]$$

The calculation yields a value of .54 that is close to the usual values for developing countries (0.2 to 0.5, according to Goreux [1977]).

The consumption vector for 1983 was calculated as shown in the right hand side of Table A.4, applying the formula for consumption expenditure in ELES (above), using the same β as in 1975, and the minimum consumption levels implied by the 1975 consumption vector.

Adjusted nominal income in 1983 was calculated by applying to the 1975 value the growth rate factor of nominal income obtained from the National Accounts. The growth of per-capita consumption between 1975 and 1983 was assumed to be equal to the growth of per-capita income (9.5%), and population in 1983 was taken to be 128.17 million.

Table A.4

Calculation of the parameters of the utility function from consumption data of the 75 matrix and ENDEF elasticities, and forecast of 1983 consumption vector

SECTOR	ESTIMATION OF THE PARAMETERS FOR 1975 (Cr$ of 1975)								FORECAST OF 1983 CONSUMPTION (Cr$ of 1983)				
	Income Elast.	AGGREGATE EXPENDIT (Cr$ mil)	Expend. Share	Per cap Expend. (CR$)	Marginal consump. shares	Utility weights	Minimum per-cap consump (CR$)	Super numeraire ratio	Price adjust factor 83/75	PER - CAPITA CONSUMPTION Minimum (Cr$ th)	Discret. (Cr$ th)	Total (Cr$ th)	AGGREGATE EXPENDIT (Cr$ bil)
Agriculture	0.50	30898	0.0477	293.43	0.0241	0.0287	213.39	0.27	0.0983	20.980	8.631	29.611	3795.3
Agro-processing	0.50	97894	0.1511	929.66	0.0763	0.0910	676.07	0.27	0.0989	66.865	27.345	94.210	12074.9
Construction	0.00	0	0.0000	0.00	0.0000	0.0000	0.00	0.00	0.0864	0.000	0.000	0.000	0.0
Manuf. cap. goods	1.19	27224	0.0420	258.54	0.0501	0.0598	92.00	0.64	0.0774	7.124	17.957	25.081	3214.6
Manuf. other goods	1.19	89497	0.1381	849.93	0.1646	0.1965	302.46	0.64	0.0844	25.541	59.033	84.574	10839.8
Petroleum	1.30	19865	0.0307	188.65	0.0397	0.0474	56.53	0.70	0.1896	10.719	14.246	24.965	3199.7
Utilities	1.30	13584	0.0210	129.00	0.0272	0.0324	38.66	0.70	0.0860	3.325	9.742	13.066	1674.7
Transport & comm.	1.37	33538	0.0518	318.50	0.0709	0.0846	82.71	0.74	0.0900	7.444	25.425	32.869	4212.8
Services	0.89	273590	0.4222	2598.20	0.3772	0.4501	1344.13	0.48	0.0884	118.821	135.225	254.046	32561.1
Non-compet. import	1.00	5089	0.0079	48.33	0.0079	0.0094	22.21	0.54	0.1375	3.054	2.816	5.870	752.4
TOTAL		591180	0.9124	5614.24	0.8379	1.0000	2828.17	0.50	0.0918	263.873	300.420	564.293	72325.4
Personal saving	2.31	56759	0.0876	539.03	0.1621							58.123	7449.6
Personal income		647939		6153.27								622.415	79775.0
Supernumerary income				3325.10								358.542	
Supernumerary ratio				0.58								0.58	
Expenditure elasticity of marginal utility					-1.85								
Frisch parameter					0.54								

Note: The calculations above use the following parameters:

Population in 1983 = 128.17 millions
Population in 1975 = 105.30 millions
Per-capita consumption growth 83/75 = 1.10187

3. Exports

Actual exports in 1983 (Table A.5) were used to update the exports column of the 1975 matrix. When the disaggregation of the sectors in the model was greater than the one in the table, the proportions in the 1975 matrix were used as a guide in the sectoral allocation. Since the services exports consisted mainly of commercialization margins, they were distributed to the remaining sectors on the basis of their respective goods exports. The two years are compared in Table A.6, which shows a decrease in the share of agricultural goods exports, relative to manufactured goods.

Table A.5
Exports in 1983
(US$ millions)

ITEM	Unit	Quantity	Average value	Revenue Sub-total	Revenue Total
TOTAL					21,899.0
Agricultural					7,829.0
Coffee	10^6 bags	17.8	130.6	2,325.0	
Soybeans	10^6 tons	10.9	235.2	2,564.0	
Cocoa	10^3 tons	291.0	1,895.8	552.0	
Sugar	10^6 tons	2.5	206.0	515.0	
Orange juice	10^3 tons	554.0	1,099.3	609.0	
Meat	10^3 tons	573.0	1,404.9	805.0	
Tobacco	10^3 tons	155.0	2,954.8	458.0	
Iron and other ores	10^6 tons	79.3	21.2		1,682.0
Other primary goods					1,093.0
Manufactured					11,296.0
Transport equipment and components				1,920.0	
Machines, mech. instr., and electr. equip.				658.0	
Oil derivatives				1163.0	
Other manufactured goods				7555.0	

Source: Banco Central do Brasil [1984].

Table A.6
Allocation of exports to sectors in the model:
Comparison of 1975 and 1983

Products/Sectors	1975 CR$ mil	1975 US$ mil	1975 Share	1983 Cr$ bil	1983 US$ mil	1983 Share
Agriculture	10404.0	1280.1	14.84%	1541.9	2672.3	12.20%
Agro-processing	20076.0	2470.2	28.64%	2975.4	5156.7	23.55%
Manuf. cap. goods	9914.0	1219.8	14.14%	1963.1	3402.2	15.54%
Manuf. other goods	27698.0	3408.2	39.51%	5484.8	9505.8	43.41%
Petroleum	2006.0	246.8	2.86%	671.1	1163.0	5.31%
TOTAL	70097.0	8625.2	100.00%	21900.0	12636.3	100.00%

4. Imports

For the imports a more detailed analysis is necessary because of the need to calculate the non-competitive import coefficients. As Table A.7 shows, the main import items in 1983 were petroleum, raw materials, capital goods and agricultural products. It can be recalled that the only competitive import in this version of the model is petroleum, while the others are all assumed to be non-competitive. The imports of raw materials and capital goods were assumed to be non-competitive because it is believed that they were compressed as much as possible during the recent international financial crisis. The imports of wheat, which are expected to persist due to a range of political, technical and economic factors, are mostly responsible for the imports of the two agricultural sectors.

Table A.7
Goods Imports in 1983 and their distribution in the model
(US$ millions)

ITEM (in imports list)	VALUE Sub-total	VALUE Total	PRODUCT (in model)
TOTAL		15,429.0	
Oil and derivatives		8,179.0	Petroleum
Wheat		727.0	Distributed to sectors 1 & 2
Capital goods		2,505.0	Capital goods
Raw materials		3,013.0	Manufactured goods
Steel, other ores	335.0		
Chemical products	1,598.0		
Coal	411.0		
Other raw materials	669.0		
Other		1,005.0	Distributed to sectors 1 to 4

Source: Banco Central do Brasil [1984].

Table A.7 also shows the allocation of the imports to several product categories of the model. As can be seen by the breakdown of the raw materials, most of the imports in this category are of goods which can be classified as manufactured in the sectoral disaggregation which was adopted. In allocating the wheat imports, they were divided between agricultural and agro-processed goods proportionately to the total imports of these goods in 1975. The imports classified as "Other" were distributed between agriculture, agro-processing and manufacturing, proportionately to the allocated imports of these goods in 1983.

Table A.8 shows the services balance for 1983, and the allocation of the flows to model categories. Imports of transportation & communication, and of other services, were considered as non-competitive because it is believed there are some limitations to import substitution - like international freight conferences, reinsurance requirements, tourism flows and technical assistance purchases - which have not been taken into account explicitly, but which appear nevertheless to be important. Remittances of profits and dividends, and the sundry flows, were included in the foreign balance equation as transfers, and are considered exogenous. Interest payments are treated separately in the foreign borrowing equations[3].

Table A.8
Net services flows for 1983 and their classification in the model
(in US$ millions)

ITEM	VALUE Sub-total	Total	CLASSIFICATION (in the model)
TOTAL		-12,748.4	
Interest		-9,554.9	Interest
Others		-3,193.5	
International travel	-392.0		Private consumption of trans.
Transport	-941.5		Transport demand
Insurance	-42.4		Other services
Profits and dividends	-757.8		Transfers abroad
Government	-111.1		Other services
Sundry	-948.7		Transfers abroad

Source: Banco Central do Brasil [1984].

Table A.9 compares forecast imports, obtained by scaling the 1975 imports coefficients matrix according to the sectoral activity and final demand growth rates between 1975 and 1983. The calculation was done in the Cr$, using the price indices of Table A.2, and converted to US$ at the adopted exchange rate. It can be seen that this projection based on simple scaling overstates the imports of petroleum and manufactured goods by US$ 2 billions and US$ 4

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3 In the model, total transfers abroad in 1983 amount to US$ 1687.5 million (equivalent to CR$ 973.7 billion), discriminated as follows: Sundry services (US$ 948.7 million) + Profits and dividends (US$ 757.8 million) + Transfers proper (US$ 107 million in the balance of payments) - Foreign direct investment (US$ 657 million of capital inflow) + Errors and omissions (US$ 531 million).

billions, respectively. For the former, the discrepancy is due to the net effect of the increase of domestic production and dollar price increases. For the latter, the major relative error is in capital goods imports, and is probably due to the maturation in the period of several import substitution projects.

Table A.9
Comparison of actual and forecast imports in 1983
(US$ millions)

Products	ACTUAL[1] Goods Allocated	Other	Services	TOTAL	FORECAST[2]	DIFFER-ENCE
Agriculture	472.5	76.0	0.0	548.5	920.2	371.7
Agro-processing	254.5	40.9	0.0	295.4	486.7	191.3
Construction	0.0	0.0	0.0	0.0	0.0	0.0
Manuf. cap. goods	2505.0	402.8	0.0	2907.8	5373.3	2465.5
Manuf. other goods	3018.0	485.3	0.0	3503.3	5067.5	1564.2
Petroleum	7016.1	0.0	0.0	7016.1	9047.2	2031.1
Utilities	0.0	0.0	0.0	0.0	0.0	0.0
Transport. & commun.	0.0	0.0	1333.5	1333.5	1562.2	228.7
Other services	0.0	0.0	153.5	153.5	193.9	40.4
TOTAL	13266.1	1005.0	1487.0	15758.1		

Notes: 1. Distributed to sectors according to discussion in text.
2. Forecast by straightforward scaling of 1975 imports matrix.

To update the non-competitive imports coefficients matrix to 1983, the relative forecast error of each goods category was used as the parameter in making a proportional adjustment of the coefficients in each row of the matrix of intermediate and final demands for imports. Also, some specific information which was available for some categories of imports for final demand was also incorporated. The result of this process is shown in Table A.10, and generates the corresponding row of Table A.1, from where the NCI coefficients required for the model can be calculated.

TABLE A.10

ADJUSTED SECTORAL IMPORTS TABLE FOR BRAZIL IN 1983
(in CR$ billions of 1983)

SECTORS / PRODUCTS	Agricul-ture	Agro-process.	Constr-uction	Manuf. cap.gds	Manuf. other	Petr-oleum	Utili-ties	Transp. & comm.	Other services	INTERMED DELIVERY *	*Private *consump.	Governmt consump.	Invest-ment	FINAL DEMAND *	TOTAL IMPORTS
Agriculture	7.3	223.1	0.5	2.7	15.6	.0	.0	0.9	2.0	252.1 *	64.2	0.2	0.0	64.4 *	316.5
Agro-processing	2.1	52.8	.0	1.8	9.6	.0	.0	9.2	9.5	85.1 *	85.4	0.0	0.0	85.4 *	170.5
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0 *	0.0	0.0	0.0	0.0 *	0.0
Manuf. cap. goods	.0	.0	21.9	179.8	137.0	.0	20.0	53.1	33.6	445.5 *	52.8	6.8	1172.8	1232.3 *	1677.8
Manuf. other goods	47.0	19.1	213.6	352.3	1113.9	12.4	4.3	11.5	39.8	1814.2 *	91.9	15.9	99.4	207.2 *	2021.4
Petroleum	.0	0.1	2.3	19.3	128.5	3836.7	.0	41.4	19.9	4048.3 *	0.0	0.0	0.0	0.0 *	4048.3
Utilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0 *	0.0	0.0	0.0	0.0 *	0.0
Transport. & commun.	4.2	11.2	16.7	44.5	120.9	10.1	0.8	331.8	151.6	691.7 *	16.6	1.2	59.9	77.7 *	769.4
Other services	.0	0.8	2.5	6.7	16.0	7.4	0.2	12.7	18.5	64.8 *	8.4	0.5	14.8	23.7 *	88.6
TOTAL	60.7	307.3	257.5	607.1	1541.6	3866.6	25.3	460.6	275.0	7401.7 *	319.2	24.6	1346.9	1690.8 *	9092.4

5. <u>Intersectoral input demand</u>

The coefficients of the input-output matrix for the technology used in the first period (Table A.11) were obtained from Table A.1, dividing each column by the gross output of the sector.

Alternative technological vectors have not been included in this version of the model for lack of reliable information readily available. However, for the agricultural, electricity and petroleum sectors it may be possible to obtain them in the future, in the context of a broader research effort, by using sectoral planning models that have already been developed in Brazil. For other sectors (manufacturing and transport) it is anticipated that econometric models incorporating substitutability between factors can be used to help generate consistent technological alternatives.

TABLE A.10

Input-output coefficients matrix for 1983

SECTORS / PRODUCTS	Agriculture	Agro-process.	Construction	Manuf. cap.gds	Manuf. other	Petroleum	Utilities	Transp. & comm.	Other services	INTERMED DELIVERY
Agriculture	0.118	0.341	0.001	0.024	0.047	.000	.000	.000	0.003	0.061
Agro-processing	0.032	0.168	.000	0.004	0.008	.000	.000	0.003	0.019	0.028
Construction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Manuf. cap. goods	0.001	0.006	0.039	0.154	0.051	0.006	0.024	0.057	0.009	0.034
Manuf. other goods	0.066	0.063	0.322	0.251	0.280	0.025	0.013	0.023	0.014	0.132
Petroleum	0.027	0.008	0.065	0.043	0.070	0.446	0.046	0.276	0.030	0.087
Utilities	0.001	0.011	0.002	0.018	0.022	0.004	0.134	0.005	0.014	0.015
Transport. & commun.	0.013	0.023	0.012	0.023	0.025	0.061	0.002	0.023	0.009	0.021
Other services	0.048	0.056	0.134	0.091	0.082	0.012	0.007	0.073	0.024	0.058
Non-comp. Imports	0.003	0.013	0.017	0.038	0.035	0.000	0.003	0.048	0.005	0.018
TOTAL INTERMEDIATE	0.300	0.609	0.592	0.646	0.619	0.554	0.230	0.507	0.126	0.455

6. <u>Labor requirements</u>

The division of value added between returns to labor and capital in the brazilian intersectoral transactions matrix assigns a suspiciously low participation to labor in some sectors[5] (see Table A.1). This is made clear by the calculation of the implied employment levels in each sector, obtained by dividing the wage payments by the sectoral average wage. An estimate of the latter was obtained by multiplying the minimum wage for 1983 by the aggregated average sectoral wage in terms of the number of minimum wages for 1975, found in Macedo [1982][6].

Table A.12
Employment/output coefficients for 1983 implied by payments to labor
(values in Cr$ billion of 1983)

SECTORS	UNITS	Agricul-ture	Agro-process.	Constr-uction	Manuf. cap.gds	Manuf. other	Petr-oleum	Utili-ties	Transp. & comm.	Other services	TOTAL
Wages	CR$ bill	1960.7	1018.4	2137.6	1434.6	3533.7	579.7	900.0	1164.7	7703.9	20433.3
Self-employment	CR$ bill	595.3	45.9	534.2	1.8	24.9	0.0	0.0	995.4	1773.2	3970.7
Formal labor payment	CR$ bill	2556.0	1064.3	2671.8	1436.4	3558.6	579.7	900.0	2160.1	9477.1	24404.0
Gross output	CR$ bill	19069.8	21120.2	16629.9	16998.9	45416.8	17000.6	4822.6	8744.1	49279.1	199082.0
Employmnt / Output	-	0.1340	0.0504	0.1607	0.0845	0.0784	0.0341	0.1866	0.2470	0.1923	0.1226
Average # min wage	-	1.02	4.69	1.73	4.02	3.57	5.82	3.20	2.20	2.50	2.252
Formal emplymt	millions	7.4	0.7	4.5	1.0	2.9	0.3	0.8	2.8	10.9	31.3
Labor unit	#/Cr$ bill	2889	616	1670	719	809	496	903	1313	1155	1282

Note: Yearly minimum wage in CR$ thous = 346.2

This procedure can only account for 31.3 million employed in 1983 of a total labor force of 47.8 million in 1984[7]. The discrepancy is 6.9 million

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[5] For agriculture the returns to capital include rents, which should be in fact classified separately.
[6] The original data for that study was a survey conducted in 1975 by IBGE to assess the compliance of the firms with the "Law of 2/3".
[7] Applying an yearly growth rate of 3% to an economically active population (PEA) of 43.8 million in 1980.

rural and 9.6 urban workers, which compares to 7.4 and 23.9 million respectively in the formal market, and may be associated with the fact that IBGE cannot survey precisely the informal employment contracts that exist in some sectors in the brazilian economy. These are unlikely to be significant in general manufacturing, petroleum and utilities sectors, which have more formalized labor relations. In construction, agro-processing and transports & communication, the number of informal links is likely to be larger, but they are not expected to be a majority. Most of the "informally" employed are in the agricultural and services sectors, which helps to explain the disproportionately high share of capital in these sectors. This fact will be used later in the calculation of the sectoral capital/output coefficients.

For the purposes of the model however, we need only keep track of the scarce labor, which in all likelihood has already entered the formal market. The sectoral labor/output coefficients for this factor are presented in Table A.12, and its availability can be modelled by assuming that its relative share in the total labor force will not increase in the future. The latter is assumed to grow at 3% per annum, in line with recent demographic studies in Brazil, and labor productivity is assumed to increase at an annual rate of 2% in all sectors, which implies a supply of effective labor units growing at 5% yearly.

7. Capital formation

The capital/output ratios were estimated indirectly from the returns to capital in the 1983 matrix, making use of the capital cost rate for each sector, which is the sum of the depreciation rate and the gross profit rate. The latter was estimated by dividing the net profits rate by one minus the corporate tax rate[7], as shown in Table A.13.

The depreciation rate and net profit rates were adapted from Taylor and Lysy [1980] to yield consistent capital/output ratios across sectors. In the agriculture and services sectors, the capital shares were reduced[8], before being divided by the capital charge ratio, to take account of the measurement problem of the labor share. In the petroleum sector the return to capital was also reduced to take into account the rent in domestic petroleum extraction, which was arbitrated to be Us$ 5/bbl.[9]

The matrix with the relative shares of the several commodities in the sectoral composition of investment is shown in Table A.14. It was constructed in a more or less ad-hoc manner[10], maintaining consistency with the investment column in Table A.1, and the capital/output ratios and depreciation rates used above.

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7 The tax rate in all the sectors was assumed to be 20%, and in agriculture it was assumed to be null.

8 The adjustment was somewhat arbitrary and consisted of subtracting from the capital share an amount equal to the wage payments. This is equivalent to assuming that the payments reported in the 1975 matrix correspond to only half of actual payments.

9 Domestic production in 1983 was 340 thousand bbl/day, implying a total rent for the year of Cr$ 716.1 billion.

10 In determining the relative composition of the vectors, the capital shares matrix used by Taylor and Lysy [1980], and the matrix constructed by Eckaus [1983] for Mexico, were used. The former could not be used directly because it was not consistent with our aggregate investment vector.

Table A.13
Calculation of the capital/output ratios for 1983
(values in Cr$ of 1983)

PRODUCTS / ITEM	Agriculture	Agro-process.	Construction	Manuf. cap.gds	Manuf. other	Petroleum	Utilities	Transp. & comm.	Other services	TOTAL
Depreciation rate(1)	0.016	0.037	0.042	0.040	0.036	0.036	0.034	0.045	0.039	
Net profit rate (2)	0.080	0.140	0.160	0.160	0.140	0.120	0.100	0.140	0.160	
Capital cost (3)	0.096	0.186	0.213	0.210	0.185	0.165	0.143	0.196	0.209	
Capital returns (4)	10670.3	5980.3	1925.5	3711.6	10741.5	6537.2	2443.8	1604.1	29596.6	73210.9
Non-capital ret. (4)	3201.1					716.1				3917.1
Other labor ret. (5)	2691.0								7703.9	10394.9
Capital ret. (adj.)	4778.2	5980.3	1925.5	3711.6	10741.5	5821.1	2443.8	1604.1	21892.7	58898.9
Implied cap. stock	49773.0	32109.0	9061.2	17674.3	58062.2	35279.7	17149.5	8173.8	104875.2	332157.7
Gross production	19069.8	21120.2	16629.9	16998.9	45416.8	17000.6	4822.6	8744.1	49279.1	199082.0
Capital/output ratio	2.610	1.520	0.545	1.040	1.278	2.075	3.556	0.935	2.128	1.668

Notes: (1) from Taylor and Lysy page 192
(2) Adapted from several sources ("best guess")
(3) Assumes corporate tax rate of 20% for industry and services.
(4) From the adjusted IO matrix for 1983
For petroleum sector assumes rent of US$ 10 on extracted domestic oil.
(5) Assumes wages row in IO matrix only account for half of actual payments to labor

Table A.14
Capital shares. by sector

SECTORS / PRODUCTS	Agriculture	Agro-process.	Construction	Manuf. cap.gds	Manuf. other	Petroleum	Utilities	Transp. & comm.	Other services
Agriculture	0.108								
Construction	0.715	0.647	0.171	0.498	0.568	0.485	0.570	0.725	0.774
Manuf. cap. goods	0.075	0.193	0.497	0.246	0.224	0.280	0.288	0.117	0.117
Manuf. other goods	0.027	0.034	0.088	0.034	0.036	0.042	0.017	0.031	0.026
Transport. & commun.	0.002	0.003	0.008	0.003	0.003	0.004	0.001	0.003	0.002
Other services	0.066	0.085	0.109	0.085	0.089	0.105	0.078	0.077	0.070
Non-comp. Imports	0.007	0.038	0.128	0.134	0.080	0.084	0.046	0.043	0.011
TOTAL	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

8. Foreign Debt

The amortization schedule of foreign debt at the end of 1983 is in Table A.15, and shows that 65% of the current debt is to be amortized in the first period of the model, 30% in the second and the remaining essentially in the third. This is a somewhat skewed profile, specially in light of the fact that the average maturity of the brazilian debt before the current financial crisis was believed to be around 8 years.

Table A.15
Amortization schedule for registered debt outstanding in december of 1983
(US$ billions)

Year	Amortization	Period	Aggregate amortization	Allocation of Indeterm.	Allocation of Differ.	TOTAL FLOW
1984	9.930					
1985	9.719					
1986	12.774					
1987	12.198	1	44.621	1.285	6.680	52.486
1988	9.733					
1989	6.496					
1990	3.481					
1991	1.215	2	20.925	0.603	3.130	24.658
1992	0.771					
1993	0.486					
1994	0.317					
1995	0.223	3	1.797	0.052	0.256	2.105
1996	0.160					
1997	0.128					
1998	0.119					
1999	0.086	4	0.493	0.010	0.074	0.577
2000 +	0.337	5	0.337	0.005	0.050	0.392
Indeterm.	1.955					
TOTAL	70.126		68.171	1.955	10.193	81.319

Source: For first column, Banco Central do Brasil [1984].

The repayment schedule is a scenario variable, in the sense that the conditions under which the country will be able to borrow in the future are as yet unknown. It was assumed that the amortization of future borrowing is spread out over three periods in the following proportions: 40%, 30% and 30%. With constant borrowing, this generates an amortization profile on outstanding debt of 53%, 31% and 16%, which is slightly less skewed than the current schedule, implying more favorable terms on new borrowing.

The parameters of the function that models the behavior of the spread rate on brazilian borrowing, in response to variations in the macroeconomic indicators that reflect the country's creditworthiness, were estimated econometrically. Several explanatory variables were tried: debt service to export ratio, level of borrowing, borrowing to real income ratio, borrowing to debt ratio, rate of growth of real income, and level of reserves.

The data for the period in which the equation was estimated (1974 to 1984) is shown in table A.16. The data for the spread rates on individual medium term loans[12] extended after 1977 in the eurobond market was collected from Euromoney and averaged, using as weights the size of the loan[13]. Prior to 1976, indications on the prevailing rate for Brazil were taken from articles in the same publication. All the economic data is denominated in US$ millions of 1983. Data on debt, borrowing and interest payments were collected from the World Debt Tables (1983-84 edition), published by the World Bank and complemented by Brazil Economic Program, of Banco Central do Brasil. Data for exports came from International Financial Statistics of the IMF. The series for real GNP, at 1970 prices and denominated in US$ billions of 1983, was constructed using the index of real production of the National Accounts,

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12 Medium term loans are defined as those with more than 5 years maturity.
13 I thank An-Jen Tai for help with these calculations.

to adjust the 1983 income converted to dollars[14]

Table A.16
Data for the estimation of the equations for spread rates

Year	Spread rate (%)	Inter-rest (1)	Amorti-zation (1)	Regist. Debt (1)	Borrow-ing (1)	Reser-ves (1)	Exports (1)	Real Income (1)
1974	0.750	1471.0	1918.7	19114.1	8072.6	5272	7951	154510
1975	0.750	2047.9	2156.5	23423.5	7032.2	4034	8670	162876
1976	1.250	1717.7	2521.1	28776.9	8216.9	6541	10128	178716
1977	1.806	2021.8	3663.5	34962.8	9466.1	7192	12120	188977
1978	1.728	3125.0	5192.8	46192.0	14588.0	11826	12659	198441
1979	0.956	4747.6	6503.6	51371.3	12279.0	8966	15244	211093
1980	0.968	6328.3	6808.3	56128.2	11055.2	5769	20132	226334
1981	2.084	7955.7	7330.8	64305.0	15968.8	6604	23293	222749
1982	2.125	9296.0	7332.6	70712.7	12759.2	3994	20175	224741
1983	2.125	8748.1	8361.2	81319.0	16000.0	4563	21899	217768
1984	2.000	8875.9	7986.0	91671.0	18338.0	9864	25500	217768

Units: (1) US$ millions
Sources: see text.
Note: data for 1984 is estimated.

