Wiebelt, Manfred

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Stopping Deforestation in the Amazon: Trade-off between Ecological and Economic Targets?

By

Manfred Wiebelt

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I. Introduction

Global warming caused by CO_2 emissions is at the centre of the discussion about environmental policy. Estimates reveal the relevance of the problem. At current rates, concentration levels of CO_2 – the principal greenhouse gas – in the atmosphere will increase by 50 percent over the next fifty years. The predicted effects upon global average temperature would be an increase in the range of 1.5° to 4.5 °C (World Bank 1992). Historically, this would be an unmatched rate of climatic change with catastrophic consequences on the sea level, as well as on agricultural productivity (Solow 1991; Nordhaus 1991).

The Amazon deforestation is one of the major contributors to the current CO_2 emissions. Estimates show a range of 0.29 Gt to 0.41 Gt per year – that is, approximately, 4.7 to 6.6 percent of global emissions to the atmosphere ranking Brazil as the fourth-largest single contributor to CO_2 emissions after the United States, the former U.S.S.R., and China. For the year 2030, these emissions are estimated to be in the range of 0.9 to 1.3 Gt per year – three times the present rate and 14 to 18 percent of global emissions (Reis and Margulis 1991). Thus, the relative contribution of Amazon deforestation to global warming will even increase in the future.

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Given this alarming scenario, policy action focusing on stopping the Amazon deforestation is urgently required both at the international and at the national level. At the international level, a comparison of the economic costs that might be involved in limiting CO_2 emissions from Amazon deforestation against those associated with other international action is asked for (Amelung and Wiebelt 1995). At the national level, solutions to the Amazon deforestation problems will require deep changes in the attitude of the Brazilian government with respect to environmental issues. The geographical vastness and demographic emptiness of the Brazilian Amazon make it still an open-access resource that is overutilized from both global and local perspectives. In addition to the inadequate institutional framework, misguided government policies have further stimulated unsustainable rates of natural resource depletion. These policies will have to be drastically reoriented in order to reconcile economic growth and environmental protection.

In sharp contrast to the need for policy action, Brazil still takes a free-rider position arguing that it's scope for policy action is severely constrained by pressing economic and social problems. It could be argued, however, that macroeconomic reforms may not only solve acute economic and social problems but also ease environmental pressure. Moreover, sectoral and regional policies to reduce deforestation do not necessarily increase economic and social pressures.

The present paper quantitatively investigates the effects of such policies. The objective is to sort out policies which protect Brazil's tropical rain forest at least economic costs. For this purpose, a computable general equilibrium (CGE) model was developed which – contrary to the widespread partial analyses of Brazilian policies – captures a wide range of policy distortions as well as the economy-wide repercussions of policies and, hence, allows for conclusions about structural responses and the change in land use patterns.

The remainder of this paper is organized as follows: Section II provides evidence on deforestation in the Brazilian Amazon and identifies the major causes of deforestation. Both serve as a basis for policy modelling. Next, Section III describes the main elements and assumptions of a multi-sectoral general equilibrium model for Brazil, while the complete model specification and the underlying data base are relegated to the Appendix. This model is used in Section IV to simulate the effects of macroeconomic, sectoral, and regional policies. The main conclusions are summarized in Section V.

II. Policy-Relevant Features of Amazon Deforestation

How much of Brazil's Amazon rain forest has actually been destroyed is heavily debated. Estimates range from 5.1 percent, provided by the Brazilian Government, to 7.64 percent calculated by the Brazilian National Institute for Space Research (INPE), to 12 percent given by the World Bank (Mahar 1989, p. 6). Applying INPE's figure to the geographical area of Legal Amazonia (Table 1) implies that some 375,000 km^2 (an area about the size of Japan) had been cleared as of 1988.

Of as much interest as the total quantity of land deforested is the rate of new clearing. INPE estimates that in 1988 121,000 km^2 of Amazonia were burned to make room for crops and pasture, of which 48,000 km^2 were rain forest. These numbers imply that Brazil is losing an area of rain forest nearly the size of Costa Rica (51,000 km^2) each year.

The extent of deforestation differs sharply among Amazonian States (Table 1). As of 1991, the clearing has been most intense in the southern states. While Maranhão cleared about 35 percent of forest land and the clearing rate in Tocantino, Mato Grosso, Pará and Rondônia still ranged between 9 and 15 percent, the northern and

Table 1 – *Deforestation in Legal Amazon States, 1975–91*

State	Geographical area[a] (1,000 km^2)	Deforested share (percent)				Annual growth (1,000 km^2) 1975–91
		1975	1978	1988	1991	
Acre	154.7	0.76	1.60	5.78	6.96	0.60
Amapá	142.4	0.11	0.12	0.55	1.19	0.10
Amazonas	1,568.0	0.05	0.11	1.26	1.48	1.40
Pará[a]	1,246.8	3.89	4.52	10.39	11.87	6.22
Rondônia	238.4	0.51	1.78	12.60	14.51	2.09
Roraima	225.0	0.02	0.06	1.22	1.87	0.26
M. Grosso[b]	802.4	1.15	2.49	8.91	10.78	4.83
Maranhão[a,b]	260.2	23.55	24.55	34.90	35.47	1.94
Tocantins[b]	269.9	1.26	1.14	7.79	8.44	1.21
Legal Amazon	4,906.9	2.55	3.10	7.64	8.68	18.80

[a] Includes the "old deforestation" areas of the Bragantine Zone: 31,822 km^2 in Pará and 60,724 km^2 in Maranhão. – [b] Includes only portion of the state pertaining to the Legal Amazon region.