The estimated coefficients of the best equations is shown in Table A.17 below, along with the relevant econometric statistics. Equations with 2 of these as explanatory variables were also explored, but they did not add much to the fit and were abandoned, because of the higher computational burden of including them in the model.

Among the single explanatory variable equations, the best fit was for the income growth, but in the model this variable does not reflect directly the situation in the foreign accounts, and was not used. The reason for a good fit might be that when the external balances deteriorated, and the spread increased, the policies that were implemented to adjust them were

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14 The exchange rate used was the average for 1983, as published in IFS.

recessionary, introducing in the data the observed negative correlation between spread rates and income growth.

Another variable with a good fit was the level of borrowing, but it was rejected because the long horizon of the model will allow for a substantial absolute growth in income, which should increase the capacity of the brazilian economy to borrow. Therefore, the equation which was adopted is #3, which uses the borrowing to real income ratio as explanatory variable, because it will endogenize the affect described above. The intercept term was eliminated because it was not significant in a previous estimation[15]. Equation #4 was used for the terminal condition term of the objective function.

Table A.17
Regression coefficients and statistics
for the spread rate on brazilian eurobond borrowing

Eq. #	Constant	Income growth	Level of Borrowing	Borrowing / Income	Debt / Income	R^2	DW
1	1.942 (13.21)	-0.1063 (-4.26)				0.668	1.76
2	-		0.00123 (13.72)			0.568	1.30
3	-			25.31 (12.35)		0.473	1.09
4	0.388 (1.09)				4.488 (3.32)	0.501	1.49

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15 This was quite satisfactory, since one would expect it to be null, ex-ante.

Mis-numbering error by the author.
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Figure A.1

Spread rate function

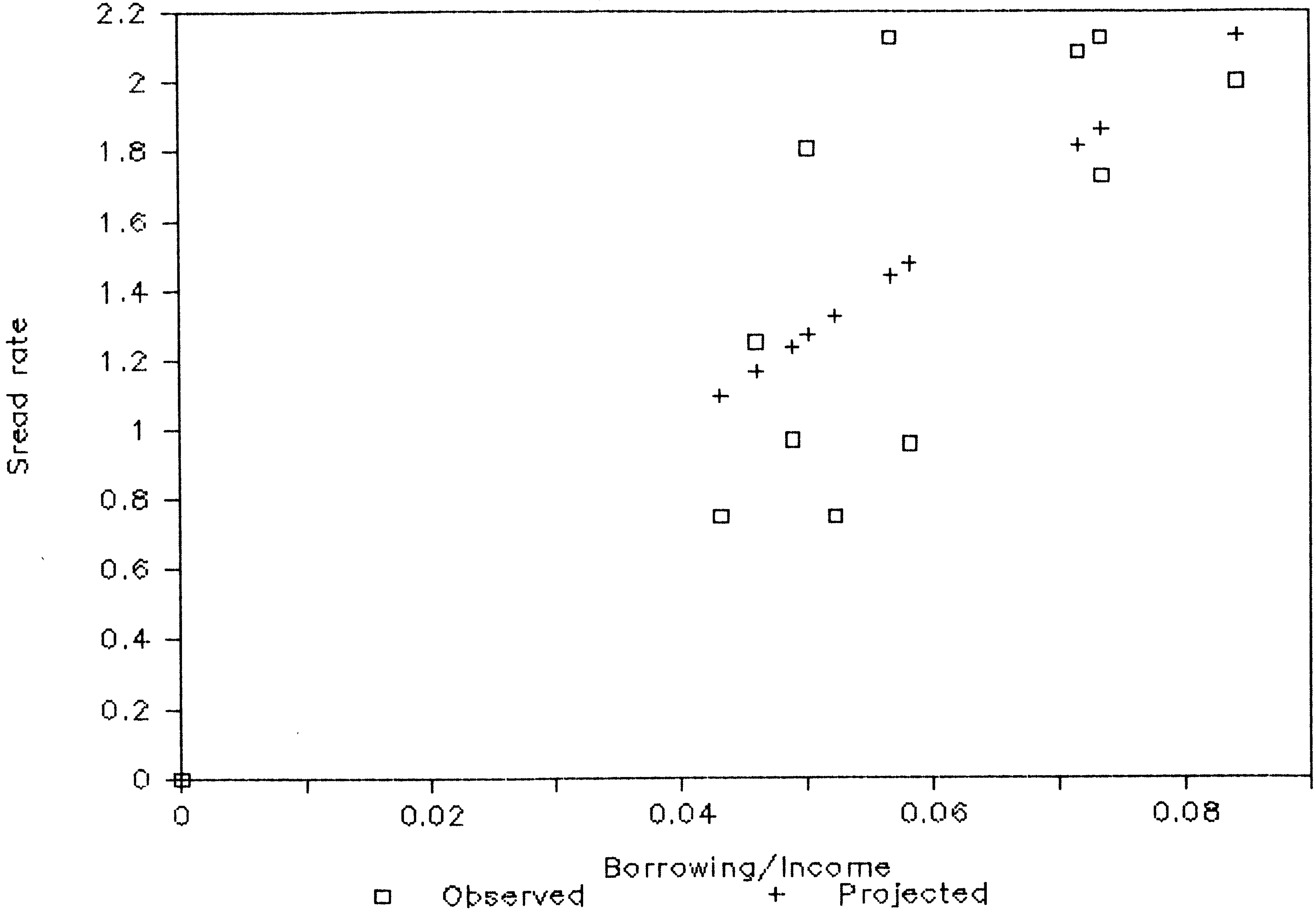

Figure A.2

Spread rate function

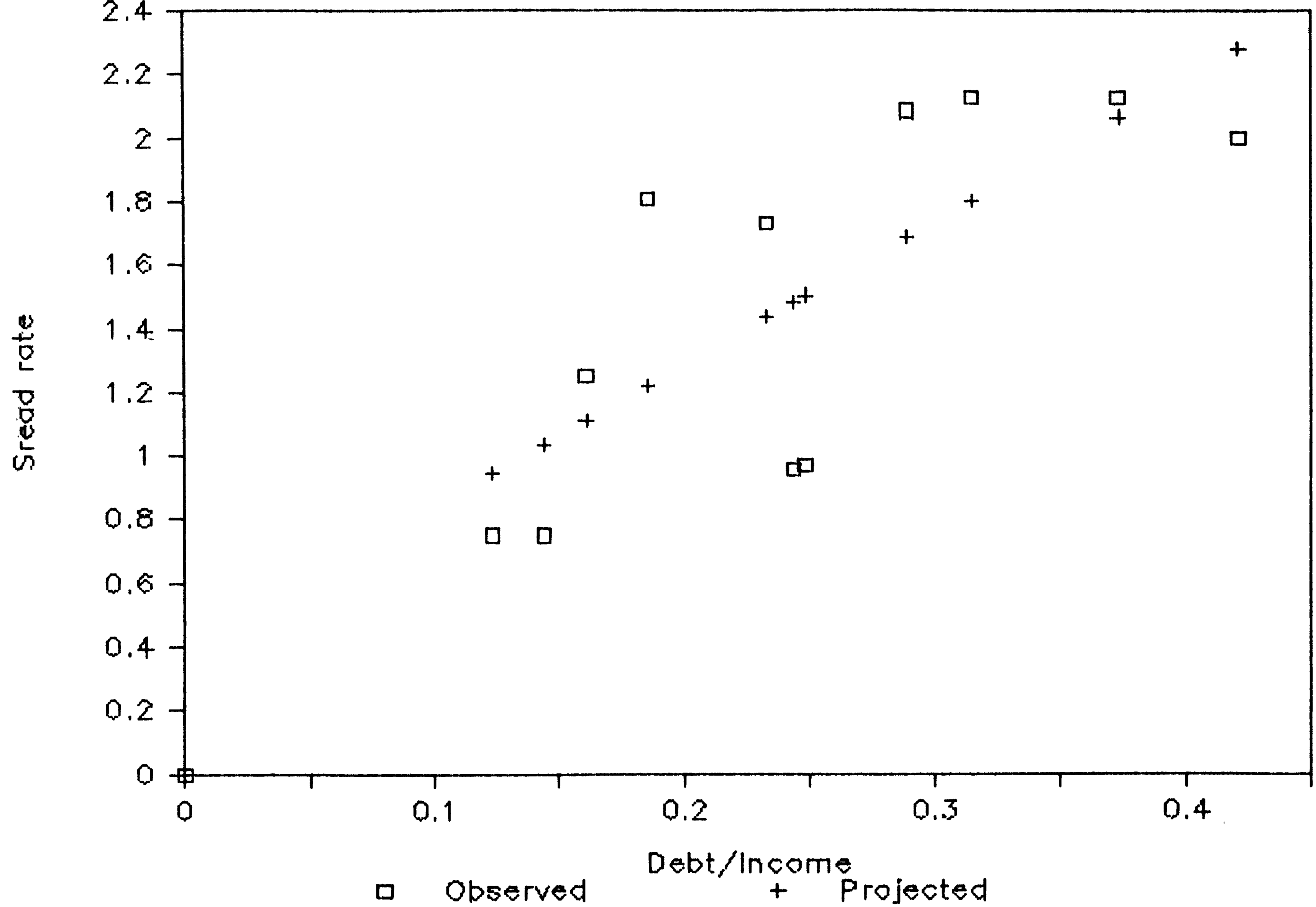

TABLE A.18

SECTORAL INPUT AND FINAL DEMAND TABLE FOR BRAZIL IN 1975

(in CR$ millions)

PRODUCTS \ SECTORS	Agriculture	Agro-process.	Construction	Manuf. cap.gds	Manuf. other	Petroleum	Utilities	Transp. & comm.	Other services	INTERMED DELIVERY	*Private *consump.	Governmt consump.	Investment	Stock change	Exports	FINAL DEMAND	* Demand
Agriculture	17218	54145	74	12	17358	30	12	8	527	89384 *	24181	230	3194	11260	7407	46280 *	135664
Agro-processing	4198	24576	0	3	2456	11	0	183	6826	38253 *	95662	522	0	4088	14293	114565 *	152818
Construction	0	0	0	0	0	0	0	0	0	0 *	0	0	166322	0	0	166322 *	166322
Manuf. cap. goods	155	1561	7151	42750	10511	1159	1169	7027	2325	73808 *	27771	966	58370	1560	7058	95725 *	169533
Manuf. other goods	14539	14529	57771	33332	149067	4693	634	2771	5312	282648 *	72190	6300	9505	8815	19720	116606 *	399254
Petroleum	1842	477	3611	594	12508	3050	688	10259	1457	34486 *	13991	1140	0	135	1428	16702 *	51188
Utilities	109	960	146	787	4282	277	2340	205	3070	12176 *	10413	604	0	0	0	11097 *	23273
Transport. & commun.	216	618	776	617	2473	3997	38	962	1479	11176 *	26041	2629	763	52	4879	34364 *	45540
Other services	8100	8604	23558	13340	33321	1872	337	8494	10291	107917 *	184587	23504	22470	1206	15127	246914 *	354831
TOTAL INTERMEDIATE	46377	105470	93087	91435	231976	15089	5218	29909	31287	649848 *	454844	36079	260624	27116	69912	848575 *	1498423
Imports	325	3887	3840	9381	16802	23555	265	5870	612	64537 *	4376	354	23612	767	0	29109 *	
Indirect Taxes	-3419	-5720	18085	1606	-5538	652	629	5902	15458	27655 *	74827	2391	14832	2042	185	94277 *	
SUB_TOTAL	43283	103637	115012	102422	243240	39296	6112	41681	47357	742040 *	534047	38024	299068	29925	70097	971961 *	
Wages	16036	5925	21917	18829	33319	1456	5083	14104	65271	181940 *							
Expenses w/labor	3170	2365	4313	6505	37751	532	1460	719	10458	75273 *							
Auton. employment	4872	0	5494	0	133	0	0	12054	11639	34192 *							
Return to capital	87295	35357	19586	43385	106392	16515	13800	19424	264791	606545 *							
VALUE ADDED	111373	43647	51310	68719	177595	18503	20343	46301	360159	897950 *							
GROSS PRODUCTION	154656	147204	166322	171141	420835	57799	26455	87982	407516	1639990 *							

TABLE A.19a

ADJUSTED IMPORT TABLE FOR BRAZIL IN 1975
(in CR$ millions)

PRODUCTS \ SECTORS	Agriculture	Agro-process.	Construction	Manuf. cap.gds	Manuf. other	Petroleum	Utilities	Transp. & comm.	Other services	INTERMED DELIVERY	*Private *consump.	Governmt consump.	Investment	TOTAL IMPORTS	GROSS DEMAND
Agriculture	93.8	2873.9	7.5	36.4	211.9	0.1	.0	8.5	27.9	3260.0 *	843.0	2.0	0.0	845.0	4105.0
Agro-processing	27.0	663.7	0.3	23.7	127.4	0.1	.0	83.5	127.3	1053.0 *	1094.0	0.0	0.0	1094.0	2147.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0 *	0.0	0.0	0.0	0.0	0.0
Manuf. cap. goods	0.2	0.8	454.3	3423.6	2608.6	0.2	225.1	690.8	643.5	8047.0 *	969.0	124.0	21539.0	22632.0	30679.0
Manuf. other goods	608.3	247.5	3180.7	4815.3	15224.0	137.1	35.2	107.8	547.1	24903.0 *	1212.0	210.0	1310.0	2732.0	27635.0
Petroleum	0.2	1.0	18.5	143.2	951.3	22935.4	0.1	209.5	147.8	24407.0 *	0.0	0.0	0.0	0.0	24407.0
Utilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0 *	0.0	0.0	0.0	0.0	0.0
Transport. & commun.	41.2	109.9	188.7	461.5	1255.4	84.3	5.1	2355.0	1580.9	6082.0 *	166.0	12.0	600.0	778.0	6860.0
Other services	0.1	9.1	31.4	76.5	182.4	68.1	1.0	98.7	211.8	679.0 *	92.0	6.0	163.0	261.0	940.0
TOTAL INTERMEDIATE	770.8	3905.8	3881.3	8980.2	20561.1	23225.2	266.5	3553.8	3286.2	68431.0 *	4376.0	354.0	23612.0	28342.0	96773.0

TABLE A.20

SECTORAL OUTPUT TABLE FOR BRAZIL IN 1975
(in CR$ millions)

PRODUCTS \ SECTORS	Agriculture	Agro-process.	Construction	Manuf. cap.gds	Manuf. other	Petroleum	Utilities	Transp. & comm.	Other services	TOTAL
Agriculture	143267	9860	0	0	422	0	3	0	1104	154656
Agro-processing	10	145019	0	0	1328	0	1	0	926	147284
Construction	0	0	166322	0	0	0	0	0	0	166322
Manuf. cap. goods	0	0	0	104450	66030	0	2	0	659	171141
Manuf. other goods	131	542	861	67778	355501	147	28	2	6213	431203
Petroleum	0	0	0	0	795	46636	0	0	0	47431
Utilities	0	0	0	0	0	0	26455	0	0	26455
Transport. & commun.	0	0	0	0	3	0	0	53264	34715	87982
Other services	0	0	0	0	4454	0	0	0	403062	407516
TOTAL	143408	155421	167183	172228	428533	46783	26489	53266	446679	1639990

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APPENDIX B

LISTING OF THE IMPLEMENTATION OF THE MODEL IN GAMS LANGUAGE

This appendix describes the implementation of the model using GAMS 2.0 - General Algebraically Modelling System - which was developed at the World Bank, and was kindly made available for this research. The solution algorithm used here was MINOS 5.0 - Modular In-Core Nonlinear Optimization System - developed at Stanford University. For an introduction to these programs, see respectively Kendrick and Meeraus [1985], and Murtagh and Saunders [1983].

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*********************************************************
*** MULTISECTORAL NON-LINEAR DYNAMIC PLANNING MODEL ***
*** FOR BRAZIL, WITH EMPHASIS ON THE FOREIGN DEBT   ***
***                                                 ***
***  COPYRIGHT BY OCTAVIO AUGUSTO FONTES TOURINHO   ***
***            MAY 1985, CAMBRIDGE, USA             ***
***                                                 ***
*** DEVELOPED UNDER UNESCO/FINEP FELLOWSHIP 82/004  ***
*********************************************************
```

```
1GAMS 2.00 CDC NOS 1.4                    85/08/03.   16.56.07.  PAGE      1
 G E N E R A L  A L G E B R A I C  M O D E L I N G  S Y S T E M
 C O M P I L A T I O N
```

```
 SETS
 TT  PERIODS  /1983,1984,1988,1992,1996,2000,2004/
      TINIT(TT)     INITIAL YEAR  /1983/
      TTERM(TT)    TERMINAL YEAR  /2004/
      T(TT)  ALL PERIODS EXCEPT INITIAL  /1984,1988,
             1992,1996,2000,2004/;
 SET G(TT)  VINTAGES FOR DEBT       /1983,1984,1988,
             1992,1996,2000,2004/;

 PARAMETER GLTT(G,TT)    FUNCTION:G LESS THAN T
           GLET(G,TT)     FUNCTION:G LESS OR EQUAL TO T;
     GLTT(G,TT) $ T(TT) = 1 $ (ORD(G) LT ORD(TT));
     GLET(G,TT) $ T(TT) = 1 $ (ORD(G) LE ORD(TT));
**** NOTE THAT ONLY DEFINED FOR THE SET T


 SET I PRODUCTS
     /AGRIC,AGROP,CONST,MANCG,MANOG,PETRO,UTILT,TRCOM,SERVC/;
 SET ITR   EXPORTABLE PRODUCTS
     /AGRIC,AGROP,MANCG,MANOG,PETRO/;
 SET ICON(I)   CONSUMMABLE PRODUCTS
     /AGRIC,AGROP,MANCG,MANOG,PETRO,UTILT,TRCOM,SERVC/;

 ALIAS(I,J)
***  J DENOTES SECTORS;

 SCALAR NYPP        NUMBER OF YEARS PER PERIOD /4/
 PARAMETER NYP(TT)   NUMBER OF YEARS IN EACH PERIOD;
 NYP(TT) $ (ORD(TT) EQ 1) = 1;
 NYP(TT) $ (ORD(TT) GT 1) = NYPP;
```

```
1GAMS 2.00 CDC NOS 1.4                         85/08/03.   16.56.07.  PAGE      2
 G E N E R A L  A L G E B R A I C  M O D E L I N G  S Y S T E M
 C O M P I L A T I O N


 ************************
 *** UTILITY FUNCTION ***
 ************************

  SCALAR SCALE    SCALE FACTOR FOR UTITY FUNCTION  /1000/;
  SCALAR NO      INITIAL POPULATION IN MILLIONS /128.17/
         GRN     GROWTH RATE OF POPULATION /0.025/
  PARAMETER N(TT)        POPULATION IN MILLIONS
            NTERM       TERMINAL POPULATION;
       N(T) = NO*(1+GRN)**(NYPP*(ORD(T)-1)+1);
       NTERM = SUM(TTERM,N(TTERM)*(1+GRN)**NYPP);

  PARAMETER DELTA    DISCOUNT RATE FOR UTILITY
            DF(TT)       DISCOUNT FACTOR PER PERIOD
            DFTERM     DISCOUNT FOR THE TERMINAL CONDITION;
       DELTA = 0.04;
       DF(T) = 1/(1+DELTA)**(NYPP*(ORD(T)-1)+1);
       DFTERM = SUM(TTERM,DF(TTERM)/(1+DELTA)**NYPP);
 *** THE TERMINAL CONDITIONS ARE EVALUATED ONE PERIOD AFTER LAST ***
  DISPLAY DF,DFTERM;

  PARAMETER RHOK  INTEREST RATE ON NON-HUMAN WEALTH,
            RHOD  INTEREST RATE ON TERMINAL DEBT ;
       RHOD = 0.06;
       RHOK = 0.082;
  PARAMETER CO(I)   CONSUMPTION IN THE INITIAL PERIOD
      /AGRIC     3797.1,
       AGROP    12080.7,
       MANCG     3220.8,
       MANOG    11197.3,
       PETRO     3195.2,
       UTILT     1677.6,
       TRCOM     4219.6,
       SERVC    32598.6/
  PARAMETER  CTO     TOTAL CONSUMPTION;
       CTO = SUM(I,CO(I));

  PARAMETER STCHO(I)  STOCK CHANGE
      /AGRIC     1211.9,
       AGROP      442.6,
       MANCG      132.2,
       MANOG      814.9,
       PETRO       28.0,
       TRCOM        5.1,
       SERVC      116.7/
```

```

SCALAR MNCO    CONSUMP OF NCI IN FIRST PERIOD /338.5/;
PARAMETER BETA(I)      ELASTICITY OF EXPENDITURE WRT INCOME
    /AGRIC   0.028,
     AGROP   0.091,
     MANCG   0.0598,
     MANOG   0.1965,
     PETRO   0.0474,
     UTILT   0.0324,
     TRCOM   0.0846,
     SERVC   0.4501     /;
SCALAR BETAMNC  ELAST OF CONSUMPTION OF NCI /0.0094/
PARAMETER GAMMA(I) MINIMUM CONSUMPTION LEVEL OF SEVERAL GOODS
    /AGRIC   20.980
     AGROP   66.865,
     MANCG   7.124,
     MANOG   25.541,
     PETRO   10.719,
     UTILT   3.325,
     TRCOM   7.444,
     SERVC   118.821/;
SCALAR GAMMAMNC  MINIMUM CONSUMP OF NCI  /3.054/
PARAMETER GAMMAT TOTAL MINIMUM CONSUMPTION AT INITIAL YEAR P;
      GAMMAT = SUM(I,GAMMA(I))+ GAMMAMNC;

SCALAR YO      INCOME IN INITIAL PERIOD  /108506/
       GRY     GROWTH RATE OF POTENTIAL INCOME  /0.05/;
* PARAMETER YPOT(TT)     POTENTIAL INCOME;
*      YPOT(T) = YO*(1+GRY)**(NYPP*(ORD(T)-1)+1);
PARAMETER YTERM        ESTIMATE OF POS-TERMINAL INCOME;
*   YTERM = SUM(TTERM,YPOT(TTERM));
    YTERM = 240000;

******************
*** GOVERNMENT ***
******************
PARAMETER GO(I)         INITIAL GOVERNMENT EXPENDITURES
    /AGRIC   32.2,
     AGROP   71.1,
     MANCG   103.8,
     MANOG   740.3,
     PETRO   299.7,
     UTILT   81.0,
     TRCOM   325.8,
     SERVC   2863.0/;
```

```
 SCALAR GRG      GROWTH RATE OF GOVERNMENT /0.03/
 PARAMETER GOV(I,TT)           GOVERNMENT EXPENDITURES;
      GOV(I,T) = GO(I)*(1+GRG)**(NYPP*(ORD(T)-1)+1);
 PARAMETER GTERM    TOTAL GOVERNMENT IN TERMINAL YEAR;
      GTERM = SUM(TTERM,SUM(I,GOV(I,TTERM)))*(1+GRG)**NYPP;

 SCALAR MNGO    NIC IN GOVERNMENT IN 1983   /26.4/
 PARAMETER MNG(TT)    PROJECTION OF NCI IN GOVERNMENT;
     MNG(T) = MNGO*(1+GRG)**(NYPP*(ORD(T)-1)+1);


***************
*** EXPORTS ***
***************
 PARAMETER EO(I)    INITIAL EXPORTS
     /AGRIC     1540.9,
      AGROP     2973.5,
      CONST        0.0,
      MANCG     1961.8,
      MANOG    5481.3,
      PETRO      670.6/
 PARAMETER GRAE   MAX RATE OF GROWTH OF AGRICULT EXPORTS,
           GRME   MAX RATE OF GROWTH OF MANUFAC EXPORTS ;
     GRAE = 0.05;
     GRME = 0.10;

*****************************
*** FOREIGN SECTOR PRICES ***
*****************************
 PARAMETER PE(I,TT)  EXPORT PRICES;
     PE(I,T) = 1;
     PARAMETER MO(I)         CONPETITIVE IMPORTS IN 1983
     /PETRO   4534.7/;
 PARAMETER  PM(I,TT)      COMPETITVE IMPORTS PRICE;
       PM(I,T) = 1.0;
 PARAMETER  PMN(J,TT)       PRICE OF NCI IN PRODUCTION,
            PMNC(TT)        PRICE OF NCI IN CONSUMPTION,
            PMNG(TT)        PRICE OF NCI IN GOVERNMENT;
       PMN(J,T) = 1.0;
       PMNC(T) = 1.0;
       PMNG(T) = 1.0;
```

```
*******************
*** TECHNOLOGY ****
******************

 PARAMETER XO(J)   GROSS OUTPUT LEVELS IN 1983
     /AGRIC      19069.8,
      AGROP     21120.2,
      CONST     16629.9,
      MANCG     16998.9,
      MANOG     45416.8,
      PETRO     17000.6,
      UTILT      4822.6,
      TRCOM      8744.1,
      SERVC     49279.1/;
 PARAMETER SHVAO  INITIAL SHARE OF VALUE ADDED IN GROSS OUTPUT
     /AGRIC  0.6920418,
      AGROP  0.3106362,
      CONST  0.4077955,
      MANCG  0.3535993,
      MANOG  0.3805508,
      PETRO  0.4463960,
      UTILT  0.7700825,
      TRCOM  0.4930295,
      SERVC  0.8737700/;
  PARAMETER LR(J)  EMPLOYMENT MEASURED AS LABOR SHARE IN OUTPUT
    /AGRIC   0.1340,
     AGROP   0.0504,
     CONST   0.1607,
     MANCG   0.0845,
     MANOG   0.0784,
     PETRO   0.0341,
     UTILT   0.1866,
     TRCOM   0.2470,
     SERVC   0.1923/;
  PARAMETER LU(J)  LABOR UNITS: EMPLOYED PER UNIT OF PRODUCT
    /AGRIC     2889,
     AGROP      616,
     CONST     1670,
     MANCG      719,
     MANOG      809,
     PETRO      496,
     UTILT      903,
     TRCOM     1313,
     SERVC     1155/;
```

```
 TABLE A(I,J)  INPUT-OUTPUT COEFFICIENTS FOR THE BASIC TECHNOLOGY
                AGRIC  AGROP  CONST  MANCG  MANOG  PETRO  UTILT  TRCOM  SERVC
       AGRIC    0.118  0.341  0.001  0.024  0.047   .000   .000   .000  0.003
       AGROP    0.032  0.168   .000  0.004  0.008   .000   .000  0.003  0.019
       MANCG    0.001  0.006  0.039  0.154  0.051  0.006  0.024  0.057  0.009
       MANOG    0.066  0.063  0.322  0.251  0.280  0.025  0.013  0.023  0.014
       PETRO    0.027  0.008  0.065  0.043  0.070  0.446  0.046  0.276  0.030
       UTILT    0.001  0.011  0.002  0.018  0.022  0.004  0.134  0.005  0.014
       TRCOM    0.013  0.023  0.012  0.023  0.025  0.061  0.002  0.023  0.009
       SERVC    0.048  0.056  0.134  0.091  0.082  0.012  0.007  0.073  0.024

********************************
*** NON-COMPETITIVE IMPORTS ***
********************************

 PARAMETER MNX(J)  NON-COMPETITVE IMPORTS REQUIREMENT IN PRODUCTION
    /AGRIC   0.003,
     AGROP   0.013,
     CONST   0.017,
     MANCG   0.038,
     MANOG   0.035,
     UTILT   0.003,
     TRCOM   0.048,
     SERVC   0.005/;
 PARAMETER MNK(J)  NON-COMPETITVE IMPORTS REQUIREMENT IN INVESTMENT
    /AGRIC   0.006,
     AGROP   0.039,
     CONST   0.094,
     MANCG   0.136,
     MANOG   0.082,
     PETRO   0.082,
     UTILT   0.049,
     TRCOM   0.074,
     SERVC   0.011/;

```

```
*****************************
*** RESOURCE AVAILABILITY ***
*****************************

 PARAMETER LO          INITIAL LABOR SUPPLY IN FORMAL MARKET
           LS(TT)      LABOR SUPPLY
           GRL         PER ANUUM RATE OF GROWTH OF LABOR FORCE
           GRLP        GROWTH RATE OF LABOR PRODUCTIVITY;
       GRL = 0.03;
       GRLP= 0.02;
       LO = SUM(J,XO(J)*LR(J));
       LS(T) = LO*(1+GRL+GRLP)**(NYPP*(ORD(T)-1)+1);
 DISPLAY LO,LS;
 SCALAR PETSO    PETROLEUM SUPPLY IN 1983 IN BBL THOS PER DAY /340/;
 PARAMETER PETS(TT)    PETROLEUM SUPPLY IN BBL THOUS PER DAY
     /1983  340
      1984  520,
      1988  600,
      1992  600,
      1996  600,
      2000  600,
      2004  600/;

*************************
*** CAPITAL FORMATION ***
*************************

  PARAMETER KR(J)  CAPITAL TO OUTPUT RATIO
*** CAPITAL TO OUTPUT RATE IN AGRIC CHANGED FROM 3.009 IN 5/16/85
    /AGRIC  2.610,
     AGROP  1.520,
     CONST  0.572,
     MANCG  1.092,
     MANOG  1.278,
     PETRO  2.075,
     UTILT  3.556,
     TRCOM  0.935,
     SERVC  2.354/;
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     PARAMETER ISH(J) SHARE OF SECTORS IN CAPITAL FORMATION
      /AGRIC   0.10,
       AGROP   0.09,
       CONST   0.03,
       MANCG   0.10,
       MANOG   0.24,
       PETRO   0.04,
       UTILT   0.06,
       TRCOM   0.04,
       SERVC   0.30/;

   PARAMETER DEPR(J)  DEPRECIATION RATE PER SECTOR
      /AGRIC   0.016,
       AGROP   0.037,
       CONST   0.042,
       MANCG   0.040,
       MANOG   0.036,
       PETRO   0.036,
       UTILT   0.034,
       TRCOM   0.045,
       SERVC   0.039/;

   PARAMETER GLAG(J)       GESTATION LAG PER SECTOR
      /AGRIC   4.0,
       AGROP   4.0,
       CONST   4.0,
       MANCG   4.0,
       MANOG   4.0,
       PETRO   4.0,
       UTILT   4.0,
       TRCOM   4.0,
       SERVC   4.0/;

   PARAMETER KO(J)     INITIAL CAPITAL STOCK
             KOT       TOTAL INITIAL CAPITAL STOCK;
       KO(J) = XO(J)*KR(J);
       KOT = SUM(J,KO(J));
   PARAMETER KONET(J,TT)    DEPRECIATED INITIAL STOCK
             DEPREF(J,TT,TT) DEPRECIATION FACTORS FOR CAPITAL STOCK;
         KONET(J,T) = KO(J)*(1-DEPR(J))**(NYPP*(ORD(T)-1)+1);
         DEPREF(J,G,T) $ GLTT(G,T) = GLAG(J)*(NYP(G)/NYPP)*
                 (1-DEPR(J))**(NYPP*(ORD(T)-ORD(G)));
   PARAMETER KAVGO   INITITAL AVERAGE NET CAPITAL TO OUTPUT RATIO;
         KAVGO = YO/KOT - SUM(J,(KO(J)/KOT)*DEPR(J));

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 PARAMETER INVO(I)    INITIAL DELIVERIES TO INVESTMENT
      /AGRIC    329.1,
       CONST  16629.9,
       MANCG   4737.0,
       MANOG    841.2,
       TRCOM     72.0,
       SERVC   2081.8/;

 TABLE KSH(I,J)            CAPITAL SHARES MATRIX
         AGRIC  AGROP  CONST  MANCG  MANOG  PETRO  UTILT  TRCOM  SERVC
  AGRIC  0.102  0.0    0.0    0.0    0.0    0.0    0.0    0.0    0
  CONST  0.731  0.645  0.169  0.495  0.565  0.482  0.567  0.726  0.761
  MANCG  0.071  0.194  0.498  0.248  0.225  0.281  0.290  0.118  0.119
  MANOG  0.025  0.034  0.088  0.034  0.036  0.043  0.017  0.032  0.026
  TRCOM  0.002  0.003  0.008  0.003  0.003  0.004  0.001  0.003  0.002
  SERVC  0.062  0.085  0.109  0.085  0.090  0.106  0.078  0.078  0.071

********************
*** FOREIGN DEBT ***
********************

 PARAMETER F(TT)     FOREIGN EXCHANGE TRANSFERS ABROAD
           FTERM     FOREIGN EXCHG TRANSF IN LAST YEAR;
      F(T) = 973.68;
      FTERM = 973.68;

 SCALAR BO    BORROWING IN INITITAL PERIOD     /9232.0/;
 SCALAR GRB   MAXIMUM RATE OF CHANGE OF BORROW /0.15/;

 PARAMETER RO(TT)  REPAYMENT OF INITIAL DEBT (CUMMUL FOR PERIOD)
        /1984   30384.4
         1988   14227.7
         1992    1214.6
         1996   332.9
         2000   226.2/;
 PARAMETER DO(TT)  INITIAL DEBT BY MATURITY,
           DOT     TOTAL INITIAL DEBT;
       DO(G) = SUM(TT$(ORD(TT) GE ORD(G)),RO(TT));
       DOT = SUM(T,RO(T));
*** CALCULATION ABOVE CONSISTENT WITH DEBT AT BEGINNING OF YEAR
*** USE OF INDEX G TO ALLOW CALCULATION OF INITIAL DEBT

 PARAMETER RS(TT,TT) REPAYMENT SCHEDULE;
 RS(T,T+1) = .40;  RS(T,T+2) = .30;  RS(T,T+3) = .30;
```

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 SCALAR ALPHA   SLOPE OF THE SPREAD RATE FUNCTION /29.69/
        ALPHA1  SLOPE OF TERMINAL DEBT SPREAD RATE FUNCTION  /5.26/;
 PARAMETER LIBOR   FIXED PART OF REAL INT RATE ON FOREIGN BORROW;
     LIBOR = 5.0;
*** NOTE INTEREST RATE ON BORROWING SPECIFIED IN PERCENTAGE TERMS

****************************
*** DEFINITION OF OUTPUT ***
****************************
*PARAMETER DEMO(I)    DEMAND IN INITIAL PERIOD;
*    DEMO(I) = CO(I) + STCHO(I) + INVO(I) + GOVO(I) + EO(I) - MO(I);
*******************************
** DECLARATION OF VARIABLES ***
*******************************

 POSITIVE VARIABLES
      B(TT)          BORROWING OF FOREING DEBT IN PERIOD T
      C(I,T)         CONSUMPTION OF COMMODITY I IN PERIOD T
      D(TT,TT)       DEBT OUTSTANDING IN  T  CONTRACTED IN G
      DT(TT)         TOTAL DEBT OUTSTANDING IN PERIOD T
      DK(J,TT)       INVESTMENT BY SECTOR J IN PERIOD T
      DKTERM         PHYSICAL INVESTMENT IN LAST PERIOD
      DTERM          TERMINAL FOREIGN DEBT
      E(I,T)         EXPORTS OF COMMODITY I IN PERIOD T
      H(TT,TT)       INTEREST PAYMENTS IN PERIOD T OF DEBT VINTAGE G
      HR(TT)         INTEREST RATE ON FOREING BORROWING
      HT(TT)         TOTAL INTEREST PAYMENTS IN PERIOD T
      INV(I,T)       DELIVERIES TO INVESTMET OF COMMODITY I IN FERIOD T
      K(J,TT)        CAPITAL STOCK OF SECTOR J IN PERIOD T
      KT(TT)         TOTAL CAPITAL STOCKT IN YEAR T
      KTERM          TERMINAL CAPITAL STOCK
***   L(T)           DEMAND FOR SKILLED LABOR IN PERIOD T
      M(I,T)         COMPETITIVE IMPORTS OF GOOD I IN PERIOD T
      MNC(T)         NON-COMPETITIVE IMPORTS IN CONSUMPTION
      R(TT,TT)       REPAYMENT IN PERIOD T ON DEBT OF VINTAGE TT
      RT(TT)         TOTAL REPAYMENT IN PERIOD T
***   SH(G)          SPREAD RATE ON LOANS CONTRACTED AT G
***   U(T)           INSTANTANEOUS UTILITY IN PERIOD T
      X(J,T)         GROSS OUTPUT OF SECTOR J IN YEAR T
      Y(TT)          OUTPUT INDEX IN PERIOD T
***   Z(I,T)         INTERMEDIATE DELIVERIES OF GOOD I IN PERIOD T
      W              POST TERMINAL UTILITY;
 VARIABLE UO         VALUE OF OBJECTIVE FUNCTION;
```

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*****************
*** EQUATIONS ***
*****************
 EQUATIONS
      OBJ          OBJECTIVE FUNCTION DEFINITION
      TERUTIL      TERMINAL UTILITY
      MATBAL       MATERIAL BALANCES
      GNPDEF       DEFINITION OF GROSS NATIONAL PRODUCT
      FEXBAL       FOREIGN EXCHANGE BALANCES
      LABREQ       FABOR REQUIREMENTS BLANCE
      CAPFOR       CAPITAL FORMATION REQUIREMENTS
      CAPREQ       CAPITAL REQUIREMENT RESTRICTION
      TERCAP       CALCULATION OF TERMINAL CAPITAL STOCK
      TERINV       INVESTMENT ALLOCATION IN THE TERMINAL YEAR
      INVDEF       DEFINITION OF INVESTMENT PER SECTOR
      ININV        INITIAL INVESTMENT ALLOCATION
      DEBREP       ACCOUNTING FOR DEBT REPAYMENT
      DEBACC       ACCOUNTING FOR DEBT DUE TO BORROWING
      TERDEB       CALCULATION OF TERMINAL DEBT
      RCALC        CALCULATION OF AMORTIZATION REPAYMENTS
      HCALC        CALCULATION OF INTEREST COST OF DEBT
      HRATE        CALCULATION OF INTEREST RATE
      KTOT         TOTAL CAPITAL STOCK ACROSS SECTORS
      RTOT         TOTALIZATION OF REPAYMENTS PER PERIOD
      HTOT         TOTALIZATION OF INTEREST PER PERIOD
      DTOT         TOTALIZATION OF DEBTS PER PERIOD;
```

```
*****************************
*** EQUATION DEFINITIONS ***
*****************************

 OBJ.. UO =E= SCALE*SUM(T,DF(T)*N(T)*NYP(T)*
                  (SUM(I$ICON(I),BETA(I)*LOG(C(I,T)/N(T)-GAMMA(I))) +
                  BETAMNC*LOG(MNC(T)/N(T)-GAMMAMNC))) +
                  W;

*** TERMINAL CONDITIONS ***
 TERUTIL.. W =E= SCALE*SUM(TTERM,(DFTERM*NTERM/DELTA)*
                 LOG((YTERM - GTERM - FTERM + RHOK*KTERM -
                      0.01*(LIBOR+ALPHA1*DTERM/YTERM) * DTERM
                      ) / NTERM - GAMMAT));

 TERCAP..   KTERM   =E=  NYPP*DKTERM +SUM(TTERM,
                         SUM(J,K(J,TTERM)*(1-DEPR(J))**NYPP));
 TERDEB..   DTERM =E= SUM(TTERM,SUM(G$GLTT(G,TTERM),D(G,TTERM)) +
                          NYPP*B(TTERM) -
                          SUM(G$GLTT(G,TTERM),NYPP*R(G,TTERM)));

*** MATERIAL BALANCES ***

 MATBAL(I,T)..  X(I,T) =G= SUM(J,A(I,J)*X(J,T)) +
                           C(I,T) + GOV(I,T) + INV(I,T) +
                           E(I,T)$ITR(I) - M(I,T)$ITR(I);
 GNPDEF(T)..    Y(T)   =E= SUM(I,SHVAO(I)*X(I,T));

*** FOREIGN EXCHANGE BALANCE ***

 FEXBAL(T)..    B(T)  =G=
                SUM(I$ITR(I),PM(I,T)*M(I,T)) +
                PMNC(T)*MNC(T) + PMNG(T)*MNG(T) +
                SUM(J,PMN(J,T)*(MNX(J)*X(J,T) + MNK(J)*DK(J,T))) -
                SUM(I$ITR(I),PE(I,T)*E(I,T)) + RT(T) + HT(T) + F(T);

*** LABOR CONSTRAINT ***

 LABREQ(T)..  SUM(J,LR(J)*X(J,T)) =L= LS(T);
```

```

** EQUATIONS FOR CAPITAL FORMATION ***

 CAPREQ(J,T)..       KR(J)*X(J,T) =L= K(J,T);

 CAPFOR(J,T)..       K(J,T) =E= KONET(J,T) +
                     SUM(G,DEPREF(J,G,T)*DK(J,G));
*** IN THE LAST TERM THE DEPRECIATION FACTOR ELIMINATES
*** THE UNDESIRABLE VINTAGES FROM THE SUMMATION
 INVDEF(I,T)..       INV(I,T)    =E= SUM(J,KSH(I,J)*DK(J,T));

 ININV(I,TINIT)..    INVO(I) =G= SUM(J,KSH(I,J)*DK(J,TINIT));

 TERINV(J)..         DKTERM*ISH(J) =E= SUM(TTERM,DK(J,TTERM));

*** EQUATIONS FOR FOREIGN DEBT **

 DEBREP(G,T) $ (GLTT(G+1,T) $ (ORD(G) GT 1))..
                 D(G,T) =E= D(G,T-1) - NYP(T)*R(G,T-1);
*** FIRST PERIOD ELIMINATED BECAUSE CALCULATED SEPARATELY

 DEBACC(G-1,G)$(ORD(G) GT 2)..
               D(G-1,G) =E= NYP(G-1)*B(G-1);

 RCALC(G,T) $ (GLTT(G,T) $ (ORD(G) GT 1))..
                 R(G,T) =E= RS(G,T)*B(G);
*** THE INITIAL YEAR IS EXCLUDED FROM THE CALCULATION BECAUSE
*** REPAYMENTS ON INITIAL DEBT ARE GIVEN EXOGENOUSLY

 HRATE(G)$(ORD(G) GT 1)..
       SCALE*HR(G) =E= SCALE*LIBOR + SCALE*ALPHA/Y(G)*B(G);
 HCALC(G,TT) $ (GLTT(G,TT) $ (ORD(G) GT 1))..
           H(G,TT) =E= D(G,TT)*0.01*HR(G);
*** NOTE THAT INTEREST ON DEBT SPECIFIED IN PERCENTAGE TERMS

*** TOTALIZATIONS ***
 KTOT(T)..  KT(T) =E= SUM(J,K(J,T));
 RTOT(T).. RT(T) =E= SUM(G$GLTT(G,T), R(G,T));
 HTOT(T).. HT(T) =E= SUM(G$GLTT(G,T), H(G,T));
 DTOT(T).. DT(T) =E= SUM(G$GLET(G,T), D(G,T));

```

```
**************
*** BOUNDS ***
**************
 B.UP(T) = BO*(1+GRB)**(NYPP*(ORD(T)-1)+1);
 B.LO(T) = BO*(1-GRB)**(NYPP*(ORD(T)-1)+1);

 C.UP(I,T)$ICON(I) = (CO(I)+STCHO(I))*(1+5*GRN)**(NYPP*(ORD(T)-1)+1);
*** GROWTH OF CONSUMPTION NOT LARGER THAN 5 TIMES POP GROWTH
 C.LO(I,T)$ICON(I) = GAMMA(I)*N(T) +1;

 DTERM.UP  = 250000;
 D.FX(TINIT,G) = DO(G);

 DK.UP(I,T) = KO(I)/2;

 E.UP("AGRIC",T) = EO("AGRIC")*(1+GRAE)**(NYPP*(ORD(T)-1)+1);
 E.UP("AGROP",T) = EO("AGROP")*(1+GRAE)**(NYPP*(ORD(T)-1)+1);
 E.UP("MANCG",T) = EO("MANCG")*(1+GRME)**(NYPP*(ORD(T)-1)+1);
 E.UP("MANOG",T) = EO("MANOG")*(1+GRME)**(NYPP*(ORD(T)-1)+1);

 H.FX(TINIT,T) = DO(T)*0.01*(LIBOR + ALPHA*(BO/YO));

 KTERM.UP = 1700000;
 KTERM.LO = KOT;

 MNC.LO(T) = GAMMAMNC*N(T) + 100;

 R.FX(TINIT,T) = RO(T)/NYP(T);

 X.UP("PETRO",T) = XO("PETRO") + (PETS(T)/PETSO - 1) *
      (XO("PETRO")*A("PETRO","PETRO") - MO("PETRO"));
*** ABOVE LIMITS ATTEMP TO MODEL EXPANSION OF EXTRACTION ONLY
*** KEEPING THE SIZE OF THE REFINING SECTOR CONSTANT.
*** IN THE NEXT FORMULA THE WHOLE SECTOR EXPANDS PROPORTIONATELY.
*X.UP("PETRO",T) = XO("PETRO")*(PETS(T)/PETSO);
*** EXPRESSION ABOVE MEASURES INITIAL DOMESTIC PROCUCTION OF OIL
 X.LO(I,T) = XO(I)/2;

**********************
*** STARTING POINT ****
**********************

 C.L(I,T) = CO(I)*(1+GRN)**(NYPP*(ORD(T)-1)+1);
 E.L(I,T) = EO(I)*(1+GRN)**(NYPP*(ORD(T)-1)+1);
 M.L(I,T) = MO(I)*(1+GRN)**(NYPP*(ORD(T)-1)+1);
 B.L(T)   = BO*(1+GRN)**(NYPP*(ORD(T)-1)+1);
 X.L(J,T) = XO(J)*(1+GRN)**(NYPP*(ORD(T)-1)+1);
 Y.L(T)   = YO*(1+GRN)**(NYPP*(ORD(T)-1)+1);
 K.L(J,T) = KO(J)*(1+GRN)**(NYPP*(ORD(T)-1)+1);
```

```

*********************************
******* CONTROL COMMANDS *********
*********************************
 MODEL MOD6A /ALL/;
 OPTION ITERLIM=3000;
 OPTION LIMROW = 0;
 OPTION LIMCOL = 0;

 SOLVE MOD6A USING NLP MAXIMIZING UO;

******************************
*** REPORT GENERATION ********
******************************
 SET AG      MACROECONOMIC AGREGATES
   /XT,ZT,YT,CT,INVT,GOVT,ET,MNT,MT,TRBAL,DTT,RTT,HTT,FET,CA,BTT,
    KT,DKT,POP,EMP,CPI,INTR,WAGE,EXGR,AIR/;
 PARAMETER AGG(AG,TT)   TABLE OF ECONOMIC AGGREGATES;
*         CT      AGGREGATE CONSUMPTION AT 1983  PRICES
*         INVT    AGGREGATE INVESTMENT
*         GOVT    AGGREGATE GOVERNMENT EXPEND
*         ET      AGGREGATE EXPORTS
*         MNT     AGGREGATE NON-COMPET IMPORTS
*         MT      AGGREGATE IMPORTS
*         TRBAL   TRADE BALANCE
*         DTT     TOTOAL DEBT OUSTANDING
*         RTT     TOTAL REPAYMENTS ON DEBT
*         HTT     TOTAL INTEREST
*         CA      CURRENT ACCOUNT
*         BTT     TOTAL BORROWING
*         EXGR    EXCHANGE RATE
*         AIR     AVERAGE INTEREST RATE ON CURRENT BORROWING
*         EMP,UNR  ENPLOYMENT LEVEL AND UNEMPLOYMENT RATE
*         CPI     CONSUMER PRICE INDEX
*         WAGE    PRICE OF GOODS IN CONSUMPTION UNITS
 PARAMETER Z(I,T)  INTERMEDIATE DEMANDS,
            SWAGE(I,T)  SECTORAL YEARLY WAGES IN CR$ MILL
            PRICE(I,T)  RELATIVE PRICES OF GOODS
            SEMP(I,T)   SECTORAL EMPLOYMENT
            SINT(I,T)   SECTORAL INTEREST RATES
            SEXP(I,T)   SHADOW PRICE OF EXPORTS;
```

```
 Z(I,T)           = SUM(J,A(I,J)*X.L(J,T));
 AGG("CPI",T)     = 0 - SUM(I,MATBAL.M(I,T)*CO(I))/CTO;
*** WEIGHTING ON CONSUMPTION INDEX EQUAL TO INITAL CONSUMPTION
 PRICE(I,T)       = 0 - MATBAL.M(I,T)/AGG("CPI",T);
 AGG("WAGE",T)    = LABREQ.M(T)/AGG("CPI",T);
*** THIS MEASURES THE PRICE OF LABOR IN CONSUMPTION UNITS
 SWAGE(I,T)       = AGG("WAGE",T)*1000/LU(I);
*** YEARLY SECTORAL WAGES IN 1983 CR$ MILLIONS
 SEMP(I,T)        = X.L(I,T)*LR(I)*LU(I)*
                      (1-GRLP)**(NYPP*(ORD(T)-1)+1)/1000000;
 AGG("EMP",T)     = SUM(I,SEMP(I,T));
*** LAST TERM ACCOUNTS FOR LABOR PRODUCTIVITY INCREASE
 AGG("KT",T)      = SUM(I,K.L(I,T));
 AGG("DKT",T)     = MAX(1000,SUM(I,DK.L(I,T)));
 SINT(I,T)        = CAPREQ.M(I,T)/AGG("CPI",T);
 AGG("INTR",T)    = SUM(I,SINT(I,T)*DK.L(I,T))/AGG("DKT",T);
*** WEIGHTING IS IN PROPORTION TO CAPACITY CHANGE
 AGG("EXGR",T)    = 0 - FEXBAL.M(T)/AGG("CPI",T);
 SEXP(I,T)        = E.M(I,T)/AGG("CPI",T);
 AGG("CT",T)      = SUM(I,C.L(I,T));
 AGG("INVT",T)    = SUM(I,INV.L(I,T));
 AGG("GOVT",T)    = SUM(I,GOV(I,T));
 AGG("ET",T)      = SUM(I$ITR(I),PE(I,T)*E.L(I,T));
 AGG("MNT",T)     =  PMNC(T)*MNC.L(T) + PMNG(T)*MNG(T) +
            SUM(J,PMN(J,T)*(MNX(J)*X.L(J,T) + MNK(J)*DK.L(J,T)));
 AGG("MT",T)      = SUM(I$ITR(I),PM(I,T)*M.L(I,T)) + AGG("MNT",T);
 AGG("TRBAL",T) = AGG("ET",T) - AGG("MT",T);
 AGG("YT",T) = AGG("CT",T)+AGG("INVT",T)+AGG("GOVT",T)+
                 AGG("TRBAL",T);
 AGG("ZT",T)      = SUM(J,Z(J,T));
 AGG("XT",T)      = SUM(J,X.L(J,T));
 AGG("POP",T)     = N(T);
 AGG("TRBAL",T) = AGG("ET",T) - AGG("MT",T);
 AGG("FET",T)     = F(T);
 AGG("CA",T)      = AGG("TRBAL",T) - HT.L(T) - F(T);
 AGG("AIR",TT)$T(TT) = HT.L(TT)/DT.L(TT);
 AGG("DTT",TT)    = DT.L(TT);
 AGG("RTT",TT)    = RT.L(TT);
 AGG("BTT",TT)    = B.L(TT);
 AGG("HTT",T)     = HT.L(T);
 DISPLAY DELTA,LIBOR,RHOK,GRN,GRL,GRLP,GRB,GRAE,GRME;
 DISPLAY W.L,KTERM.L,KTERM.UP,DTERM.L,DTERM.UP,YTERM;
 DISPLAY AGG,X.L,Z,C.L,INV.L,DK.L,K.L,GOV;
 DISPLAY E.L,E.UP,M.L,M.UP,D.L,R.L,B.L,H.L;
 DISPLAY SWAGE,PRICE,SEMP,SINT,SEXP;
```

SYMBOL LISTING

SETS

AG	MACROECONOMIC AGREGATES
G	VINTAGES FOR DEBT
ICON	CONSUMMABLE PRODUCTS
ITR	EXPORTABLE PRODUCTS
I	PRODUCTS
J	ALIASED WITH I
TINIT	INITIAL YEAR
TTERM	TERMINAL YEAR
TT	PERIODS
T	ALL PERIODS EXCEPT INITIAL

PARAMETERS

AGG	TABLE OF ECONOMIC AGGREGATES
ALPHA1	SLOPE OF TERMINAL DEBT SPREAD RATE FUNCTION
ALPHA	SLOPE OF THE SPREAD RATE FUNCTION
A	INPUT-OUTPUT COEFFICIENTS FOR THE BASIC TECHNOLOGY
BETAMNC	ELAST OF CONSUMPTION OF NCI
BETA	ELASTICITY OF EXPENDITURE WRT INCOME
BO	BORROWING IN INITITAL PERIOD
CTO	TOTAL CONSUMPTION
CO	CONSUMPTION IN THE INITIAL PERIOD
DELTA	DISCOUNT RATE FOR UTILITY
DEPREF	DEPRECIATION FACTORS FOR CAPITAL STOCK
DEPR	DEPRECIATION RATE PER SECTOR
DFTERM	DISCOUNT FOR THE TERMINAL CONDITION
DF	DISCOUNT FACTOR PER PERIOD
DOT	TOTAL INITIAL DEBT
DO	INITIAL DEBT BY MATURITY
EO	INITIAL EXPORTS
FTERM	FOREIGN EXCHG TRANSF IN LAST YEAR
F	FOREIGN EXCHANGE TRANSFERS ABROAD
GAMMAMNC	MINIMUM CONSUMP OF NCI
GAMMAT	TOTAL MINIMUM CONSUMPTION AT INITIAL YEAR P
GAMMA	MINIMUM CONSUMPTION LEVEL OF SEVERAL GOODS
GLAG	GESTATION LAG PER SECTOR
GLET	FUNCTION:G LESS OR EQUAL TO T
GLTT	FUNCTION:G LESS THAN T
GOV	GOVERNMENT EXPENDITURES
GRAE	MAX RATE OF GROWTH OF AGRICULT EXPORTS
GRB	MAXIMUM RATE OF CHANGE OF BORROW

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1GAMS 2.00 CDC NOS 1.4                         85/08/03.   16.56.07.  PAGE     18
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 SYMBOL LISTING


 PARAMETERS

 GRG         GROWTH RATE OF GOVERNMENT
 GRLP        GROWTH RATE OF LABOR PRODUCTIVITY
 GRL         PER ANUUM RATE OF GROWTH OF LABOR FORCE
 GRME        MAX RATE OF GROWTH OF MANUFAC EXPORTS
 GRN         GROWTH RATE OF POPULATION
 GRY         GROWTH RATE OF POTENTIAL INCOME
 GTERM       TOTAL GOVERNMENT IN TERMINAL YEAR
 GO          INITIAL GOVERNMENT EXPENDITURES
 INVO        INITIAL DELIVERIES TO INVESTMENT
 ISH         SHARE OF SECTORS IN CAPITAL FORMATION
 KAVGO       INITITAL AVERAGE NET CAPITAL TO OUTPUT RATIO
 KR          CAPITAL TO OUTPUT RATIO
 KSH         CAPITAL SHARES MATRIX
 KONET       DEPRECIATED INITIAL STOCK
 KOT         TOTAL INITIAL CAPITAL STOCK
 KO          INITIAL CAPITAL STOCK
 LIBOR       FIXED PART OF REAL INT RATE ON FOREIGN BORROW
 LR          EMPLOYMENT MEASURED AS LABOR SHARE IN OUTPUT
 LS          LABOR SUPPLY
 LU          LABOR UNITS: EMPLOYED PER UNIT OF PRODUCT
 LO          INITIAL LABOR SUPPLY IN FORMAL MARKET
 MNCO        CONSUMP OF NCI IN FIRST PERIOD
 MNGO        NIC IN GOVERNMENT IN 1983
 MNG         PROJECTION OF NCI IN GOVERNMENT
 MNK         NON-COMPETITVE IMPORTS REQUIREMENT IN INVESTMENT
 MNX         NON-COMPETITVE IMPORTS REQUIREMENT IN PRODUCTION
 MO          CONPETITIVE IMPORTS IN 1983
 NTERM       TERMINAL POPULATION
 NYPP        NUMBER OF YEARS PER PERIOD
 NYP         NUMBER OF YEARS IN EACH PERIOD
 NO          INITIAL POPULATION IN MILLIONS
 N           POPULATION IN MILLIONS
 PETSO       PETROLEUM SUPPLY IN 1983 IN BBL THOS PER DAY
 PETS        PETROLEUM SUPPLY IN BBL THOUS PER DAY
 PE          EXPORT PRICES
 PMNC        PRICE OF NCI IN CONSUMPTION
 PMNG        PRICE OF NCI IN GOVERNMENT
 PMN         PRICE OF NCI IN PRODUCTION
 PM          COMPETITVE IMPORTS PRICE
 PRICE       RELATIVE PRICES OF GOODS
```

SYMBOL LISTING

PARAMETERS

RHOD	INTEREST RATE ON TERMINAL DEBT
RHOK	INTEREST RATE ON NON-HUMAN WEALTH
RS	REPAYMENT SCHEDULE
RO	REPAYMENT OF INITIAL DEBT (CUMMUL FOR PERIOD)
SCALE	SCALE FACTOR FOR UTITY FUNCTION
SEMP	SECTORAL EMPLOYMENT
SEXP	SHADOW PRICE OF EXPORTS
SHVAO	INITIAL SHARE OF VALUE ADDED IN GROSS OUTPUT
SINT	SECTORAL INTEREST RATES
STCHO	STOCK CHANGE
SWAGE	SECTORAL YEARLY WAGES IN CR$ MILL
XO	GROSS OUTPUT LEVELS IN 1983
YTERM	ESTIMATE OF POS-TERMINAL INCOME
YO	INCOME IN INITIAL PERIOD
Z	INTERMEDIATE DEMANDS

VARIABLES

B	BORROWING OF FOREING DEBT IN PERIOD T
C	CONSUMPTION OF COMMODITY I IN PERIOD T
DKTERM	PHYSICAL INVESTMENT IN LAST PERIOD
DK	INVESTMENT BY SECTOR J IN PERIOD T
DTERM	TERMINAL FOREIGN DEBT
DT	TOTAL DEBT OUTSTANDING IN PERIOD T
D	DEBT OUTSTANDING IN T CONTRACTED IN G
E	EXPORTS OF COMMODITY I IN PERIOD T
HR	INTEREST RATE ON FOREING BORROWING
HT	TOTAL INTEREST PAYMENTS IN PERIOD T
H	INTEREST PAYMENTS IN PERIOD T OF DEBT VINTAGE G
INV	DELIVERIES TO INVESTMET OF COMMODITY I IN FERIOD T
KTERM	TERMINAL CAPITAL STOCK
KT	TOTAL CAPITAL STOCKT IN YEAR T
K	CAPITAL STOCK OF SECTOR J IN PERIOD T
MNC	NON-COMPETITIVE IMPORTS IN CONSUMPTION
M	COMPETITIVE IMPORTS OF GOOD I IN PERIOD T
RT	TOTAL REPAYMENT IN PERIOD T
R	REPAYMENT IN PERIOD T ON DEBT OF VINTAGE TT
UO	VALUE OF OBJECTIVE FUNCTION
W	POST TERMINAL UTILITY
X	GROSS OUTPUT OF SECTOR J IN YEAR T
Y	OUTPUT INDEX IN PERIOD T

SYMBOL LISTING

EQUATIONS

CAPFOR	CAPITAL FORMATION REQUIREMENTS
CAPREQ	CAPITAL REQUIREMENT RESTRICTION
DEBACC	ACCOUNTING FOR DEBT DUE TO BORROWING
DEBREP	ACCOUNTING FOR DEBT REPAYMENT
DTOT	TOTALIZATION OF DEBTS PER PERIOD
FEXBAL	FOREIGN EXCHANGE BALANCES
GNPDEF	DEFINITION OF GROSS NATIONAL PRODUCT
HCALC	CALCULATION OF INTEREST COST OF DEBT
HRATE	CALCULATION OF INTEREST RATE
HTOT	TOTALIZATION OF INTEREST PER PERIOD
ININV	INITIAL INVESTMENT ALLOCATION
INVDEF	DEFINITION OF INVESTMENT PER SECTOR
KTOT	TOTAL CAPITAL STOCK ACROSS SECTORS
LABREQ	FABOR REQUIREMENTS BLANCE
MATBAL	MATERIAL BALANCES
OBJ	OBJECTIVE FUNCTION DEFINITION
RCALC	CALCULATION OF AMORTIZATION REPAYMENTS
RTOT	TOTALIZATION OF REPAYMENTS PER PERIOD
TERCAP	CALCULATION OF TERMINAL CAPITAL STOCK
TERDEB	CALCULATION OF TERMINAL DEBT
TERINV	INVESTMENT ALLOCATION IN THE TERMINAL YEAR
TERUTIL	TERMINAL UTILITY

MODEL STATISTICS

```
NUMBER OF MAJOR ROWS = 22
NUMBER OF MINOR ROWS = 328
NUMBER OF MAJOR COLS = 23
NUMBER OF MINOR COLS = 461
NUMBER OF NON-ZEROES = 1976
NUMBER OF NL N-Z     = 98
SIZE OF NL CODE      = 1685
SIZE OF NL CONPOOL   = 39
MODEL GENERATION     =        29.076 SECONDS


EXECUTION TIME       =        34.770 SECONDS
```

APPENDIX C

SOLUTION REPORT FOR THE BASE CASE

```
**** SOLVER STATUS      1 NORMAL COMPLETION
**** MODEL STATUS       2 LOCALLY OPTIMAL
**** OBJECTIVE VALUE          27230572.2745

 RESOURCE USAGE, LIMIT         408.705      1000.000
 ITERATION COUNT, LIMIT       1202          3000
 EVALUATION ERRORS               0             0

     M I N O S  ---  VERSION  5.0   APR  1984
     = = = = =
     COURTESY OF B. A. MURTAGH AND M. A. SAUNDERS,
                 DEPARTMENT OF OPERATIONS RESEARCH,
                 STANFORD UNIVERSITY,
                 STANFORD   CALIFORNIA   94305   U.S.A.


 WORK SPACE NEEDED (ESTIMATE)  --    36727 WORDS.
 WORK SPACE AVAILABLE          --    43038 WORDS.
 (MAXIMUM OBTAINABLE           --    85700 WORDS.)


 EXIT -- OPTIMAL SOLUTION FOUND
```

```
----    656 PARAMETER DELTA      =        0.040 DISCOUNT RATE FOR UTILITY

            PARAMETER LIBOR      =        5.000 FIXED PART OF REAL INT RATE
                                                ON FOREIGN BORROW
            PARAMETER RHOK       =        0.082 INTEREST RATE ON NON-HUMAN
                                                WEALTH
            PARAMETER GRN        =        0.025 GROWTH RATE OF POPULATION
            PARAMETER GRL        =        0.030 PER ANUUM RATE OF GROWTH OF
                                                LABOR FORCE
            PARAMETER GRLP       =        0.020 GROWTH RATE OF LABOR
                                                PRODUCTIVITY
            PARAMETER GRB        =        0.150 MAXIMUM RATE OF CHANGE OF
                                                BORROW
            PARAMETER GRAE       =        0.050 MAX RATE OF GROWTH OF
                                                AGRICULT EXPORTS
            PARAMETER GRME       =        0.100 MAX RATE OF GROWTH OF MANUFAC
                                                EXPORTS

----    657 VAR.L      W         =    1.5538E+7 POST TERMINAL UTILITY
            VAR.L      KTERM     =  1108310.250 TERMINAL CAPITAL STOCK
            VAR.UP     KTERM     =  1700000.000 TERMINAL CAPITAL STOCK
            VAR.L      DTERM     =    65359.814 TERMINAL FOREIGN DEBT
            VAR.UP     DTERM     =   250000.000 TERMINAL FOREIGN DEBT
            PARAMETER YTERM      =   240000.000 ESTIMATE OF POS-TERMINAL
                                                INCOME

----    658 PARAMETER AGG         TABLE OF ECONOMIC AGGREGATES
```

	1984	1988	1992	1996	2000	2004
XT	207777.845	250651.889	303714.812	368044.572	445744.941	542421.452
ZT	90539.899	109387.448	132312.569	160707.462	194659.259	237979.704
YT	111319.219	134127.583	162621.355	196571.722	237804.527	287505.195
CT	76631.549	91388.837	112177.718	134820.397	163186.639	193828.345
INVT	27392.124	35225.631	41310.708	50152.051	60859.276	75778.705
GOVT	4652.407	5236.325	5893.530	6633.220	7465.747	8402.765
ET	12927.530	15669.996	22022.520	30407.392	39998.153	53774.582
MNT	5918.727	7136.858	8780.888	10765.388	13281.155	16936.553
MT	10284.391	13393.207	18783.121	25441.338	33705.288	44279.201
TRBAL	2643.139	2276.790	3239.399	4966.054	6292.865	9495.381
DTT	46385.800	53672.151	64518.916	74261.785	79039.452	79057.468
RTT	7596.100	7324.000	7143.233	9750.819	10319.037	10286.672
HTT	3491.046	4014.801	4701.437	5186.790	5323.689	5097.287
FET	973.680	973.680	973.680	973.680	973.680	973.680
CA	-1821.588	-2711.691	-2435.717	-1194.417	-4.504	3424.414
BTT	9417.688	10035.691	9578.950	10945.235	10323.541	6862.258
KT	358294.848	426727.221	517795.943	623056.131	751363.171	907985.313
DKT	28946.768	36951.675	43481.330	52742.945	64084.466	80205.232

658 PARAMETER AGG TABLE OF ECONOMIC AGGREGATES

	1984	1988	1992	1996	2000	2004
POP	131.374	145.013	160.067	176.684	195.026	215.272
EMP	31.999	35.623	40.008	44.743	50.071	56.019
CPI	11.701	8.798	6.306	4.720	3.520	2.706
INTR	0.168	0.148	0.129	0.124	0.127	0.113
WAGE	2.335	2.371	2.653	2.706	2.661	2.843
EXGR	1.086	1.027	1.027	1.023	1.022	1.022
AIR	0.075	0.075	0.073	0.070	0.067	0.064

---- 658 VAR.L X GROSS OUTPUT OF SECTOR J IN YEAR T

	1984	1988	1992	1996	2000	2004
AGRIC	18764.683	20852.900	26115.255	31287.246	37542.103	45160.352
AGROP	21679.999	22585.644	29952.553	35370.563	41864.958	49541.205
CONST	18287.610	24107.569	28054.462	34146.601	41248.851	50686.498
MANCG	18491.141	23164.447	26293.300	32677.142	38353.481	45984.855
MANOG	47000.510	60102.541	75751.362	96715.741	123616.951	159201.520
PETRO	16910.385	19331.093	19331.093	19331.093	19331.093	19331.093
UTILT	4827.461	5899.004	7324.211	9029.605	11108.310	13648.195
TRCOM	8544.441	10319.179	12389.336	14896.090	18079.813	21475.098
SERVC	53271.615	64289.513	78503.241	94590.490	114599.381	137392.636

---- 658 PARAMETER Z INTERMEDIATE DEMANDS

	1984	1988	1992	1996	2000	2004
AGRIC	12438.026	13760.089	17750.338	21401.066	25821.446	31271.445
AGROP	5730.472	6287.617	8107.631	9689.788	11608.637	13900.491
MANCG	7290.522	9153.478	10916.931	13573.099	16552.867	20424.284
MANOG	27722.180	34902.171	42416.646	52838.419	65284.783	81619.484
PETRO	17674.445	21183.755	23934.615	27508.533	31892.778	37330.127
UTILT	3163.718	3876.166	4771.272	5890.630	7251.118	8958.702
TRCOM	4279.496	5122.136	6048.919	7190.665	8567.125	10309.414
SERVC	12241.040	15102.037	18366.217	22615.261	27680.504	34165.757

---- 658 VAR.L C CONSUMPTION OF COMMODITY I IN PERIOD T

	1984	1988	1992	1996	2000	2004
AGRIC	4458.534	4651.910	5479.643	6386.900	7472.518	8718.023
AGROP	12754.119	14499.415	17139.278	19969.384	23323.486	27224.388
MANCG	3431.342	4225.504	5293.350	6512.662	8046.392	9705.578
MANOG	11535.487	14355.566	18064.576	22199.248	27363.970	33070.490
PETRO	3292.913	4056.253	5007.670	6058.391	7367.024	8786.084
UTILT	1580.313	1928.937	2447.252	3020.024	3723.311	4538.809
TRCOM	3850.092	4723.692	5801.408	7089.544	8806.075	10345.452
SERVC	35728.749	42947.561	52944.540	63584.246	77083.863	91439.522

---- 658 VAR.L INV DELIVERIES TO INVESTMET OF COMMODITY I IN FERIOD T

	1984	1988	1992	1996	2000	2004
AGRIC	217.012	436.950	452.819	546.396	663.147	818.093
CONST	18287.610	24107.569	28054.462	34146.601	41248.851	50686.498
MANCG	5504.383	6505.634	7852.998	9467.064	11636.724	15027.252
MANOG	950.904	1158.906	1379.597	1667.985	2039.527	2571.380
TRCOM	79.278	95.660	113.913	137.434	168.116	214.148
SERVC	2352.937	2920.913	3456.918	4186.571	5102.911	6461.333

---- 658 VAR.L DK INVESTMENT BY SECTOR J IN PERIOD T

	1983	1984	1988	1992	1996	2000
AGRIC		2127.568	4283.826	4439.401	5356.826	6501.439
AGROP	2038.695	1497.412	4000.868	3652.169	4349.406	5143.979
CONST	1347.727	1244.684	1108.090	1503.872	1785.710	2279.845
MANCG	2372.039	2036.324	1806.893	2824.190	2893.599	3660.782
MANOG	4113.518	6234.506	7619.227	9999.565	12810.066	16756.825
PETRO	1082.748	2452.357	1367.909	1367.909	1367.909	1367.909
UTILT	600.358	1507.163	1944.666	2357.475	2885.258	3534.041
TRCOM	181.227	750.805	889.641	1073.092	1329.897	1504.531
SERVC	13922.498	11095.949	13930.555	16263.656	19964.274	23335.114

+	2004
AGRIC	8020.523
AGROP	7218.471
CONST	2406.157
MANCG	8020.523
MANOG	19249.256
PETRO	3208.209
UTILT	4812.314
TRCOM	3208.209
SERVC	24061.569

---- 658 VAR.L K CAPITAL STOCK OF SECTOR J IN PERIOD T

	1984	1988	1992	1996	2000	2004
AGRIC	48975.823	54426.069	68160.816	81659.711	97984.889	117868.519
AGROP	32953.599	34330.178	45527.880	53763.255	63634.736	75302.632
CONST	10460.513	13789.530	16047.152	19531.856	23594.343	28992.677
MANCG	20192.325	25295.576	28712.283	35683.439	41882.001	50215.461
MANOG	60066.652	76811.048	96810.240	123602.717	157982.463	203459.542
PETRO	35089.048	40112.018	40112.018	40112.018	40112.018	40112.018
UTILT	17166.452	20976.858	26044.894	32109.276	39501.151	48532.981
TRCOM	7989.052	9648.432	11584.029	13927.845	16904.625	20079.217
SERVC	125401.382	151337.513	184796.630	222666.014	269766.944	323422.266

---- 658 PARAMETER GOV GOVERNMENT EXPENDITURES

	1984	1988	1992	1996	2000	2004
AGRIC	33.166	37.329	42.014	47.287	53.222	59.901
AGROP	73.233	82.424	92.769	104.413	117.517	132.267
MANCG	106.914	120.333	135.435	152.434	171.566	193.099
MANOG	762.509	858.211	965.924	1087.156	1223.603	1377.176
PETRO	308.691	347.434	391.041	440.120	495.358	557.530
UTILT	83.430	93.901	105.687	118.951	133.881	150.684
TRCOM	335.574	377.691	425.095	478.448	538.498	606.084
SERVC	2948.890	3319.002	3735.566	4204.412	4732.103	5326.023

---- 659 VAR.L E EXPORTS OF COMMODITY I IN PERIOD T

	1984	1988	1992	1996	2000	2004
AGRIC	1617.945	1966.622	2390.442	2905.597	3531.771	4292.890
AGROP	3122.175	1716.187	4612.874	5606.978	6815.316	8284.060
MANCG	2157.980	3159.499	2094.585	2971.883	1945.997	634.643
MANOG	6029.430	8827.688	12924.619	18922.934	27705.068	40562.990

---- 659 VAR.UP E EXPORTS OF COMMODITY I IN PERIOD T

	1984	1988	1992	1996	2000	2004
AGRIC	1617.945	1966.622	2390.442	2905.597	3531.771	4292.890
AGROP	3122.175	3795.023	4612.874	5606.978	6815.316	8284.060
MANCG	2157.980	3159.499	4625.822	6772.666	9915.860	14517.810
MANOG	6029.430	8827.688	12924.619	18922.934	27705.068	40562.990

---- 659 VAR.L M COMPETITIVE IMPORTS OF GOOD I IN PERIOD T

	1984	1988	1992	1996	2000	2004
MANCG					0.066	
PETRO	4365.664	6256.349	10002.232	14675.950	20424.067	27342.648

---- 659 VAR.UP M COMPETITIVE IMPORTS OF GOOD I IN PERIOD T

ALL +INF

---- 659 VAR.L D DEBT OUTSTANDING IN T CONTRACTED IN G

	1983	1984	1988	1992	1996	2000
1983	46385.800	46385.800	16001.400	1773.700	559.100	226.200
1984			37670.751	22602.450	11301.225	
1988				40142.765	24085.659	12042.830
1992					38315.801	22989.481
1996						43780.942

+	2004
1992	11494.740
1996	26268.565
2000	41294.163

---- 659 VAR.L R REPAYMENT IN PERIOD T ON DEBT OF VINTAGE TT

	1984	1988	1992	1996	2000	2004
1983	7596.100	3556.925	303.650	83.225	56.550	
1984		3767.075	2825.306	2825.306		
1988			4014.277	3010.707	3010.707	
1992				3831.580	2873.685	2873.685
1996					4378.094	3283.571
2000						4129.416

---- 659 VAR.L B BORROWING OF FOREING DEBT IN PERIOD T

1984 9417.688, 1988 10035.691, 1992 9578.950, 1996 10945.235
2000 10323.541, 2004 6862.258

---- 659 VAR.L H INTEREST PAYMENTS IN PERIOD T OF DEBT VINTAGE G

	1984	1988	1992	1996	2000	2004
1983	3491.046	1204.283	133.491	42.078	17.024	
1984		2810.518	1686.311	843.155		
1988			2881.635	1728.981	864.491	
1992				2572.575	1543.545	771.773
1996					2898.629	1739.178
2000						2586.337

---- 660 PARAMETER SWAGE SECTORAL YEARLY WAGES IN CR$ MILL

	1984	1988	1992	1996	2000	2004
AGRIC	0.808	0.821	0.918	0.937	0.921	0.984
AGROP	3.790	3.850	4.307	4.393	4.320	4.615
CONST	1.398	1.420	1.589	1.620	1.593	1.702
MANCG	3.247	3.298	3.690	3.763	3.701	3.954
MANOG	2.886	2.931	3.280	3.345	3.289	3.514
PETRO	4.707	4.781	5.349	5.456	5.365	5.732
UTILT	2.586	2.626	2.938	2.997	2.947	3.148
TRCOM	1.778	1.806	2.021	2.061	2.027	2.165
SERVC	2.021	2.053	2.297	2.343	2.304	2.461

---- 660 PARAMETER PRICE RELATIVE PRICES OF GOODS

	1984	1988	1992	1996	2000	2004
AGRIC	0.710	0.943	0.942	0.939	0.942	0.931
AGROP	0.990	1.027	1.009	1.003	1.007	0.990
CONST	1.172	1.046	1.093	1.095	1.090	1.104
MANCG	1.035	1.015	1.027	1.023	1.022	1.022
MANOG	1.037	1.000	1.003	0.999	0.999	0.995
PETRO	1.086	1.027	1.027	1.023	1.022	1.022
UTILT	1.224	1.214	1.207	1.198	1.199	1.183
TRCOM	1.272	1.258	1.309	1.317	1.309	1.351
SERVC	0.966	0.948	0.947	0.950	0.950	0.954

---- 660 PARAMETER SEMP SECTORAL EMPLOYMENT

	1984	1988	1992	1996	2000	2004
AGRIC	7.119	7.297	8.429	9.314	10.309	11.438
AGROP	0.660	0.634	0.775	0.844	0.922	1.006
CONST	4.810	5.848	6.277	7.047	7.852	8.900
MANCG	1.101	1.272	1.332	1.527	1.653	1.828
MANOG	2.921	3.446	4.006	4.717	5.561	6.606
PETRO	0.280	0.296	0.273	0.251	0.232	0.214
UTILT	0.797	0.898	1.029	1.170	1.328	1.505
TRCOM	2.716	3.025	3.350	3.715	4.159	4.557
SERVC	11.595	12.907	14.537	16.157	18.055	19.965

---- 660 PARAMETER SINT SECTORAL INTEREST RATES

	1984	1988	1992	1996	2000	2004
AGRIC	0.047	0.125	0.109	0.105	0.108	0.094
AGROP	0.181	0.151	0.131	0.126	0.129	0.115
CONST	0.331	0.134	0.132	0.122	0.124	0.098
MANCG	0.159	0.149	0.135	0.128	0.130	0.116
MANOG	0.173	0.148	0.130	0.125	0.127	0.113
PETRO	0.193	0.144	0.130	0.124	0.126	0.110
UTILT	0.149	0.146	0.128	0.123	0.125	0.112
TRCOM	0.168	0.166	0.143	0.139	0.141	0.136
SERVC	0.166	0.156	0.131	0.128	0.131	0.117

---- 660 PARAMETER SEXP SHADOW PRICE OF EXPORTS

	1984	1988	1992	1996	2000	2004
AGRIC	0.376	0.084	0.086	0.084	0.080	0.091
AGROP	0.096	EPS	0.019	0.020	0.015	0.031
MANCG	0.051	0.012	-1.3836E-5	-3.0040E-4	1.9192E-5	-1.9051E-4
MANOG	0.049	0.027	0.024	0.024	0.023	0.026
PETRO	EPS	EPS	EPS	EPS	EPS	EPS

EXECUTION TIME = 17.498 SECONDS

APPENDIX D

LISTINGS CONTAINING THE MAIN RESULTS OF THE SENSITIVITY RUNS

<u>Table of contents</u>

LISTING D.A.1

SENSITIVITY TO THE MODEL'S HORIZON
(7 PERIODS)

```
SETS
TT  PERIODS  /1983,1984,1988,1992,1996,2000,2004,2008/
     TINIT(TT)     INITIAL YEAR  /1983/
     TTERM(TT)    TERMINAL YEAR  /2008/
     T(TT)  ALL PERIODS EXCEPT INITIAL  /1984,1988,
            1992,1996,2000,2004,2008/;
SET G(TT)  VINTAGES FOR DEBT       /1983,1984,1988,
            1992,1996,2000,2004,2008/;

PARAMETER PETS(TT)    PETROLEUM SUPPLY IN BBL THOUS PER DAY
    /1983  340
     1984  520,
     1988  600,
     1992  600,
     1996  600,
     2000  600,
     2004  600,
     2008  600/;

**** SOLVER STATUS     1 NORMAL COMPLETION
**** MODEL STATUS      2 LOCALLY OPTIMAL
**** OBJECTIVE VALUE         28390910.4520

 RESOURCE USAGE, LIMIT        565.874     1000.000
 ITERATION COUNT, LIMIT      1441         3000
 EVALUATION ERRORS              0            0

    M I N O S  ---  VERSION  5.0   APR  1984
    = = = = =
    COURTESY OF B. A. MURTAGH AND M. A. SAUNDERS,
                DEPARTMENT OF OPERATIONS RESEARCH,
                STANFORD UNIVERSITY,
                STANFORD   CALIFORNIA   94305   U.S.A.

 WORK SPACE NEEDED (ESTIMATE)  --    44744 WORDS.
 WORK SPACE AVAILABLE          --    52256 WORDS.
 (MAXIMUM OBTAINABLE           --    85700 WORDS.)

 EXIT -- OPTIMAL SOLUTION FOUND
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1GAMS 2.00 CDC NOS 1.4                              85/08/11.   16.35.13.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 E X E C U T I N G


 ----     657 PARAMETER DELTA        =         0.040 DISCOUNT RATE FOR UTILITY
              PARAMETER LIBOR        =         5.000 FIXED PART OF REAL INT RATE
                                                     ON FOREIGN BORROW
              PARAMETER RHOK         =         0.082 INTEREST RATE ON NON-HUMAN
                                                     WEALTH
              PARAMETER GRAE         =         0.050 MAX RATE OF GROWTH OF
                                                     AGRICULT EXPORTS
              PARAMETER GRME         =         0.100 MAX RATE OF GROWTH OF MANUFAC
                                                     EXPORTS

 ----     658 VAR.L     W            =     1.4905E+7 POST TERMINAL UTILITY
              VAR.L     KTERM        =   1314131.149 TERMINAL CAPITAL STOCK
              VAR.UP    KTERM        =   1700000.000 TERMINAL CAPITAL STOCK
              VAR.L     DTERM        =     72187.703 TERMINAL FOREIGN DEBT
              VAR.UP    DTERM        =    250000.000 TERMINAL FOREIGN DEBT
              PARAMETER YTERM        =    292000.000 ESTIMATE OF POS-TERMINAL
                                                     INCOME

 ----     659 PARAMETER AGG         TABLE OF ECONOMIC AGGREGATES
```

	1984	1988	1992	1996	2000	2004
XT	207789.836	250555.950	303360.343	367798.842	444051.633	540410.892
ZT	90552.835	109299.681	132032.002	160368.855	193431.036	235272.490
YT	111317.076	134139.046	162561.724	196769.893	237463.417	288537.967
CT	76669.464	91552.995	112474.882	135786.909	164041.899	202161.374
INVT	27367.377	35182.121	41520.434	49558.150	62446.605	70015.711
GOVT	4652.407	5236.325	5893.530	6633.220	7465.747	8402.765
ET	12927.530	15552.044	21446.302	30161.293	40616.149	53139.940
MNT	5919.925	7117.222	8766.617	10660.094	13157.180	16600.436
MT	10299.701	13384.439	18773.424	25369.679	37106.984	45181.823
TRBAL	2627.829	2167.605	2672.878	4791.614	3509.165	7958.117
DTT	46385.800	53733.390	65041.279	77247.308	83755.362	96501.036
RTT	7596.100	7330.124	7196.388	10059.411	10852.617	12195.910
HTT	3491.046	4020.897	4750.706	5444.947	5721.903	6501.812
FET	973.680	973.680	973.680	973.680	973.680	973.680
CA	-1836.897	-2826.972	-3051.507	-1627.013	-3186.419	482.625
BTT	9432.997	10157.096	10247.895	11686.425	14039.036	11713.286
KT	358296.813	426623.796	517450.097	623609.054	749124.989	912287.398
DKT	28920.471	36889.308	43693.370	52062.054	65637.017	74253.883
POP	131.374	145.013	160.067	176.684	195.026	215.272
EMP	31.998	35.617	40.042	44.735	50.252	55.907
CPI	11.691	8.770	6.279	4.672	3.493	2.550
INTR	0.168	0.147	0.130	0.127	0.124	0.127
WAGE	2.324	2.387	2.640	2.663	2.703	2.730
EXGR	1.082	1.026	1.027	1.023	1.023	1.032
AIR	0.075	0.075	0.073	0.070	0.068	0.067

```
1GAMS 2.00 CDC NOS 1.4                              85/08/11.   16.35.13.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 E X E C U T I N G

         659 PARAMETER AGG        TABLE OF ECONOMIC AGGREGATES

    +         2008

 XT      655638.676
 ZT      286843.677
 YT      347902.209
 CT      238080.329
 INVT     87691.590
 GOVT      9457.386
 ET       85861.834
 MNT      20892.790
 MT       73188.930
 TRBAL    12672.904
 DTT      94570.538
 RTT      12402.952
 HTT       6103.515
 FET        973.680
 CA        5595.709
 BTT       6807.244
 KT     1088222.350
 DKT      92813.994
 POP        237.620
 EMP         61.819
 CPI          2.002
 INTR         0.118
 WAGE         2.771
 EXGR         1.016
 AIR          0.065
```

LISTING D.A.2

SENSITIVITY TO THE MODEL'S HORIZON
(8 PERIODS)

```
SETS
TT   PERIODS  /1983,1984,1988,1992,1996,2000,2004,2008,2012/
     TINIT(TT)      INITIAL YEAR  /1983/
     TTERM(TT)     TERMINAL YEAR  /2012/
     T(TT)  ALL PERIODS EXCEPT INITIAL  /1984,1988,
            1992,1996,2000,2004,2008,2012/;
SET G(TT)  VINTAGES FOR DEBT        /1983,1984,1988,
            1992,1996,2000,2004,2008,2012/;

PARAMETER PETS(TT)    PETROLEUM SUPPLY IN BBL THOUS PER DAY
    /1983  340
      1984  520,
      1988  600,
      1992  600,
      1996  600,
      2000  600,
      2004  600,
      2008  600,
      2012  600/;

**** SOLVER STATUS     1 NORMAL COMPLETION
**** MODEL STATUS      2 LOCALLY OPTIMAL
**** OBJECTIVE VALUE         29502315.4737

 RESOURCE USAGE, LIMIT        759.989     1000.000
 ITERATION COUNT, LIMIT      1716         3000
 EVALUATION ERRORS              0            0

     M I N O S  ---  VERSION  5.0   APR  1984
     = = = = =
     COURTESY OF B. A. MURTAGH AND M. A. SAUNDERS,
                 DEPARTMENT OF OPERATIONS RESEARCH,
                 STANFORD UNIVERSITY,
                 STANFORD   CALIFORNIA   94305   U.S.A.

 WORK SPACE NEEDED (ESTIMATE)  --   53522 WORDS.
 WORK SPACE AVAILABLE          --   62291 WORDS.
 (MAXIMUM OBTAINABLE           --   85700 WORDS.)

 EXIT -- OPTIMAL SOLUTION FOUND
```

```
1GAMS 2.00 CDC NOS 1.4                          85/08/13.   23.19.09.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 E X E C U T I N G


 ----     658 PARAMETER DELTA         =         0.040 DISCOUNT RATE FOR UTILITY
              PARAMETER LIBOR         =         5.000 FIXED PART OF REAL INT RATE
                                                      ON FOREIGN BORROW
              PARAMETER RHOK          =         0.082 INTEREST RATE ON NON-HUMAN
                                                      WEALTH
              PARAMETER GRAE          =         0.050 MAX RATE OF GROWTH OF
                                                      AGRICULT EXPORTS
              PARAMETER GRME          =         0.100 MAX RATE OF GROWTH OF MANUFAC
                                                      EXPORTS

 ----     659 VAR.L     W             =    1.4280E+7 POST TERMINAL UTILITY
              VAR.L     KTERM         =  1548520.486 TERMINAL CAPITAL STOCK
              VAR.UP    KTERM         =  1700000.000 TERMINAL CAPITAL STOCK
              VAR.L     DTERM         =    75743.437 TERMINAL FOREIGN DEBT
              VAR.UP    DTERM         =   250000.000 TERMINAL FOREIGN DEBT
              PARAMETER YTERM         =   354000.000 ESTIMATE OF POS-TERMINAL
                                                      INCOME

 ----     660 PARAMETER AGG           TABLE OF ECONOMIC AGGREGATES
```

	1984	1988	1992	1996	2000	2004
XT	207797.859	250524.631	303261.578	367507.017	443762.000	537758.494
ZT	90561.472	109274.668	131940.248	160135.259	193040.882	233251.691
YT	111315.387	134136.619	162572.732	196728.038	237712.773	288824.606
CT	76691.234	91595.774	112639.326	136033.748	165155.198	203237.294
INVT	27351.888	35195.049	41473.035	49764.114	61654.472	72028.479
GOVT	4652.407	5236.325	5893.530	6633.220	7465.747	8402.765
ET	12927.530	15496.136	21331.562	29645.865	38052.426	53139.954
MNT	5921.000	7113.345	8748.597	10643.720	13008.345	15682.197
MT	10307.673	13386.665	18764.720	25348.908	34615.071	47983.885
TRBAL	2619.857	2109.471	2566.842	4296.956	3437.355	5156.068
DTT	46385.800	53765.276	65318.419	78053.637	86825.961	100915.338
RTT	7596.100	7333.313	7224.580	10145.349	11180.917	12705.349
HTT	3491.046	4024.076	4776.966	5516.357	5986.019	6878.460
FET	973.680	973.680	973.680	973.680	973.680	973.680
CA	-1844.869	-2888.286	-3183.805	-2193.081	-3522.344	-2696.072
BTT	9440.969	10221.598	10408.385	12338.430	14703.261	15401.421
KT	358298.595	426561.640	517426.040	623344.915	749724.112	909127.500
DKT	28904.551	36897.367	43632.594	52267.261	64716.057	75541.982
POP	131.374	145.013	160.067	176.684	195.026	215.272
EMP	31.997	35.616	40.045	44.766	50.239	56.157
CPI	11.688	8.762	6.267	4.657	3.460	2.537
INTR	0.169	0.146	0.132	0.126	0.128	0.132
WAGE	2.310	2.411	2.615	2.695	2.658	2.585
EXGR	1.079	1.024	1.026	1.024	1.022	1.028
AIR	0.075	0.075	0.073	0.071	0.069	0.068

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1GAMS 2.00 CDC NOS 1.4                              85/08/13.   23.19.09.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 E X E C U T I N G
```

660 PARAMETER AGG   TABLE OF ECONOMIC AGGREGATES

+	2008	2012
XT	649774.332	804080.723
ZT	282224.130	351062.337
YT	347523.999	428684.023
CT	241579.199	300689.544
INVT	97513.445	87691.590
GOVT	9457.386	10644.371
ET	74675.643	105532.264
MNT	20026.204	24334.363
MT	75701.673	75873.745
TRBAL	-1026.031	29658.519
DTT	111699.625	149491.016
RTT	14273.076	18519.774
HTT	7448.137	10247.944
FET	973.680	973.680
CA	-9447.848	18436.895
BTT	23720.923	82.879
KT	1090710.316	1357079.067
DKT	102716.201	92813.994
POP	237.620	262.288
EMP	63.452	69.546
CPI	1.956	1.428
INTR	0.106	0.116
WAGE	2.978	2.789
EXGR	1.019	1.017
AIR	0.067	0.069

LISTING D.A.3

SENSITIVITY TO THE MODEL'S HORIZON (10 PERIODS)

```
SETS
TT  PERIODS  /1983,1984,1988,1992,1996,2000,2004,
                 2008,2012,2016,2020/
     TINIT(TT)     INITIAL YEAR  /1983/
     TTERM(TT)    TERMINAL YEAR  /2020/
     T(TT)  ALL PERIODS EXCEPT INITIAL  /1984,1988,
             1992,1996,2000,2004,2008,2012,2016,2020/;
SET G(TT)  VINTAGES FOR DEBT       /1983,1984,1988,
             1992,1996,2000,2004,2008,2012,2016,2020/;

PARAMETER PETS(TT)    PETROLEUM SUPPLY IN BBL THOUS PER DAY
    /1983  340
      1984  520,
      1988  600,
      1992  600,
      1996  600,
      2000  600,
      2004  600,
      2008  730,
      2012  880,
      2016 1070,
      2020 1300/;
```

```
**** SOLVER STATUS     ERROR INTERNAL SOLVER ERROR
**** MODEL STATUS      7 INTERMEDIATE NONOPTIMAL
**** OBJECTIVE VALUE         31549487.2275

 RESOURCE USAGE, LIMIT        1152.999     1500.000
 ITERATION COUNT, LIMIT       2084         3000
 EVALUATION ERRORS               0            0

    M I N O S  ---  VERSION  5.0   APR  1984
    = = = = =
    COURTESY OF B. A. MURTAGH AND M. A. SAUNDERS,
                DEPARTMENT OF OPERATIONS RESEARCH,
                STANFORD UNIVERSITY,
                STANFORD   CALIFORNIA   94305   U.S.A.

 WORK SPACE NEEDED (ESTIMATE)  --    73592 WORDS.
 WORK SPACE AVAILABLE          --    80818 WORDS.
 (MAXIMUM OBTAINABLE           --    85700 WORDS.)
  MAJOR ITERATIONS          41
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1GAMS 2.00 CDC NOS 1.4                              85/08/20.   00.10.45.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 C O M P I L A T I O N


----     662 PARAMETER DELTA      =        0.040 DISCOUNT RATE FOR UTILITY
             PARAMETER LIBOR      =        5.000 FIXED PART OF REAL INT RATE
                                                 ON FOREIGN BORROW
             PARAMETER RHOK       =        0.082 INTEREST RATE ON NON-HUMAN
                                                 WEALTH
             PARAMETER GRAE       =        0.050 MAX RATE OF GROWTH OF
                                                 AGRICULT EXPORTS
             PARAMETER GRME       =        0.100 MAX RATE OF GROWTH OF MANUFAC
                                                 EXPORTS

----     663 VAR.L     W          =    1.2976E+7 POST TERMINAL UTILITY
             VAR.L     KTERM      =  1700000.000 TERMINAL CAPITAL STOCK
             VAR.UP    KTERM      =  1700000.000 TERMINAL CAPITAL STOCK
             VAR.L     DTERM      =    97631.666 TERMINAL FOREIGN DEBT
             VAR.UP    DTERM      =   250000.000 TERMINAL FOREIGN DEBT
             PARAMETER YTERM      =   523000.000 ESTIMATE OF POS-TERMINAL
                                                 INCOME

----     664 PARAMETER AGG         TABLE OF ECONOMIC AGGREGATES
```

	1984	1988	1992	1996	2000	2004
XT	207799.204	250526.801	303270.528	367353.865	444151.344	538004.860
ZT	90562.858	109277.663	131943.179	160022.560	193291.885	233723.257
YT	111315.076	134134.814	162588.028	196664.146	237834.141	288049.381
CT	76693.777	91589.396	112659.850	136100.328	165146.655	201929.477
INVT	27350.357	35203.477	41426.148	49950.039	61169.109	73238.448
GOVT	4652.407	5236.325	5893.530	6633.220	7465.747	8402.765
ET	12927.530	15493.782	21366.457	29349.740	38052.270	53140.010
MNT	5921.270	7114.323	8739.322	10667.158	13025.319	16232.223
MT	10308.994	13388.166	18757.958	25369.180	33999.640	48661.319
TRBAL	2618.536	2105.616	2608.499	3980.560	4052.630	4478.691
DTT	46385.800	53770.562	65341.229	77918.445	87909.026	99914.333
RTT	7596.100	7333.841	7226.940	10132.362	11287.879	12616.058
HTT	3491.046	4024.603	4779.123	5504.525	6080.277	6781.731
FET	973.680	973.680	973.680	973.680	973.680	973.680
CA	-1846.191	-2892.667	-3144.304	-2497.645	-3001.327	-3276.721
BTT	9442.291	10226.508	10371.244	12630.007	14289.205	15892.778
KT	358298.897	426555.969	517457.284	623146.499	750414.872	907771.790
DKT	28903.069	36906.382	43576.358	52482.421	64229.099	77234.811
POP	131.374	145.013	160.067	176.684	195.026	215.272
EMP	31.996	35.617	40.042	44.783	50.193	56.159
CPI	11.684	8.762	6.265	4.654	3.459	2.559
INTR	0.169	0.145	0.132	0.126	0.128	0.129
WAGE	2.308	2.416	2.609	2.697	2.662	2.655
EXGR	1.079	1.023	1.025	1.024	1.021	1.023
AIR	0.075	0.075	0.073	0.071	0.069	0.068

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1GAMS 2.00 CDC NOS 1.4                                   85/08/20.   00.14.38.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 E X E C U T I N G
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664 PARAMETER AGG TABLE OF ECONOMIC AGGREGATES

+	2008	2012	2016	2020
XT	652943.507	787212.455	942935.780	1029805.503
ZT	283358.064	340989.620	402015.245	419756.641
YT	349443.316	421441.165	511947.119	581306.137
CT	248440.668	299401.324	388211.743	512829.605
INVT	84341.779	104895.994	111628.927	27802.459
GOVT	9457.386	10644.371	11980.333	13483.970
ET	67496.303	93292.925	115196.476	170765.100
MNT	20142.127	24781.670	28973.416	28742.725
MT	60292.819	86793.448	115070.360	143574.999
TRBAL	7203.484	6499.477	126.115	27190.102
DTT	113021.215	118216.814	126542.158	161575.740
RTT	14432.875	15347.305	16458.822	20035.012
HTT	7528.704	7607.133	7910.831	10230.403
FET	973.680	973.680	973.680	973.680
CA	-1298.900	-2081.336	-8758.395	15986.019
BTT	15731.775	17428.641	25217.218	4048.993
KT	1096259.644	1306906.815	1574237.632	1830020.393
DKT	89176.457	110632.910	117096.654	29426.508
POP	237.620	262.288	289.517	319.573
EMP	62.180	69.046	76.399	74.984
CPI	1.891	1.437	1.004	0.692
INTR	0.126	0.114	0.099	0.312
WAGE	2.656	2.859	3.029	
EXGR	1.018	1.011	1.016	1.072
AIR	0.067	0.064	0.063	0.063

LISTING D.B.1

SENSITIVITY TO THE DISCOUNT RATE
(DELTA = 5%)

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1GAMS 2.00 CDC NOS 1.4                              85/08/21.   01.25.26.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 E X E C U T I N G


 **** SOLVER STATUS     ERROR INTERNAL SOLVER ERROR
 **** MODEL STATUS      7 INTERMEDIATE NONOPTIMAL
 **** OBJECTIVE VALUE         20433838.2985

  RESOURCE USAGE, LIMIT         430.809      1000.000
  ITERATION COUNT, LIMIT      1273           3000
  EVALUATION ERRORS               0             0

      M I N O S  ---  VERSION  5.0   APR  1984
      = = = = =
      COURTESY OF B. A. MURTAGH AND M. A. SAUNDERS,
                  DEPARTMENT OF OPERATIONS RESEARCH,
                  STANFORD UNIVERSITY,
                  STANFORD   CALIFORNIA   94305   U.S.A.


  WORK SPACE NEEDED (ESTIMATE)  --    36727 WORDS.
  WORK SPACE AVAILABLE          --    43038 WORDS.
  (MAXIMUM OBTAINABLE           --    85700 WORDS.)

  MAJOR ITERATIONS          37
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1GAMS 2.00 CDC NOS 1.4                              85/08/21.   01.25.26.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 E X E C U T I N G


----      656 PARAMETER DELTA         =          0.050 DISCOUNT RATE FOR UTILITY
              PARAMETER LIBOR         =          5.000 FIXED PART OF REAL INT RATE
                                                       ON FOREIGN BORROW
              PARAMETER RHOK          =          0.092 INTEREST RATE ON NON-HUMAN
              PARAMETER GRAE          =          0.050 MAX RATE OF GROWTH OF
                                                       AGRICULT EXPORTS
              PARAMETER GRME          =          0.100 MAX RATE OF GROWTH OF MANUFAC
                                                       EXPORTS
                                                       WEALTH

----      657 VAR.L      W            =    9787035.667 POST TERMINAL UTILITY
              VAR.L      KTERM        =    1031915.793 TERMINAL CAPITAL STOCK
              VAR.UP     KTERM        =    1700000.000 TERMINAL CAPITAL STOCK
              VAR.L      DTERM        =     108129.637 TERMINAL FOREIGN DEBT
              VAR.UP     DTERM        =     250000.000 TERMINAL FOREIGN DEBT
              PARAMETER YTERM         =     240000.000 ESTIMATE OF POS-TERMINAL
                                                       INCOME


----      658 PARAMETER AGG           TABLE OF ECONOMIC AGGREGATES
```

	1984	1988	1992	1996	2000	2004
XT	207977.439	249346.160	301974.429	367320.522	442742.448	542607.983
ZT	90753.738	108214.686	131060.968	159856.738	192632.294	235678.765
YT	111274.757	134021.678	162152.337	196868.397	236569.667	290763.579
CT	77244.607	93343.273	113098.455	136770.567	163806.992	207110.259
INVT	27006.799	34813.642	42216.827	48891.349	64156.011	55735.679
GOVT	4652.407	5236.325	5893.530	6633.220	7465.747	8402.765
ET	12927.530	14108.055	19783.510	29926.089	38052.155	63609.354
MNT	5948.943	7109.796	8761.125	10595.387	13540.486	16165.639
MT	10556.586	13479.617	18839.986	25352.829	36911.239	44094.478
TRBAL	2370.944	628.437	943.524	4573.260	1140.916	19514.877
DTT	46385.800	54760.930	72637.492	94745.042	108715.236	140078.138
RTT	7596.100	7432.878	7971.422	11960.119	13857.715	17364.670
HTT	3491.046	4123.898	5496.732	7092.128	8007.962	10554.071
FET	973.680	973.680	973.680	973.680	973.680	973.680
CA	-2093.782	-4469.140	-5526.888	-3492.548	-7840.725	7987.125
BTT	9689.882	11902.018	13498.310	15452.668	21698.441	9377.544
KT	358327.184	425143.639	514538.112	623768.611	746386.143	918323.897
DKT	28543.642	36508.201	44389.972	51347.437	67747.100	58991.415
POP	131.374	145.013	160.067	176.684	195.026	215.272
EMP	31.976	35.517	40.021	44.709	50.363	54.894
CPI	11.435	8.089	5.718	4.085	2.976	2.032
INTR	0.176	0.145	0.141	0.139	0.131	0.170
WAGE	2.172	2.442	2.503	2.513	2.645	2.016
EXGR	1.012	1.024	1.023	1.022	1.024	1.060
AIR	0.075	0.075	0.076	0.075	0.074	0.075

LISTING D.B.2

SENSITIVITY TO THE DISCOUNT RATE (DELTA = 6%)

```
1GAMS 2.00 CDC NOS 1.4                               85/08/21.   00.05.33.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 E X E C U T I N G


 **** SOLVER STATUS      1 NORMAL COMPLETION
 **** MODEL STATUS       2 LOCALLY OPTIMAL
 **** OBJECTIVE VALUE          16157805.9171

  RESOURCE USAGE, LIMIT          432.255      1000.000
  ITERATION COUNT, LIMIT        1277          3000
  EVALUATION ERRORS                0             0

      M I N O S  ---  VERSION  5.0   APR  1984
      = = = = =
      COURTESY OF B. A. MURTAGH AND M. A. SAUNDERS,
                  DEPARTMENT OF OPERATIONS RESEARCH,
                  STANFORD UNIVERSITY,
                  STANFORD   CALIFORNIA   94305   U.S.A.


  WORK SPACE NEEDED (ESTIMATE)  --    36727 WORDS.
  WORK SPACE AVAILABLE          --    43038 WORDS.
  (MAXIMUM OBTAINABLE           --    85700 WORDS.)

  EXIT -- OPTIMAL SOLUTION FOUND
```

```
1GAMS 2.00 CDC NOS 1.4                          85/08/21.   00.05.33.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 E X E C U T I N G


 ----      656 PARAMETER DELTA          =          0.060 DISCOUNT RATE FOR UTILITY
               PARAMETER LIBOR          =          5.000 FIXED PART OF REAL INT RATE
                                                         ON FOREIGN BORROW
               PARAMETER RHOK           =          0.102 INTEREST RATE ON NON-HUMAN
                                                         WEALTH
               PARAMETER GRAE           =          0.050 MAX RATE OF GROWTH OF
                                                         AGRICULT EXPORTS
               PARAMETER GRME           =          0.100 MAX RATE OF GROWTH OF MANUFAC
                                                         EXPORTS

 ----      657 VAR.L     W              =    6440245.648 POST TERMINAL UTILITY
               VAR.L     KTERM          =    1014060.470 TERMINAL CAPITAL STOCK
               VAR.UP    KTERM          =    1700000.000 TERMINAL CAPITAL STOCK
               VAR.L     DTERM          =     171617.850 TERMINAL FOREIGN DEBT
               VAR.UP    DTERM          =     250000.000 TERMINAL FOREIGN DEBT
               PARAMETER YTERM          =     240000.000 ESTIMATE OF POS-TERMINAL
                                                         INCOME

 ----      658 PARAMETER AGG          TABLE OF ECONOMIC AGGREGATES
```

	1984	1988	1992	1996	2000	2004
XT	207643.424	248457.980	301009.635	365770.899	442790.687	534280.905
ZT	90470.346	107291.442	130342.820	159112.993	192929.473	229052.594
YT	111241.855	133940.153	161740.725	195845.101	236396.696	289235.343
CT	78209.583	95279.125	114117.586	136070.549	163146.239	213759.327
INVT	26935.838	33867.375	41154.352	49586.000	62062.938	54406.031
GOVT	4652.407	5236.325	5893.530	6633.220	7465.747	8402.765
ET	11837.662	13953.809	19940.882	29283.876	37721.110	59373.701
MNT	5931.224	7226.386	8926.089	10812.804	13464.518	15992.967
MT	10393.636	14396.482	19365.625	25728.544	33999.338	46706.481
TRBAL	1444.026	-442.673	575.257	3555.332	3721.772	12667.220
DTT	46385.800	58468.600	82159.224	109740.139	134011.692	165488.599
RTT	7596.100	7803.645	8979.210	13735.931	16858.300	20594.488
HTT	3491.046	4506.303	6496.806	8649.540	10617.319	13225.853
FET	973.680	973.680	973.680	973.680	973.680	973.680
CA	-3020.700	-5922.656	-6895.229	-6067.888	-7869.227	-1532.313
BTT	10616.800	13726.301	15874.439	19803.819	24727.527	22126.801
KT	358302.130	424809.358	510817.563	616136.879	742358.784	905038.453
DKT	28467.343	35671.550	43370.628	52106.363	65396.660	57584.098
POP	131.374	145.013	160.067	176.684	195.026	215.272
EMP	32.002	35.400	39.614	44.310	49.913	54.521
CPI	11.090	7.461	5.180	3.642	2.551	1.611
INTR	0.186	0.154	0.146	0.145	0.143	0.219
WAGE	2.014	2.339	2.437	2.455	2.490	1.240
EXGR	0.996	1.033	1.029	1.028	1.025	1.124
AIR	0.075	0.077	0.079	0.079	0.079	0.080

LISTING D.B.3

SENSITIVITY TO THE DISCOUNT RATE
(DELTA = 8%)

```
1GAMS 2.00 CDC NOS 1.4                              85/08/21.   00.15.31.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 E X E C U T I N G


 **** SOLVER STATUS      1 NORMAL COMPLETION
 **** MODEL STATUS       2 LOCALLY OPTIMAL
 **** OBJECTIVE VALUE          11225073.2612

  RESOURCE USAGE, LIMIT          430.386      1000.000
  ITERATION COUNT, LIMIT        1264          3000
  EVALUATION ERRORS                0             0

     M I N O S  ---  VERSION  5.0   APR  1984
     = = = = =
     COURTESY OF B. A. MURTAGH AND M. A. SAUNDERS,
                 DEPARTMENT OF OPERATIONS RESEARCH,
                 STANFORD UNIVERSITY,
                 STANFORD   CALIFORNIA   94305   U.S.A.


  WORK SPACE NEEDED (ESTIMATE)  --    36727 WORDS.
  WORK SPACE AVAILABLE          --    43038 WORDS.
  (MAXIMUM OBTAINABLE           --    85700 WORDS.)

  EXIT -- OPTIMAL SOLUTION FOUND
```

1GAMS 2.00 CDC NOS 1.4 85/08/21. 00.15.31.
G E N E R A L A L G E B R A I C M O D E L I N G S Y S T E M
E X E C U T I N G

```
----    656 PARAMETER DELTA        =         0.080 DISCOUNT RATE FOR UTILITY
            PARAMETER LIBOR        =         5.000 FIXED PART OF REAL INT RATE
                                                   ON FOREIGN BORROW
            PARAMETER RHOK         =         0.122 INTEREST RATE ON NON-HUMAN
                                                   WEALTH
            PARAMETER GRAE         =         0.050 MAX RATE OF GROWTH OF
                                                   AGRICULT EXPORTS
            PARAMETER GRME         =         0.100 MAX RATE OF GROWTH OF MANUFAC
                                                   EXPORTS

----    657 VAR.L     W            =   3035828.506 POST TERMINAL UTILITY
            VAR.L     KTERM        =    982202.447 TERMINAL CAPITAL STOCK
            VAR.UP    KTERM        =   1700000.000 TERMINAL CAPITAL STOCK
            VAR.L     DTERM        =    250000.000 TERMINAL FOREIGN DEBT
            VAR.UP    DTERM        =    250000.000 TERMINAL FOREIGN DEBT
            PARAMETER YTERM        =    240000.000 ESTIMATE OF POS-TERMINAL
                                                   INCOME

----    658 PARAMETER AGG          TABLE OF ECONOMIC AGGREGATES
```

	1984	1988	1992	1996	2000	2004
XT	207694.760	245993.677	298960.299	364694.085	444505.606	522428.988
ZT	90446.143	105219.406	128697.116	158452.395	194160.241	220947.997
YT	111357.544	133542.054	161335.706	195263.145	237167.578	285893.857
CT	79034.314	98200.631	115877.687	135670.015	162480.618	218494.917
INVT	26226.797	33666.675	41207.004	50435.368	57533.291	50870.545
GOVT	4652.407	5236.325	5893.530	6633.220	7465.747	8402.765
ET	11839.745	13953.809	19941.015	28601.197	43382.173	59374.598
MNT	5891.073	7232.217	8927.477	10978.545	13177.786	15587.134
MT	10395.719	17515.386	21583.529	26076.655	33694.251	51248.968
TRBAL	1444.026	-3561.577	-1642.514	2524.541	9687.922	8125.630
DTT	46385.800	58468.600	94632.718	136915.440	177970.811	206435.749
RTT	7596.100	7803.645	10226.560	16640.563	22110.887	26001.342
HTT	3491.046	4505.773	7954.486	11814.704	15830.476	18043.013
FET	973.680	973.680	973.680	973.680	973.680	973.680
CA	-3020.700	-9041.030	-10570.680	-10263.843	-7116.234	-10891.063
BTT	10616.800	16844.675	20797.240	26904.406	29227.121	36892.405
KT	358371.848	421761.116	507346.440	613192.394	743756.832	886177.951
DKT	27688.687	35501.477	43432.774	53123.085	60426.322	53842.090
POP	131.374	145.013	160.067	176.684	195.026	215.272
EMP	31.969	35.326	39.490	44.272	49.531	54.053
CPI	10.700	6.465	4.281	2.875	1.872	1.081
INTR	0.196	0.180	0.161	0.161	0.161	0.295
WAGE	1.884	2.027	2.264	2.250	2.245	
EXGR	0.988	1.032	1.046	1.047	1.048	1.222
AIR	0.075	0.077	0.084	0.086	0.089	0.087

LISTING D.C.1

SENSITIVITY TO LIBOR RATE
(value = 2%)

```
**** SOLVER STATUS     1 NORMAL COMPLETION
**** MODEL STATUS      2 LOCALLY OPTIMAL
**** OBJECTIVE VALUE         27334762.5827

 RESOURCE USAGE, LIMIT        132.050     1000.000
 ITERATION COUNT, LIMIT       297         2000
 EVALUATION ERRORS              0            0

     M I N O S  ---  VERSION  5.0   APR  1984
     = = = = =
     COURTESY OF B. A. MURTAGH AND M. A. SAUNDERS,
                 DEPARTMENT OF OPERATIONS RESEARCH,
                 STANFORD UNIVERSITY,
                 STANFORD   CALIFORNIA   94305   U.S.A.


 WORK SPACE NEEDED (ESTIMATE)  --    36727 WORDS.
 WORK SPACE AVAILABLE          --    43038 WORDS.
 (MAXIMUM OBTAINABLE           --    85700 WORDS.)

 EXIT -- OPTIMAL SOLUTION FOUND
```

```
1GAMS 2.00 CDC NOS 1.4                          85/06/01.   21.22.22.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 E X E C U T I N G

 ----     718 PARAMETER DELTA        =         0.040 DISCOUNT RATE FOR UTILITY
              PARAMETER LIBOR        =         2.000 FIXED PART OF REAL INT RATE
                                                     ON FOREIGN BORROW
              PARAMETER RHOK         =         0.082 INTEREST RATE ON NON-HUMAN
                                                     WEALTH
              PARAMETER GRAE         =         0.050 MAX RATE OF GROWTH OF
                                                     AGRICULT EXPORTS
              PARAMETER GRME         =         0.100 MAX RATE OF GROWTH OF MANUFAC
                                                     EXPORTS

 ----     719 VAR.L      W           =     1.5517E+7 POST TERMINAL UTILITY
              VAR.L      KTERM       =   1108319.263 TERMINAL CAPITAL STOCK
              VAR.UP     KTERM       =   1700000.000 TERMINAL CAPITAL STOCK
              VAR.L      DTERM       =    132615.513 TERMINAL FOREIGN DEBT
              VAR.UP     DTERM       =    250000.000 TERMINAL FOREIGN DEBT
              PARAMETER YTERM        =    240000.000 ESTIMATE OF POS-TERMINAL
                                                     INCOME

 ----     720 PARAMETER AGG          TABLE OF ECONOMIC AGGREGATES
```

	1984	1988	1992	1996	2000	2004
XT	206767.503	247597.410	301231.121	366277.121	444831.363	543085.122
ZT	89666.564	106484.691	129877.803	158927.990	193684.768	238514.641
CT	79202.017	96476.379	116740.352	138317.769	165297.396	193405.257
INVT	27477.268	35370.864	41334.589	50139.720	60818.317	75630.486
GOVT	4652.407	5236.325	5893.530	6633.220	7465.747	8402.765
ET	9791.828	12271.884	19927.935	28699.045	38052.460	54461.851
MNT	5716.795	6984.825	8665.527	10703.278	13316.210	16953.809
MT	9739.375	15227.556	21208.615	27143.903	33803.536	44283.687
TRBAL	52.452	-2955.673	-1280.680	1555.143	4248.924	10178.164
DTT	46385.800	58468.600	85194.539	111319.922	130895.914	143165.254
RTT	7596.100	7803.645	9282.742	13939.439	16679.690	18293.067
HTT	2099.472	2752.132	4276.986	5475.461	6342.579	6567.049
FET	973.680	973.680	973.680	973.680	973.680	973.680
CA	-3020.700	-6681.485	-6531.346	-4893.998	-3067.335	2637.435
BTT	10616.800	14485.130	15814.088	18833.437	19747.025	15655.632
KT	358191.438	426339.104	518079.058	623547.030	751947.677	908701.297
DKT	28876.982	37090.996	43522.637	52765.628	64125.830	80048.354
POP	131.374	145.013	160.067	176.684	195.026	215.272
EMP	32.090	35.854	40.207	44.881	50.136	55.999
CPI	11.042	8.029	5.917	4.538	3.453	2.713
INTR	0.170	0.141	0.122	0.117	0.122	0.106
WAGE	2.282	2.528	2.795	2.849	2.749	2.942
EXGR	1.007	1.018	1.027	1.024	1.022	1.022
AIR	0.045	0.047	0.050	0.049	0.048	0.046

LISTING D.C.2

SENSITIVITY TO LIBOR RATE
(value = 4%)

```
**** SOLVER STATUS     1 NORMAL COMPLETION
**** MODEL STATUS      2 LOCALLY OPTIMAL
**** OBJECTIVE VALUE         27261293.9237

 RESOURCE USAGE, LIMIT          94.148      1000.000
 ITERATION COUNT, LIMIT        190          2000
 EVALUATION ERRORS               0             0

     M I N O S  ---  VERSION  5.0   APR  1984
     = = = = =
     COURTESY OF B. A. MURTAGH AND M. A. SAUNDERS,
                 DEPARTMENT OF OPERATIONS RESEARCH,
                 STANFORD UNIVERSITY,
                 STANFORD   CALIFORNIA   94305   U.S.A.

 WORK SPACE NEEDED (ESTIMATE)  --    36727 WORDS.
 WORK SPACE AVAILABLE          --    43038 WORDS.
 (MAXIMUM OBTAINABLE           --    85700 WORDS.)

 EXIT -- OPTIMAL SOLUTION FOUND

 MAJOR ITERATIONS          11
 NORM RG / NORM PI  1.426E-04
 TOTAL USED             96.97 UNITS
 MINOS5 TIME            87.49 (INTERPRETER -       22.72)
```

```
1GAMS 2.00 CDC NOS 1.4                        85/06/01.   21.12.11.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 E X E C U T I N G

----      718 PARAMETER DELTA        =          0.040 DISCOUNT RATE FOR UTILITY
              PARAMETER LIBOR        =          4.000 FIXED PART OF REAL INT RATE
                                                      ON FOREIGN BORROW
              PARAMETER RHOK         =          0.082 INTEREST RATE ON NON-HUMAN
                                                      WEALTH
              PARAMETER GRAE         =          0.050 MAX RATE OF GROWTH OF
                                                      AGRICULT EXPORTS
              PARAMETER GRME         =          0.100 MAX RATE OF GROWTH OF MANUFAC
                                                      EXPORTS

----      719 VAR.L     W            =     1.5529E+7 POST TERMINAL UTILITY
              VAR.L     KTERM        =   1108307.560 TERMINAL CAPITAL STOCK
              VAR.UP    KTERM        =   1700000.000 TERMINAL CAPITAL STOCK
              VAR.L     DTERM        =     87698.838 TERMINAL FOREIGN DEBT
              VAR.UP    DTERM        =    250000.000 TERMINAL FOREIGN DEBT
              PARAMETER YTERM        =    240000.000 ESTIMATE OF POS-TERMINAL
                                                      INCOME


----      720 PARAMETER AGG          TABLE OF ECONOMIC AGGREGATES
```

	1984	1988	1992	1996	2000	2004
XT	207865.542	249512.138	302734.179	367405.884	445443.681	542674.085
ZT	90640.487	108380.175	131407.716	160040.861	194338.843	238186.081
CT	77180.043	93004.178	113721.257	136184.275	163887.226	193630.055
INVT	27197.778	35404.347	41422.670	50117.184	60836.553	75729.821
GOVT	4652.407	5236.325	5893.530	6633.220	7465.747	8402.765
ET	12753.328	16572.856	20540.576	29763.550	39351.079	54062.876
MNT	5907.638	7087.283	8739.899	10743.816	13293.691	16944.195
MT	10466.139	16173.026	18991.470	26077.021	33729.460	44281.708
TRBAL	2287.190	399.830	1549.106	3686.529	5621.619	9781.168
DTT	46385.800	53240.514	69295.351	84867.873	95190.798	99740.715
RTT	7596.100	7280.836	7614.402	10867.535	12276.480	12852.323
HTT	3027.188	3439.859	4468.557	5293.580	5785.418	5797.018
FET	973.680	973.680	973.680	973.680	973.680	973.680
CA	-1713.679	-4013.709	-3893.130	-2580.731	-1137.479	3010.469
BTT	9309.779	11294.546	11507.532	13448.266	13413.959	9841.854
KT	358305.334	425781.151	517580.455	623364.401	751582.193	908216.631
DKT	28707.935	37108.809	43599.672	52723.783	64090.784	80153.493
POP	131.374	145.013	160.067	176.684	195.026	215.272
EMP	31.990	35.654	40.082	44.795	50.093	56.010
CPI	11.552	8.533	6.172	4.647	3.497	2.710
INTR	0.164	0.140	0.131	0.119	0.126	0.110
WAGE	2.360	2.510	2.633	2.786	2.682	2.881
EXGR	1.015	1.017	1.024	1.025	1.022	1.022
AIR	0.065	0.065	0.064	0.062	0.061	0.058

LISTING D.C.3

SENSITIVITY TO LIBOR RATE
(value = 6%)

```
**** SOLVER STATUS     1 NORMAL COMPLETION
**** MODEL STATUS      2 LOCALLY OPTIMAL
**** OBJECTIVE VALUE         27202557.1622

 RESOURCE USAGE, LIMIT          98.060      1000.000
 ITERATION COUNT, LIMIT        196          2000
 EVALUATION ERRORS               0             0

     M I N O S  ---  VERSION  5.0   APR  1984
     = = = = =
     COURTESY OF B. A. MURTAGH AND M. A. SAUNDERS,
                 DEPARTMENT OF OPERATIONS RESEARCH,
                 STANFORD UNIVERSITY,
                 STANFORD   CALIFORNIA   94305   U.S.A.


 WORK SPACE NEEDED (ESTIMATE)  --    36727 WORDS.
 WORK SPACE AVAILABLE          --    43038 WORDS.
 (MAXIMUM OBTAINABLE           --    85700 WORDS.)

 EXIT -- OPTIMAL SOLUTION FOUND
```

```
1GAMS 2.00 CDC NOS 1.4                              85/06/01.   21.23.25.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 E X E C U T I N G


 ----     718 PARAMETER DELTA      =          0.040 DISCOUNT RATE FOR UTILITY
              PARAMETER LIBOR      =          6.000 FIXED PART OF REAL INT RATE
                                                    ON FOREIGN BORROW
              PARAMETER RHOK       =          0.082 INTEREST RATE ON NON-HUMAN
                                                    WEALTH
              PARAMETER GRAE       =          0.050 MAX RATE OF GROWTH OF
                                                    AGRICULT EXPORTS
              PARAMETER GRME       =          0.100 MAX RATE OF GROWTH OF MANUFAC
                                                    EXPORTS

 ----     719 VAR.L     W          =     1.5548E+7 POST TERMINAL UTILITY
              VAR.L     KTERM      =   1108452.375 TERMINAL CAPITAL STOCK
              VAR.UP    KTERM      =   1700000.000 TERMINAL CAPITAL STOCK
              VAR.L     DTERM      =     43280.369 TERMINAL FOREIGN DEBT
              VAR.UP    DTERM      =    250000.000 TERMINAL FOREIGN DEBT
              PARAMETER YTERM      =    240000.000 ESTIMATE OF POS-TERMINAL
                                                    INCOME


 ----     720 PARAMETER AGG         TABLE OF ECONOMIC AGGREGATES
```

	1984	1988	1992	1996	2000	2004
XT	207551.705	251416.034	305003.648	368713.924	446089.271	542155.735
ZT	90305.336	110052.607	133362.330	161492.898	194972.430	237793.607
CT	76090.826	90157.490	110806.014	133028.491	162572.518	193876.977
INVT	27689.349	35159.349	40880.342	50375.260	60763.510	75906.844
GOVT	4652.407	5236.325	5893.530	6633.220	7465.747	8402.765
ET	12927.530	17748.832	24553.757	31859.173	41390.702	53528.642
MNT	5879.716	7184.214	8822.563	10790.685	13265.829	16936.073
MT	9993.460	14122.784	19314.888	25465.802	34341.466	44289.173
TRBAL	2934.070	3626.049	5238.868	6393.371	7049.236	9239.468
DTT	46385.800	54363.855	62262.872	65676.943	64529.928	59443.182
RTT	7596.100	7393.171	6928.004	8883.395	8640.041	7860.791
HTT	3954.904	4627.123	5118.706	5132.937	4803.869	4225.085
FET	973.680	973.680	973.680	973.680	973.680	973.680
CA	-1994.514	-1974.754	-853.518	286.754	1271.687	4040.703
BTT	9590.614	9367.925	7781.522	8596.642	7368.354	3820.087
KT	358260.434	427919.996	518891.602	622244.504	751430.801	907536.821
DKT	29252.582	36951.019	43042.136	52946.137	63960.304	80340.856
POP	131.374	145.013	160.067	176.684	195.026	215.272
EMP	32.024	35.673	39.919	44.688	50.046	56.025
CPI	11.859	9.034	6.420	4.823	3.538	2.707
INTR	0.165	0.173	0.113	0.136	0.126	0.117
WAGE	2.437	1.981	2.873	2.538	2.668	2.791
EXGR	1.172	1.055	1.038	1.019	1.024	1.021
AIR	0.085	0.085	0.082	0.078	0.074	0.071

LISTING D.C.4

SENSITIVITY TO LIBOR RATE
(value = 8%)

```
**** SOLVER STATUS      1 NORMAL COMPLETION
**** MODEL STATUS       2 LOCALLY OPTIMAL
**** OBJECTIVE VALUE          27150358.2557

 RESOURCE USAGE, LIMIT          109.670      1000.000
 ITERATION COUNT, LIMIT         233          2000
 EVALUATION ERRORS                0             0

     M I N O S  ---  VERSION  5.0   APR  1984
     = = = = =
     COURTESY OF B. A. MURTAGH AND M. A. SAUNDERS,
                 DEPARTMENT OF OPERATIONS RESEARCH,
                 STANFORD UNIVERSITY,
                 STANFORD   CALIFORNIA   94305   U.S.A.


 WORK SPACE NEEDED (ESTIMATE)   --    36727 WORDS.
 WORK SPACE AVAILABLE           --    43038 WORDS.
 (MAXIMUM OBTAINABLE            --    85700 WORDS.)

 EXIT -- OPTIMAL SOLUTION FOUND
```

```
1GAMS 2.00 CDC NOS 1.4                              85/06/01.   21.24.10.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 E X E C U T I N G


 ----    718 PARAMETER DELTA          =         0.040 DISCOUNT RATE FOR UTILITY
             PARAMETER LIBOR          =         8.000 FIXED PART OF REAL INT RATE
                                                      ON FOREIGN BORROW
             PARAMETER RHOK           =         0.082 INTEREST RATE ON NON-HUMAN
                                                      WEALTH
             PARAMETER GRAE           =         0.050 MAX RATE OF GROWTH OF
                                                      AGRICULT EXPORTS
             PARAMETER GRME           =         0.100 MAX RATE OF GROWTH OF MANUFAC
                                                      EXPORTS


 ----    719 VAR.L      W             =    1.5568E+7 POST TERMINAL UTILITY
             VAR.L      KTERM         =  1111184.633 TERMINAL CAPITAL STOCK
             VAR.UP     KTERM         =  1700000.000 TERMINAL CAPITAL STOCK
             VAR.L      DTERM         =    11991.947 TERMINAL FOREIGN DEBT
             VAR.UP     DTERM         =   250000.000 TERMINAL FOREIGN DEBT
             PARAMETER YTERM          =   240000.000 ESTIMATE OF POS-TERMINAL
                                                      INCOME


 ----    720 PARAMETER AGG          TABLE OF ECONOMIC AGGREGATES
```

	1984	1988	1992	1996	2000	2004
XT	206943.922	251592.103	305155.193	370056.833	449662.178	540937.757
ZT	89708.119	110156.963	133341.937	162705.189	198169.557	237231.644
CT	75164.062	88914.621	110004.843	130278.919	157744.268	192598.159
INVT	27865.892	35165.705	40738.597	50520.741	59580.984	77471.114
GOVT	4652.407	5236.325	5893.530	6633.220	7465.747	8402.765
ET	12927.530	17748.832	24553.757	34208.174	47454.592	52618.277
MNT	5753.874	7094.181	8802.506	10943.588	13248.728	17024.677
MT	9127.962	12724.525	18179.977	25232.999	34001.699	44408.879
TRBAL	3799.568	5024.307	6373.779	8975.175	13452.894	8209.398
DTT	46385.800	54612.727	61396.285	64838.932	58231.107	30063.213
RTT	7596.100	7418.058	6845.078	8795.555	7959.896	4821.970
HTT	4882.620	5746.517	6260.761	6349.539	5437.240	2717.902
FET	973.680	973.680	973.680	973.680	973.680	973.680
CA	-2056.732	-1695.889	-860.662	1651.956	7041.973	4517.817
BTT	9652.832	9113.947	7705.740	7143.598	917.922	304.154
KT	358215.723	428577.436	519596.549	622579.531	752826.132	903217.245
DKT	29427.680	36976.444	42974.022	53230.960	62596.287	81996.501
POP	131.374	145.013	160.067	176.684	195.026	215.272
EMP	32.071	35.719	39.895	44.593	49.799	55.999
CPI	12.299	9.295	6.499	4.979	3.696	2.737
INTR	0.226	0.196	0.108	0.134	0.123	0.135
WAGE	1.599	1.513	2.858	2.504	2.718	2.533
EXGR	1.478	1.268	1.208	1.097	1.030	1.018
AIR	0.105	0.105	0.102	0.098	0.093	0.090

LISTING D.D

BALANCED CURRENT ACCOUNT SCENARIO

```
1GAMS 2.00 CDC NOS 1.4                                85/06/05.   00.35.25.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 C O M P I L A T I O N


     *************************
     *** PARAMETER CHANGES ***
     *************************

      B.UP(T) = 20000;
      B.LO(T) = 0;
      EQUATION BALCA    ENFORCES CURRENT ACCOUNT BALANCING;
      BALCA(T)..   B(T) =L= RT(T);


**** SOLVER STATUS     1 NORMAL COMPLETION
**** MODEL STATUS      2 LOCALLY OPTIMAL
**** OBJECTIVE VALUE          27217363.2562

 RESOURCE USAGE, LIMIT         108.683      1000.000
 ITERATION COUNT, LIMIT        277          2000
 EVALUATION ERRORS               0             0

     M I N O S  ---  VERSION  5.0   APR  1984
     = = = = =
     COURTESY OF B. A. MURTAGH AND M. A. SAUNDERS,
                 DEPARTMENT OF OPERATIONS RESEARCH,
                 STANFORD UNIVERSITY,
                 STANFORD   CALIFORNIA   94305   U.S.A.


 WORK SPACE NEEDED (ESTIMATE)  --    37159 WORDS.
 WORK SPACE AVAILABLE          --    43506 WORDS.
 (MAXIMUM OBTAINABLE           --    85700 WORDS.)

 EXIT -- OPTIMAL SOLUTION FOUND
```

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1GAMS 2.00 CDC NOS 1.4                               85/06/05.   00.36.00.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 E X E C U T I N G


 ----      721 PARAMETER DELTA        =          0.040 DISCOUNT RATE FOR UTILITY
               PARAMETER LIBOR        =          5.000 FIXED PART OF REAL INT RATE
                                                       ON FOREIGN BORROW
               PARAMETER RHOK         =          0.082 INTEREST RATE ON NON-HUMAN
                                                       WEALTH
               PARAMETER GRAE         =          0.050 MAX RATE OF GROWTH OF
                                                       AGRICULT EXPORTS
               PARAMETER GRME         =          0.100 MAX RATE OF GROWTH OF MANUFAC
                                                       EXPORTS


 ----      722 VAR.L      W           =     1.5557E+7 POST TERMINAL UTILITY
               VAR.L      KTERM       =   1118708.633 TERMINAL CAPITAL STOCK
               VAR.UP     KTERM       =   1700000.000 TERMINAL CAPITAL STOCK
               VAR.L      DTERM       =     46385.800 TERMINAL FOREIGN DEBT
               VAR.UP     DTERM       =    250000.000 TERMINAL FOREIGN DEBT
               PARAMETER YTERM        =    240000.000 ESTIMATE OF POS-TERMINAL
                                                       INCOME


 ----      723 PARAMETER AGG         TABLE OF ECONOMIC AGGREGATES
```

	1984	1988	1992	1996	2000	2004
XT	206444.701	251203.317	304021.406	367095.027	443980.618	539568.163
ZT	89242.609	109898.079	132458.392	160054.261	192864.886	235705.806
CT	74745.176	89522.337	112053.135	135166.646	166583.718	196103.617
INVT	27670.191	35138.806	40816.939	50668.782	60194.928	78745.884
GOVT	4652.407	5236.325	5893.530	6633.220	7465.747	8402.765
ET	12927.530	17432.931	22726.458	29284.552	38052.155	53139.940
MNT	5669.592	7107.852	8722.446	10662.762	13097.321	16925.184
MT	8462.804	13133.014	18649.495	25375.197	34278.137	49455.032
TRBAL	4464.726	4299.917	4076.964	3909.355	3774.018	3684.908
DTT	46385.800	46385.800	46385.800	46385.800	46385.800	46385.800
RTT	7596.100	6595.365	5220.626	6428.915	6172.913	5964.028
HTT	3491.046	3326.237	3103.284	2935.675	2800.338	2711.228
FET	973.680	973.680	973.680	973.680	973.680	973.680
CA	3.1941E-9	-2.7139E-9	-1.1372E-8	2.4513E-8	3.3157E-8	6.4138E-8
BTT	7596.100	6595.365	5220.626	6428.915	6172.913	5964.028
KT	358206.614	427764.309	518541.466	621508.069	751809.653	905399.278
DKT	29227.618	36894.062	42932.165	53193.810	63332.860	83345.735
POP	131.374	145.013	160.067	176.684	195.026	215.272
EMP	32.096	35.718	39.977	44.805	50.144	56.287
CPI	12.711	9.165	6.310	4.708	3.418	2.661
INTR	0.312	0.201	0.121	0.137	0.131	0.106
WAGE	0.283	1.603	2.759	2.514	2.600	2.944
EXGR	1.768	1.080	1.043	1.019	1.023	1.023
AIR	0.075	0.072	0.067	0.063	0.060	0.058

LISTING D.E.1

SENSITIVITY TO EXPORT MARKETS
(protectionist scenario)

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**************************
*** PARAMETER CHANGES ***
**************************

 GRAE = 0.031;
 GRME = 0.075;

 E.UP("AGRIC",T) = EO("AGRIC")*(1+GRAE)**(NYPP*(ORD(T)-1)+1);
 E.UP("AGROP",T) = EO("AGROP")*(1+GRAE)**(NYPP*(ORD(T)-1)+1);
 E.UP("MANCG",T) = EO("MANCG")*(1+GRME)**(NYPP*(ORD(T)-1)+1);
 E.UP("MANOG",T) = EO("MANOG")*(1+GRME)**(NYPP*(ORD(T)-1)+1);

**** SOLVER STATUS     1 NORMAL COMPLETION
**** MODEL STATUS      2 LOCALLY OPTIMAL
**** OBJECTIVE VALUE         27209380.9857

 RESOURCE USAGE, LIMIT        254.375     1000.000
 ITERATION COUNT, LIMIT       642         2000
 EVALUATION ERRORS              0            0

     M I N O S  ---  VERSION  5.0   APR  1984
     = = = = =
     COURTESY OF B. A. MURTAGH AND M. A. SAUNDERS,
                 DEPARTMENT OF OPERATIONS RESEARCH,
                 STANFORD UNIVERSITY,
                 STANFORD   CALIFORNIA   94305   U.S.A.


 WORK SPACE NEEDED (ESTIMATE)  --    36727 WORDS.
 WORK SPACE AVAILABLE          --    43038 WORDS.
 (MAXIMUM OBTAINABLE           --    85700 WORDS.)

 EXIT -- OPTIMAL SOLUTION FOUND
```

```
1GAMS 2.00 CDC NOS 1.4                              85/06/16.   11.17.34.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 E X E C U T I N G

 ----      725 PARAMETER DELTA       =        0.040 DISCOUNT RATE FOR UTILITY
               PARAMETER LIBOR       =        5.000 FIXED PART OF REAL INT RATE
                                                    ON FOREIGN BORROW
               PARAMETER RHOK        =        0.082 INTEREST RATE ON NON-HUMAN
                                                    WEALTH
               PARAMETER GRAE        =        0.031 MAX RATE OF GROWTH OF
                                                    AGRICULT EXPORTS
               PARAMETER GRME        =        0.075 MAX RATE OF GROWTH OF MANUFAC
                                                    EXPORTS


 ----      726 VAR.L     W           =    1.5497E+7 POST TERMINAL UTILITY
               VAR.L     KTERM       =  1112513.911 TERMINAL CAPITAL STOCK
               VAR.UP    KTERM       =  1700000.000 TERMINAL CAPITAL STOCK
               VAR.L     DTERM       =   119679.904 TERMINAL FOREIGN DEBT
               VAR.UP    DTERM       =   250000.000 TERMINAL FOREIGN DEBT
               PARAMETER YTERM       =   240000.000 ESTIMATE OF POS-TERMINAL
                                                    INCOME


 ----      727 PARAMETER AGG         TABLE OF ECONOMIC AGGREGATES
```

	1984	1988	1992	1996	2000	2004
XT	207062.688	250453.079	302114.296	364265.495	440234.821	535455.972
ZT	89836.463	109144.331	130626.123	157549.813	189480.553	232701.051
YT	111479.459	134343.141	163007.162	196351.071	237979.951	286205.179
CT	75799.487	90807.414	113991.938	137202.234	169782.916	197452.275
INVT	27699.180	34896.484	40340.276	50356.165	58897.552	79263.316
GOVT	4652.407	5236.325	5893.530	6633.220	7465.747	8402.765
ET	12655.679	15944.414	20212.136	25771.122	33036.313	42559.479
MNT	5746.766	6965.607	8481.011	10364.611	12774.317	16549.742
MT	9327.294	12541.496	17430.718	23611.670	31202.577	41472.655
TRBAL	3328.385	3402.918	2781.418	2159.453	1833.736	1086.824
DTT	46385.800	50931.164	56203.947	64735.177	77429.639	94717.148
RTT	7596.100	7049.901	6270.621	8574.758	9787.357	11689.234
HTT	3491.046	3747.434	3940.545	4359.388	5181.933	6353.833
FET	973.680	973.680	973.680	973.680	973.680	973.680
CA	-1136.341	-1318.196	-2132.807	-3173.616	-4321.877	-6240.689
BTT	8732.441	8368.097	8403.429	11748.373	14109.234	17929.923
KT	358221.279	427764.113	517468.551	618526.990	747817.547	896639.393
DKT	29222.716	36637.397	42461.369	52921.972	62142.522	83893.392
POP	131.374	145.013	160.067	176.684	195.026	215.272
EMP	32.062	35.699	39.876	44.626	49.786	55.856
CPI	12.032	8.966	6.170	4.627	3.348	2.644
INTR	0.207	0.193	0.116	0.138	0.134	0.099
WAGE	1.840	1.529	2.601	2.242	2.270	2.834
EXGR	1.368	1.308	1.395	1.422	1.466	1.388
AIR	0.075	0.074	0.070	0.067	0.067	0.067

LISTING D.E.2

SENSITIVITY TO EXPORT MARKETS
(expansionist scenario)

```
*************************
*** PARAMETER CHANGES ***
*************************

 GRAE = 0.05;
 GRME = 0.135;

 E.UP("AGRIC",T) = EO("AGRIC")*(1+GRAE)**(NYPP*(ORD(T)-1)+1);
 E.UP("AGROP",T) = EO("AGROP")*(1+GRAE)**(NYPP*(ORD(T)-1)+1);
 E.UP("MANCG",T) = EO("MANCG")*(1+GRME)**(NYPP*(ORD(T)-1)+1);
 E.UP("MANOG",T) = EO("MANOG")*(1+GRME)**(NYPP*(ORD(T)-1)+1);
```

```
**** SOLVER STATUS     1 NORMAL COMPLETION
**** MODEL STATUS      2 LOCALLY OPTIMAL
**** OBJECTIVE VALUE         27236490.5518

 RESOURCE USAGE, LIMIT         105.903     1000.000
 ITERATION COUNT, LIMIT        239         2000
 EVALUATION ERRORS               0            0

     M I N O S  ---  VERSION  5.0   APR  1984
     = = = = =
     COURTESY OF B. A. MURTAGH AND M. A. SAUNDERS,
                 DEPARTMENT OF OPERATIONS RESEARCH,
                 STANFORD UNIVERSITY,
                 STANFORD   CALIFORNIA   94305   U.S.A.


 WORK SPACE NEEDED (ESTIMATE)  --    36727 WORDS.
 WORK SPACE AVAILABLE          --    43038 WORDS.
 (MAXIMUM OBTAINABLE           --    85700 WORDS.)

 EXIT -- OPTIMAL SOLUTION FOUND
```

```
1GAMS 2.00 CDC NOS 1.4                               85/06/16.   14.49.57.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 E X E C U T I N G

 ----     725 PARAMETER DELTA        =        0.040 DISCOUNT RATE FOR UTILITY
              PARAMETER LIBOR        =        5.000 FIXED PART OF REAL INT RATE
                                                    ON FOREIGN BORROW
              PARAMETER RHOK         =        0.082 INTEREST RATE ON NON-HUMAN
                                                    WEALTH
              PARAMETER GRAE         =        0.050 MAX RATE OF GROWTH OF
                                                    AGRICULT EXPORTS
              PARAMETER GRME         =        0.135 MAX RATE OF GROWTH OF MANUFAC
                                                    EXPORTS


 ----     726 VAR.L     W            =   1.5539E+7 POST TERMINAL UTILITY
              VAR.L     KTERM        = 1106772.597 TERMINAL CAPITAL STOCK
              VAR.UP    KTERM        = 1700000.000 TERMINAL CAPITAL STOCK
              VAR.L     DTERM        =   61353.723 TERMINAL FOREIGN DEBT
              VAR.UP    DTERM        =  250000.000 TERMINAL FOREIGN DEBT
              PARAMETER YTERM        =  240000.000 ESTIMATE OF POS-TERMINAL
                                                    INCOME


 ----     727 PARAMETER AGG         TABLE OF ECONOMIC AGGREGATES
```

	1984	1988	1992	1996	2000	2004
XT	207922.417	250630.789	303429.037	367079.820	446278.626	545268.203
ZT	90673.848	109378.542	131992.490	159460.700	194314.978	238810.570
YT	111320.244	134170.415	162819.230	197053.930	238735.627	289473.385
CT	76555.669	91201.887	112205.538	136057.114	163442.165	193697.032
INVT	27295.010	35458.524	41818.210	51050.542	61910.491	73461.518
GOVT	4652.407	5236.325	5893.530	6633.220	7465.747	8402.765
ET	13188.038	15688.983	24136.825	36946.038	57533.093	87396.575
MNT	5928.325	7081.833	8617.317	10565.191	13228.021	16984.248
MT	10370.880	13415.305	21234.874	33632.985	51615.871	73484.505
TRBAL	2817.158	2273.678	2901.951	3313.054	5917.223	13912.070
DTT	46385.800	52976.072	63560.390	74286.905	85661.025	89413.704
RTT	7596.100	7254.392	7036.939	9713.894	10965.231	11444.158
HTT	3491.046	3946.078	4609.900	5182.904	5881.713	5923.394
FET	973.680	973.680	973.680	973.680	973.680	973.680
CA	-1647.568	-2646.080	-2681.629	-2843.530	-938.170	7014.995
BTT	9243.668	9900.472	9718.568	12557.424	11903.401	4429.163
KT	358317.488	426338.292	518106.101	624934.558	756472.263	917016.301
DKT	28844.559	37115.469	43862.387	53557.606	65132.137	77752.689
POP	131.374	145.013	160.067	176.684	195.026	215.272
EMP	31.983	35.611	40.118	44.987	50.359	55.989
CPI	11.731	8.821	6.308	4.655	3.510	2.711
INTR	0.170	0.141	0.135	0.125	0.122	0.114
WAGE	2.293	2.482	2.558	2.675	2.748	2.826
EXGR	1.075	1.018	1.024	1.041	1.013	0.997
AIR	0.075	0.074	0.073	0.070	0.069	0.066

LISTING D.F.1

SENSITIVITY TO DOMESTIC PETROLEUM PRODUCTION
(large oil find scenario)

```
*************************
*** PARAMETER CHANGES ***
*************************

 PETS("1992") = 700;
 PETS("1996") = 800;
 PETS("2000") = 1000;
 PETS("2004") = 1200;
 X.UP("PETRO",T) = XO("PETRO")*(PETS(T)/PETSO);

```

```
**** SOLVER STATUS     1 NORMAL COMPLETION
**** MODEL STATUS      2 LOCALLY OPTIMAL
**** OBJECTIVE VALUE         27273677.9447

 RESOURCE USAGE, LIMIT        114.219      1000.000
 ITERATION COUNT, LIMIT       259          2000
 EVALUATION ERRORS              0             0

     M I N O S  ---  VERSION  5.0   APR  1984
     = = = = =
     COURTESY OF B. A. MURTAGH AND M. A. SAUNDERS,
                 DEPARTMENT OF OPERATIONS RESEARCH,
                 STANFORD UNIVERSITY,
                 STANFORD   CALIFORNIA   94305   U.S.A.


 WORK SPACE NEEDED (ESTIMATE)  --    36727 WORDS.
 WORK SPACE AVAILABLE          --    43038 WORDS.
 (MAXIMUM OBTAINABLE           --    85700 WORDS.)

 EXIT -- OPTIMAL SOLUTION FOUND
```

```
1GAMS 2.00 CDC NOS 1.4                          85/06/05.   22.47.03.   8
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 E X E C U T I N G

-----     789 PARAMETER DELTA       =          0.040 DISCOUNT RATE FOR UTILITY
              PARAMETER LIBOR       =          5.000 FIXED PART OF REAL INT RATE
                                                     ON FOREIGN BORROW
              PARAMETER RHOK        =          0.082 INTEREST RATE ON NON-HUMAN
                                                     WEALTH
              PARAMETER GRAE        =          0.050 MAX RATE OF GROWTH OF
                                                     AGRICULT EXPORTS
              PARAMETER GRME        =          0.100 MAX RATE OF GROWTH OF MANUFAC
                                                     EXPORTS


 ----     790 VAR.L     W           =     1.5584E+7 POST TERMINAL UTILITY
              VAR.L     KTERM       =   1173316.997 TERMINAL CAPITAL STOCK
              VAR.UP    KTERM       =   1700000.000 TERMINAL CAPITAL STOCK
              VAR.L     DTERM       =     64970.447 TERMINAL FOREIGN DEBT
              VAR.UP    DTERM       =    250000.000 TERMINAL FOREIGN DEBT
              PARAMETER YTERM       =    240000.000 ESTIMATE OF POS-TERMINAL
                                                     INCOME


 ----     791 PARAMETER AGG         TABLE OF ECONOMIC AGGREGATES
```

	1984	1988	1992	1996	2000	2004
XT	207910.337	254078.439	310502.723	376796.072	458478.259	560133.827
ZT	90643.622	111445.040	135449.628	164926.425	200544.570	246349.759
YT	111060.602	135561.237	166481.312	201321.769	245020.784	297478.557
CT	75542.647	89684.238	113269.073	135388.562	165238.545	197048.865
INVT	28802.619	39163.347	43272.117	54276.142	65628.156	79717.977
GOVT	4652.407	5236.325	5893.530	6633.220	7465.747	8402.765
ET	12679.295	10794.311	20243.754	27435.509	47968.015	53139.940
MNT	6206.113	7072.161	8571.783	10547.877	12912.904	16305.511
MT	10616.367	9316.983	16197.163	22411.663	41279.679	40830.988
TRBAL	2062.928	1477.327	4046.591	5023.845	6688.336	12308.951
DTT	46385.800	55992.992	70972.223	79948.752	86513.956	87404.832
RTT	7596.100	7556.084	7823.376	10499.865	11323.537	11281.105
HTT	3491.046	4248.455	5317.043	5691.466	5937.375	5726.675
FET	973.680	973.680	973.680	973.680	973.680	973.680
CA	-2401.798	-3744.808	-2244.132	-1641.301	-222.719	5608.596
BTT	9997.898	11300.892	10067.508	12141.166	11546.256	5672.508
KT	358339.419	433566.790	539457.384	650194.238	792344.290	963802.514
DKT	30649.272	40964.006	45580.505	57118.203	69174.226	84374.612
POP	131.374	145.013	160.067	176.684	195.026	215.272
EMP	31.957	35.486	40.057	44.871	50.218	56.163
CPI	12.018	9.077	6.210	4.690	3.459	2.645
INTR	0.144	0.181	0.128	0.124	0.132	0.112
WAGE	2.981	1.891	2.677	2.717	2.579	2.856
EXGR	1.076	1.008	1.034	1.022	1.023	1.022
AIR	0.075	0.076	0.075	0.071	0.069	0.066

LISTING D.F.2

SENSITIVITY TO PETROLEUM PRICES
(yearly growth rate of 4%)

```
*************************
*** PARAMETER CHANGES ***
*************************

 PARAMETER GRPP   GROWTH RATE OF PETROLEUM PRICES;
     GRPP = 0.04;
 PM("PETRO",T) = (1+GRPP)**(NYPP*(ORD(T)-1)+1);
 DISPLAY GRPP,PM;
 E.FX("PETRO",T)= 0;
```

```
----    665 PARAMETER PM         COMPETITVE IMPORTS PRICE
```

	1984	1988	1992	1996	2000	2004
PETRO	1.040	1.217	1.423	1.665	1.948	2.279

```
**** SOLVER STATUS     1 NORMAL COMPLETION
**** MODEL STATUS      2 LOCALLY OPTIMAL
**** OBJECTIVE VALUE         26980411.4599

 RESOURCE USAGE, LIMIT         152.284      1000.000
 ITERATION COUNT, LIMIT        357          2000
 EVALUATION ERRORS               0             0

     M I N O S  ---  VERSION  5.0   APR  1984
     = = = = =
     COURTESY OF B. A. MURTAGH AND M. A. SAUNDERS,
                 DEPARTMENT OF OPERATIONS RESEARCH,
                 STANFORD UNIVERSITY,
                 STANFORD   CALIFORNIA   94305   U.S.A.


 WORK SPACE NEEDED (ESTIMATE)  --    36727 WORDS.
 WORK SPACE AVAILABLE          --    43038 WORDS.
 (MAXIMUM OBTAINABLE           --    85700 WORDS.)

 EXIT -- OPTIMAL SOLUTION FOUND
```

```
1GAMS 2.00 CDC NOS 1.4                         85/06/06.   22.46.20.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 E X E C U T I N G

 ----     722 PARAMETER DELTA        =         0.040 DISCOUNT RATE FOR UTILITY
             PARAMETER LIBOR        =         5.000 FIXED PART OF REAL INT RATE
                                                     ON FOREIGN BORROW
              PARAMETER RHOK         =         0.082 INTEREST RATE ON NON-HUMAN
                                                     WEALTH
              PARAMETER GRAE         =         0.050 MAX RATE OF GROWTH OF
                                                     AGRICULT EXPORTS
              PARAMETER GRME         =         0.100 MAX RATE OF GROWTH OF MANUFAC
                                                     EXPORTS


 ----     723 VAR.L       W          =     1.5483E+7 POST TERMINAL UTILITY
              VAR.L       KTERM      =   1078531.685 TERMINAL CAPITAL STOCK
              VAR.UP      KTERM      =   1700000.000 TERMINAL CAPITAL STOCK
              VAR.L       DTERM      =    107862.995 TERMINAL FOREIGN DEBT
              VAR.UP      DTERM      =    250000.000 TERMINAL FOREIGN DEBT
              PARAMETER YTERM        =    240000.000 ESTIMATE OF POS-TERMINAL
                                                     INCOME


 ----     724 PARAMETER AGG         TABLE OF ECONOMIC AGGREGATES
```

	1984	1988	1992	1996	2000	2004
XT	207247.073	251661.689	305096.748	369256.462	449913.039	545530.740
ZT	90006.611	110211.404	133215.490	161428.254	198334.178	238773.193
YT	111263.427	133151.292	159559.897	188815.567	222169.046	261415.061
CT	75548.320	88703.799	108706.846	129388.435	150291.322	186377.160
INVT	27875.089	35206.715	41191.286	49936.628	62856.235	66993.283
GOVT	4652.407	5236.325	5893.530	6633.220	7465.747	8402.765
ET	12927.530	17748.832	24553.757	34208.174	47968.015	67657.750
MNT	5826.520	7119.235	8738.382	10806.798	13293.176	16348.453
MT	9739.919	13744.380	20785.521	31350.891	46412.273	68015.897
TRBAL	3187.611	4004.453	3768.236	2857.284	1555.743	-358.147
DTT	46385.800	51494.262	54577.004	58619.373	66593.959	81465.106
RTT	7596.100	7106.211	6116.373	7959.045	8538.785	10026.526
HTT	3491.046	3801.458	3805.148	3877.250	4299.849	5267.646
FET	973.680	973.680	973.680	973.680	973.680	973.680
CA	-1277.116	-770.685	-1010.592	-1993.647	-3717.787	-6599.472
BTT	8873.216	7876.897	7126.965	9952.692	12256.572	16625.998
KT	358227.172	428629.869	519765.627	624434.174	752233.747	916895.022
DKT	29437.641	37008.065	43398.912	52686.961	66141.555	70906.619
POP	131.374	145.013	160.067	176.684	195.026	215.272
EMP	32.052	35.712	39.934	44.562	49.939	55.365
CPI	12.066	9.361	6.700	5.156	4.102	3.038
INTR	0.173	0.196	0.092	0.139	0.084	0.156
WAGE	2.385	1.424	2.790	1.896	2.583	1.261
EXGR	1.253	1.144	1.174	1.181	1.128	1.154
AIR	0.075	0.074	0.070	0.066	0.065	0.065

LISTING D.G.1

SENSITIVITY TO NON-COMPETITIVE IMPORTS COEFFICIENTS (20% reduction)

```
1GAMS 2.00 CDC NOS 1.4                       85/08/11.   17.42.13.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 C O M P I L A T I O N

     *************************
     *** PARAMETER CHANGES ***
     *************************

      PARAMETER MNX1(J)  TEMPORARY VARIABLE
                MNK1(J)  TEMPORARY VARIABLE;
      MNX1(J) = MNX(J)*0.8;
      MNX(J) = MNX1(J);
      MNK1(J) = MNK(J)*0.8;
      MNK(J) = MNK1(J);
      DISPLAY MNX,MNK;

**** SOLVER STATUS     1 NORMAL COMPLETION
**** MODEL STATUS      2 LOCALLY OPTIMAL
**** OBJECTIVE VALUE         27288951.0313

 RESOURCE USAGE, LIMIT          107.062      1000.000
 ITERATION COUNT, LIMIT         224          2000
 EVALUATION ERRORS                0             0

     M I N O S  ---  VERSION  5.0   APR  1984
     = = = = =
     COURTESY OF B. A. MURTAGH AND M. A. SAUNDERS,
                 DEPARTMENT OF OPERATIONS RESEARCH,
                 STANFORD UNIVERSITY,
                 STANFORD   CALIFORNIA   94305   U.S.A.


 WORK SPACE NEEDED (ESTIMATE)  --    36727 WORDS.
 WORK SPACE AVAILABLE          --    43038 WORDS.
 (MAXIMUM OBTAINABLE           --    85700 WORDS.)

 EXIT -- OPTIMAL SOLUTION FOUND
```

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1GAMS 2.00 CDC NOS 1.4                              85/08/11.   17.42.51.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 E X E C U T I N G


 ----     728 PARAMETER DELTA      =          0.040 DISCOUNT RATE FOR UTILITY
              PARAMETER LIBOR      =          5.000 FIXED PART OF REAL INT RATE
                                                    ON FOREIGN BORROW
              PARAMETER RHOK       =          0.082 INTEREST RATE ON NON-HUMAN
                                                    WEALTH
              PARAMETER GRAE       =          0.050 MAX RATE OF GROWTH OF
                                                    AGRICULT EXPORTS
              PARAMETER GRME       =          0.100 MAX RATE OF GROWTH OF MANUFAC
                                                    EXPORTS

 ----     729 VAR.L     W          =     1.5551E+7 POST TERMINAL UTILITY
              VAR.L     KTERM      =   1125268.701 TERMINAL CAPITAL STOCK
              VAR.UP    KTERM      =   1700000.000 TERMINAL CAPITAL STOCK
              VAR.L     DTERM      =     63378.200 TERMINAL FOREIGN DEBT
              VAR.UP    DTERM      =    250000.000 TERMINAL FOREIGN DEBT
              PARAMETER YTERM      =    240000.000 ESTIMATE OF POS-TERMINAL
                                                    INCOME


 ----     730 PARAMETER AGG          TABLE OF ECONOMIC AGGREGATES
```

	1984	1988	1992	1996	2000	2004
XT	207953.271	249887.880	302511.583	367077.521	445585.701	540570.898
ZT	90722.568	108695.330	131428.989	159861.841	194254.104	237025.835
YT	112306.470	135285.429	163850.486	198313.743	240443.255	289459.332
CT	77062.204	92974.544	113494.379	136578.883	165553.863	193663.797
INVT	27140.498	34925.792	41767.302	50559.214	59560.671	80649.833
GOVT	4652.407	5236.325	5893.530	6633.220	7465.747	8402.765
ET	12927.530	14485.251	20083.908	28222.991	39653.850	53139.940
MNT	4924.234	5907.121	7232.107	8901.937	10888.342	14085.730
MT	9476.169	12336.484	17388.634	23680.565	31790.876	46397.002
TRBAL	3451.361	2148.767	2695.275	4542.426	7862.974	6742.938
DTT	46385.800	50439.262	60543.079	70958.018	76234.600	69026.673
RTT	7596.100	7000.711	6697.156	9244.420	9930.243	9210.642
HTT	3491.046	3701.042	4325.329	4887.892	5087.312	4357.140
FET	973.680	973.680	973.680	973.680	973.680	973.680
CA	-1013.365	-2525.954	-2603.735	-1319.146	1801.982	1412.118
BTT	8609.465	9526.666	9300.890	10563.566	8128.261	7798.523
KT	358320.086	425720.881	515561.677	622694.045	752869.361	903684.103
DKT	28689.523	36629.938	43893.735	53188.824	62677.785	85360.902
POP	131.374	145.013	160.067	176.684	195.026	215.272
EMP	31.980	35.540	39.993	44.839	50.033	56.300
CPI	11.588	8.537	6.194	4.629	3.449	2.710
INTR	0.170	0.136	0.130	0.121	0.127	0.102
WAGE	2.282	2.574	2.660	2.787	2.675	3.020
EXGR	1.035	1.013	1.011	1.012	1.008	1.003
AIR	0.075	0.073	0.071	0.069	0.067	0.063

LISTING D.G.2

SENSITIVITY TO NON-COMPETITIVE IMPORTS COEFFICIENTS
(20% increase)

```
1GAMS 2.00 CDC NOS 1.4                          85/08/11.   17.53.33.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 E X E C U T I N G


      *************************
      *** PARAMETER CHANGES ***
      *************************

       PARAMETER MNX1(J)  TEMPORARY VARIABLE
                 MNK1(J)  TEMPORARY VARIABLE;
       MNX1(J) = MNX(J)*1.2;
       MNX(J) = MNX1(J);
       MNK1(J) = MNK(J)*1.2;
       MNK(J) = MNK1(J);
       DISPLAY MNX,MNK;

 **** SOLVER STATUS     1 NORMAL COMPLETION
 **** MODEL STATUS      2 LOCALLY OPTIMAL
 **** OBJECTIVE VALUE         27169495.4360

  RESOURCE USAGE, LIMIT          88.586      1000.000
  ITERATION COUNT, LIMIT        179          2000
  EVALUATION ERRORS               0             0

      M I N O S  ---  VERSION  5.0   APR  1984
      = = = = =
      COURTESY OF B. A. MURTAGH AND M. A. SAUNDERS,
                  DEPARTMENT OF OPERATIONS RESEARCH,
                  STANFORD UNIVERSITY,
                  STANFORD   CALIFORNIA   94305   U.S.A.

  WORK SPACE NEEDED (ESTIMATE)  --   36727 WORDS.
  WORK SPACE AVAILABLE          --   43038 WORDS.
  (MAXIMUM OBTAINABLE           --   85700 WORDS.)

  EXIT -- OPTIMAL SOLUTION FOUND
```

```
1GAMS 2.00 CDC NOS 1.4                                 85/08/11.   17.53.33.
 G E N E R A L  A L G E B R A I C  M O D E L I N G  S Y S T E M
 E X E C U T I N G


 ----     728 PARAMETER DELTA         =        0.040 DISCOUNT RATE FOR UTILITY
              PARAMETER LIBOR         =        5.000 FIXED PART OF REAL INT RATE
                                                     ON FOREIGN BORROW
              PARAMETER RHOK          =        0.082 INTEREST RATE ON NON-HUMAN
                                                     WEALTH
              PARAMETER GRAE          =        0.050 MAX RATE OF GROWTH OF
                                                     AGRICULT EXPORTS
              PARAMETER GRME          =        0.100 MAX RATE OF GROWTH OF MANUFAC
                                                     EXPORTS

 ----     729 VAR.L      W            =    1.5524E+7 POST TERMINAL UTILITY
              VAR.L      KTERM        =  1091105.964 TERMINAL CAPITAL STOCK
              VAR.UP     KTERM        =  1700000.000 TERMINAL CAPITAL STOCK
              VAR.L      DTERM        =    67716.629 TERMINAL FOREIGN DEBT
              VAR.UP     DTERM        =   250000.000 TERMINAL FOREIGN DEBT
              PARAMETER YTERM         =   240000.000 ESTIMATE OF POS-TERMINAL
                                                     INCOME


 ----     730 PARAMETER AGG        TABLE OF ECONOMIC AGGREGATES
```

	1984	1988	1992	1996	2000	2004
XT	207564.877	251233.153	304728.858	369069.753	446013.612	544317.711
ZT	90318.704	109868.969	133119.991	161695.960	195136.506	238994.756
YT	110342.574	132951.630	161237.928	194723.010	235142.576	285588.691
CT	76157.117	90270.497	110716.711	132590.881	160773.779	193781.032
INVT	27676.515	35130.938	41062.292	49893.642	62095.618	70877.461
GOVT	4652.407	5236.325	5893.530	6633.220	7465.747	8402.765
ET	12927.530	16847.787	23790.437	32848.117	41973.931	59518.417
MNT	6903.599	8412.554	10370.939	12650.782	15734.530	19734.264
MT	11070.995	14533.917	20225.041	27242.849	37166.500	46990.984
TRBAL	1856.535	2313.870	3565.395	5605.268	4807.431	12527.433
DTT	46385.800	56818.564	68790.436	78894.958	82806.724	90062.065
RTT	7596.100	7638.641	7617.581	10391.480	10836.915	11514.240
HTT	3491.046	4333.158	5117.846	5609.530	5647.586	5967.394
FET	973.680	973.680	973.680	973.680	973.680	973.680
CA	-2608.191	-2992.968	-2526.131	-977.942	-1813.835	5586.359
BTT	10204.291	10631.609	10143.712	11369.421	12650.750	5927.881
KT	358260.051	427847.570	518676.856	622920.881	750001.753	912161.059
DKT	29234.492	36914.796	43258.428	52445.166	65428.789	75017.687
POP	131.374	145.013	160.067	176.684	195.026	215.272
EMP	32.024	35.671	39.938	44.638	50.098	55.727
CPI	11.840	9.011	6.428	4.846	3.594	2.709
INTR	0.161	0.172	0.115	0.136	0.124	0.126
WAGE	2.469	1.980	2.837	2.518	2.684	2.639
EXGR	1.144	1.055	1.051	1.032	1.038	1.041
AIR	0.075	0.076	0.074	0.071	0.068	0.066

LISTING D.H.1

MODEL WITH ALTERNATIVE SPREAD RATE FUNCTION
(base case)

```
1GAMS 2.00 CDC NOS 1.4                          85/09/01.   12.07.47.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 E X E C U T I N G


      ********************************
      *** NEW SPREAD RATE FUNCTION ***
      ********************************
      HRATE(G)$(ORD(G) GT 1)..
            SCALE*HR(G) =E= SCALE*LIBOR + SCALE*ALPHA1/Y(G)*DT(G);
      HCALC(G,TT) $ (GLTT(G,TT) $ (ORD(G) GT 1))..
                H(G,TT) =E= D(G,TT)*0.01*HR(G);

 **** SOLVER STATUS     1 NORMAL COMPLETION
 **** MODEL STATUS      2 LOCALLY OPTIMAL
 **** OBJECTIVE VALUE         27231499.2084

  RESOURCE USAGE, LIMIT        828.082      1000.000
  ITERATION COUNT, LIMIT      2555          3000
  EVALUATION ERRORS              0             0

      M I N O S  ---  VERSION  5.0   APR  1984
      = = = = =
      COURTESY OF B. A. MURTAGH AND M. A. SAUNDERS,
                  DEPARTMENT OF OPERATIONS RESEARCH,
                  STANFORD UNIVERSITY,
                  STANFORD   CALIFORNIA   94305   U.S.A.


  WORK SPACE NEEDED (ESTIMATE)  --    36727 WORDS.
  WORK SPACE AVAILABLE          --    43038 WORDS.
  (MAXIMUM OBTAINABLE           --    85700 WORDS.)

  EXIT -- OPTIMAL SOLUTION FOUND
```

```
1GAMS 2.00 CDC NOS 1.4                            85/09/01.   12.07.47.
 G E N E R A L  A L G E B R A I C  M O D E L I N G  S Y S T E M
 E X E C U T I N G


 ----    656 PARAMETER DELTA        =         0.040 DISCOUNT RATE FOR UTILITY
             PARAMETER LIBOR        =         5.000 FIXED PART OF REAL INT RATE
                                                    ON FOREIGN BORROW
             PARAMETER RHOK         =         0.082 INTEREST RATE ON NON-HUMAN
                                                    WEALTH
             PARAMETER GRAE         =         0.050 MAX RATE OF GROWTH OF
                                                    AGRICULT EXPORTS
             PARAMETER GRME         =         0.100 MAX RATE OF GROWTH OF MANUFAC
                                                    EXPORTS

 ----    657 VAR.L     W            =     1.5514E+7 POST TERMINAL UTILITY
             VAR.L     KTERM        =   1074142.955 TERMINAL CAPITAL STOCK
             VAR.UP    KTERM        =   1700000.000 TERMINAL CAPITAL STOCK
             VAR.L     DTERM        =     64415.066 TERMINAL FOREIGN DEBT
             VAR.UP    DTERM        =    250000.000 TERMINAL FOREIGN DEBT
             PARAMETER YTERM        =    240000.000 ESTIMATE OF POS-TERMINAL
                                                    INCOME

 ----    658 PARAMETER AGG        TABLE OF ECONOMIC AGGREGATES
```

	1984	1988	1992	1996	2000	2004
XT	207896.222	249471.138	303898.943	367835.536	443213.240	549439.153
ZT	90666.703	108348.839	132457.924	160455.453	192721.983	242754.910
YT	111324.640	133968.059	162668.178	196769.194	236790.960	289910.970
CT	77023.729	92980.177	112146.202	135530.822	164601.088	193017.114
INVT	27160.064	35492.691	41330.040	49524.115	63776.132	65411.624
GOVT	4652.407	5236.325	5893.530	6633.220	7465.747	8402.765
ET	12927.530	13745.075	22068.144	2.8676E+9	38052.155	67357.626
MNT	5904.879	7154.240	8772.842	10610.890	13700.297	16773.273
MT	10439.090	13486.209	18769.738	2.8676E+9	37104.163	44278.158
TRBAL	2488.440	258.866	3298.405	5081.037	947.993	23079.468
DTT	46385.800	54290.945	72914.510	84376.833	92296.313	119062.078
RTT	7596.100	7385.879	7992.074	10910.534	12082.539	14634.010
HTT	3491.046	3941.077	5190.306	6087.226	6665.754	8444.035
FET	973.680	973.680	973.680	973.680	973.680	973.680
CA	-1976.286	-4655.891	-2865.581	-1979.869	-6691.441	13661.753
BTT	9572.386	12041.771	10857.655	12890.404	18773.981	972.257
KT	358310.450	425643.754	518046.636	623312.579	748506.147	919282.658
DKT	28672.246	37257.831	43487.810	51974.608	67516.724	69232.569
POP	131.374	145.013	160.067	176.684	195.026	215.272
EMP	31.986	35.640	40.015	44.724	50.319	55.345
CPI	11.597	8.537	6.303	4.687	3.475	2.721
INTR	0.168	0.141	0.121	0.132	0.124	0.107
WAGE	2.291	2.494	2.781	2.604	2.717	2.922
EXGR	1.032	1.018	1.027	1.020	1.024	1.022
AIR	0.075	0.073	0.071	0.072	0.072	0.071

LISTING D.H.2

MODEL WITH ALTERNATIVE SPREAD RATE FUNCTION
(high petroleum prices)

```
1GAMS 2.00 CDC NOS 1.4                          85/09/01.   12.18.29.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 C O M P I L A T I O N


 *************************
 *** PARAMETER CHANGES ***
 *************************

  PARAMETER GRPP   GROWTH RATE OF PETROLEUM PRICES;
      GRPP = 0.04;
  PM("PETRO",T) = (1+GRPP)**(NYPP*(ORD(T)-1)+1);
  DISPLAY GRPP,PM;
  E.FX("PETRO",T)= 0;


**** SOLVER STATUS     1 NORMAL COMPLETION
**** MODEL STATUS      2 LOCALLY OPTIMAL
**** OBJECTIVE VALUE         26979286.6160

 RESOURCE USAGE, LIMIT        173.331     1000.000
 ITERATION COUNT, LIMIT       338         2000
 EVALUATION ERRORS              0            0

     M I N O S  ---  VERSION  5.0   APR  1984
     = = = = =
     COURTESY OF B. A. MURTAGH AND M. A. SAUNDERS,
                 DEPARTMENT OF OPERATIONS RESEARCH,
                 STANFORD UNIVERSITY,
                 STANFORD   CALIFORNIA   94305   U.S.A.


 WORK SPACE NEEDED (ESTIMATE)  --   36727 WORDS.
 WORK SPACE AVAILABLE          --   43038 WORDS.
 (MAXIMUM OBTAINABLE           --   85700 WORDS.)

 EXIT -- OPTIMAL SOLUTION FOUND
```

```
1GAMS 2.00 CDC NOS 1.4                              85/09/01.   12.19.11.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 E X E C U T I N G


 ----     726 PARAMETER DELTA          =          0.040 DISCOUNT RATE FOR UTILITY
              PARAMETER LIBOR          =          5.000 FIXED PART OF REAL INT RATE
                                                        ON FOREIGN BORROW
              PARAMETER RHOK           =          0.082 INTEREST RATE ON NON-HUMAN
                                                        WEALTH
              PARAMETER GRAE           =          0.050 MAX RATE OF GROWTH OF
                                                        AGRICULT EXPORTS
              PARAMETER GRME           =          0.100 MAX RATE OF GROWTH OF MANUFAC
                                                        EXPORTS

 ----     727 VAR.L      W             =      1.5477E+7 POST TERMINAL UTILITY
              VAR.L      KTERM         =    1078090.972 TERMINAL CAPITAL STOCK
              VAR.UP     KTERM         =    1700000.000 TERMINAL CAPITAL STOCK
              VAR.L      DTERM         =     114106.984 TERMINAL FOREIGN DEBT
              VAR.UP     DTERM         =     250000.000 TERMINAL FOREIGN DEBT
              PARAMETER YTERM          =     240000.000 ESTIMATE OF POS-TERMINAL
                                                        INCOME

 ----     728 PARAMETER AGG          TABLE OF ECONOMIC AGGREGATES
```

	1984	1988	1992	1996	2000	2004
XT	207380.510	251718.854	305126.934	369296.725	450009.188	545381.248
ZT	90141.531	110288.637	133232.548	161483.364	198464.913	238551.888
YT	111221.282	133106.981	159567.910	188727.621	222084.423	261677.393
CT	75754.158	88697.405	108753.851	129472.830	150187.671	186508.063
INVT	27852.557	35245.659	41160.532	49909.353	62971.388	66827.725
GOVT	4652.407	5236.325	5893.530	6633.220	7465.747	8402.765
ET	12927.530	17748.832	24553.757	34208.174	47968.015	67657.750
MNT	5859.791	7132.077	8742.175	10832.033	13299.526	16294.082
MT	9965.371	13821.240	20793.760	31495.956	46508.399	67718.910
TRBAL	2962.159	3927.592	3759.997	2712.218	1459.616	-61.160
DTT	46385.800	52396.068	55801.351	60461.911	70242.767	87098.814
RTT	7596.100	7196.392	6252.335	8194.129	8951.843	10683.388
HTT	3491.046	3805.233	3951.457	4183.752	4699.948	5717.202
FET	973.680	973.680	973.680	973.680	973.680	973.680
CA	-1502.567	-851.321	-1165.140	-2445.214	-4214.012	-6752.042
BTT	9098.667	8047.713	7417.475	10639.343	13165.855	17435.430
KT	358234.691	428551.924	519847.543	624388.822	752092.725	917197.418
DKT	29416.278	37045.460	43369.380	52661.552	66246.811	70731.390
POP	131.374	145.013	160.067	176.684	195.026	215.272
EMP	32.043	35.711	39.932	44.559	49.945	55.363
CPI	11.967	9.359	6.695	5.141	4.100	3.048
INTR	0.151	0.196	0.091	0.141	0.082	0.155
WAGE	2.710	1.447	2.812	1.912	2.627	1.220
EXGR	1.179	1.118	1.173	1.153	1.111	1.186
AIR	0.075	0.073	0.071	0.069	0.067	0.066

LISTING D.H.3

MODEL WITH ALTERNATIVE SPREAD RATE FUNCTION
(protectionist export markets)

```
1GAMS 2.00 CDC NOS 1.4                              85/09/01.   12.20.30.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 C O M P I L A T I O N


   *************************
   *** PARAMETER CHANGES ***
   *************************

    GRAE = 0.03;
    GRME = 0.075;

    E.UP("AGRIC",T) = EO("AGRIC")*(1+GRAE)**(NYPP*(ORD(T)-1)+1);
    E.UP("AGROP",T) = EO("AGROP")*(1+GRAE)**(NYPP*(ORD(T)-1)+1);
    E.UP("MANCG",T) = EO("MANCG")*(1+GRME)**(NYPP*(ORD(T)-1)+1);
    E.UP("MANOG",T) = EO("MANOG")*(1+GRME)**(NYPP*(ORD(T)-1)+1);

**** SOLVER STATUS     1 NORMAL COMPLETION
**** MODEL STATUS      2 LOCALLY OPTIMAL
**** OBJECTIVE VALUE         27208426.6223

 RESOURCE USAGE, LIMIT        265.326      1000.000
 ITERATION COUNT, LIMIT       650          2000
 EVALUATION ERRORS              0             0

     M I N O S  ---  VERSION  5.0   APR  1984
     = = = = =
     COURTESY OF B. A. MURTAGH AND M. A. SAUNDERS,
                 DEPARTMENT OF OPERATIONS RESEARCH,
                 STANFORD UNIVERSITY,
                 STANFORD   CALIFORNIA   94305   U.S.A.


 WORK SPACE NEEDED (ESTIMATE)  --    36727 WORDS.
 WORK SPACE AVAILABLE          --    43038 WORDS.
 (MAXIMUM OBTAINABLE           --    85700 WORDS.)

 EXIT -- OPTIMAL SOLUTION FOUND
```

```
1GAMS 2.00 CDC NOS 1.4                          85/09/01.   12.21.29.
 G E N E R A L   A L G E B R A I C   M O D E L I N G   S Y S T E M
 E X E C U T I N G


 ----     729 PARAMETER DELTA          =          0.040 DISCOUNT RATE FOR UTILITY
              PARAMETER LIBOR          =          5.000 FIXED PART OF REAL INT RATE
                                                        ON FOREIGN BORROW
              PARAMETER RHOK           =          0.082 INTEREST RATE ON NON-HUMAN
                                                        WEALTH
              PARAMETER GRAE           =          0.030 MAX RATE OF GROWTH OF
                                                        AGRICULT EXPORTS
              PARAMETER GRME           =          0.075 MAX RATE OF GROWTH OF MANUFAC
                                                        EXPORTS

 ----     730 VAR.L     W              =      1.5489E+7 POST TERMINAL UTILITY
              VAR.L     KTERM          =    1112351.645 TERMINAL CAPITAL STOCK
              VAR.UP    KTERM          =    1700000.000 TERMINAL CAPITAL STOCK
              VAR.L     DTERM          =     128273.371 TERMINAL FOREIGN DEBT
              VAR.UP    DTERM          =     250000.000 TERMINAL FOREIGN DEBT
              PARAMETER YTERM          =     240000.000 ESTIMATE OF POS-TERMINAL
                                                        INCOME

 ----     731 PARAMETER AGG            TABLE OF ECONOMIC AGGREGATES
```

	1984	1988	1992	1996	2000	2004
XT	207213.419	250526.628	302128.435	364281.481	440254.023	535272.829
ZT	89981.660	109218.472	130648.283	157586.498	189534.364	232488.185
YT	111452.452	134326.161	162987.591	196303.120	237940.238	286286.223
CT	76000.229	90920.343	114094.738	137412.759	169867.403	197472.820
INVT	27701.144	34880.770	40322.899	50328.429	58960.850	79223.975
GOVT	4652.407	5236.325	5893.530	6633.220	7465.747	8402.765
ET	12651.164	15918.960	20160.467	2.8676E+9	32912.199	42386.583
MNT	5779.307	6981.994	8492.561	10391.868	12779.422	16498.421
MT	9552.493	12630.235	17484.043	2.8676E+9	31265.961	41199.919
TRBAL	3098.672	3288.724	2676.424	1928.711	1646.238	1186.663
DTT	46385.800	51850.017	57654.599	67139.994	81942.921	101580.466
RTT	7596.100	7141.787	6429.469	8870.078	10302.999	12496.442
HTT	3491.046	3766.189	4074.093	4655.760	5581.944	6886.210
FET	973.680	973.680	973.680	973.680	973.680	973.680
CA	-1366.054	-1451.145	-2371.349	-3700.728	-4909.386	-6673.226
BTT	8962.154	8592.932	8800.818	12570.810	15212.385	19169.669
KT	358228.869	427785.628	517420.308	618413.551	747604.757	896666.046
DKT	29226.141	36620.771	42444.966	52895.625	62198.477	83851.753
POP	131.374	145.013	160.067	176.684	195.026	215.272
EMP	32.052	35.693	39.867	44.614	49.776	55.844
CPI	11.930	8.940	6.159	4.611	3.344	2.647
INTR	0.187	0.190	0.116	0.138	0.133	0.097
WAGE	2.126	1.591	2.615	2.273	2.297	2.813
EXGR	1.289	1.271	1.379	1.380	1.451	1.442
AIR	0.075	0.073	0.071	0.069	0.068	0.068