Source: May and Reis (1993).

western states of Amapá, Roraima, Amazonas, and Acre conserved over 93 percent of their forests. The regional concentration of deforestation in the southern states of Legal Amazonia influences not only the effectiveness and the costs but also the potential local resistance against alternative measures to preserve the rain forest.[1]

Most deforestation in the Amazon is the result of small-scale farming and cattle ranching, Squatters who practice shifting cultivation are the leading agents in the conversion of forest lands to subsistence crop. Conversion to perennial crops or – as is more common – pastures, usually occurs in a second stage. Logging in Amazonia has generally been a by-product of clearing for agricultural purposes. Mining and hydroelectric development, by contrast, played a minor and indirect role (Amelung and Diehl 1992). The expansion of the agricultural frontier is decisively conditioned by the government's construction of roads, since the existence of a road network is a prerequisite for economic and demographic settlement of the so-called terra firme (uplands between rivers that had previously served as principal transport corridors).[2] It comes, therefore, as no surprise that deforestation has followed a very predictable pattern (Serôa da Motta 1993). Much of the clearing has been concentrated along a few major highways or in areas targeted by the government for development.

Because deforestation activities are not independent events, it is difficult to attribute to each a proportion of the deforestation taking place. Land frequently goes through a succession of uses in the transformation from undisturbed forest to cleared land (Mahar 1989, pp. 7ff.). For example, the process starts with the government building a road into a virgin forest. The newly accessible land is then first utilized by loggers who remove the commercially valuable species and move on. Next, marginal farmers burn the remaining forest to improve the soil's fertility. After 3 to 4 years, falling yields force the farmers to leave. The land then becomes pasture, or is abandoned.

Notwithstanding the difficulties to identify the land use which led to deforestation, some estimations give a rough indication. Areas logged can be calculated using production figures for timber (IBGE 1992, p. 564) and assuming that an average hectare supplies 60 m^3 of

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[1] The annual growth rates of absolute deforestation which is relevant for the CO_2 emissions caused by Brazil show that the southern states of Pará and Mato Grosso figure prominently. Hence, the southern states are also most important for the international effects of deforestation in Brazil.

[2] See May and Reis (1993) for a more detailed analysis of the user structure in Brazil's tropical rain forest.

commercial timber (Myers 1980). This estimation shows for Classic Amazonia that the logged area soared from 1,900 km^2 in 1980 to 7,900 km^2 in 1989. When the Legal Amazon is considered, the area logged increases from 2,470 km^2 in 1980 to 8,550 km^2 in 1989.[3] These numbers suggest that the scale of logging operations in the Amazon quadrupled in the 1980s. State data show that this increase was heavily concentrated in the southern Amazon.

Estimates for the forest land converted to cropland can be derived from annual state data on land in production for an extensive list of annual and perennial crops (IBGE 1985, pp. 438ff.; IBGE 1992, pp. 539ff.). For 1980, the estimated areas of cropland were 9,386 km^2 in Classic Amazonia and 67,542 km^2 in the Legal Amazon; for 1989, the respective numbers were 17,273 km^2 and 100,371 km^2.[4] These numbers imply that between 1980 and 1989, the land being used to grow crops increased about 85 percent in Classic Amazonia and about 50 percent in the Legal Amazon. Again the increase in cropland was heavily concentrated in the south.

Because converted rain forest can only be farmed for 3 to 4 years, considerable forest clearing is necessary just to maintain the current quantity of cropland. Assuming farmers just maintain the 1989 level of cropland and each hectare has a 4-year productive live, 25,093 km^2 of forest must be cleared each year. This is over three times the estimated area being logged. These estimates indicate how much more important farming pressures are as a source of deforestation in the Amazon than the pressures from logging. It also implies that a large quantity of commercially valuable timber is simply being destroyed under current farming practices.[5]

Estimates of the amount of pasture in the Amazon can be derived from state data on cattle herds assuming a stocking rate of 0.75 head per hectare (Myers 1980). This implies that the land use for pasture increased from 49,160 km^2 in 1980 to 176,000 km^2 in 1989 in Classic Amazonia and from 156,960 km^2 to 283,280 km^2 in Legal Amazonia,

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[3] These latter figures include southern Goiás and eastern Maranhão, which are not part of the Legal Amazon. Estimates will be little affected because these areas are not heavily forested.

[4] The cropland estimates for the Legal Amazon are biased upward by the inclusion of southern Goiás and eastern Maranhão.

[5] Wood removal rates associated with agropastoral expansion are, in fact, quite inefficient, averaging only about 19 percent of estimated timber volume removed by land clearing, even when fuelwood and charcoal production is included in the estimate. See May and Reis (1993, pp. 29f.).

respectively.[6] Hence in both areas about 14,000 km^2 have been added to pasture land in each year.

The short description of deforestation in Brazil has shown three aspects:

(1) the absolute area of the rain forest destroyed in Brazil each year compares to the area of a small country;
(2) the dynamics of deforestation differ sharply among Amazonian states with clearing being most intensive in the southern states;
(3) estimates of additional land use show a clear ranking with respect to the sectoral contribution to deforestation with cattle-ranching on top followed by small-scale farming and, to a much lesser extent, logging.

While the total extent of land clearing emphasizes the relevance of focusing on Brazil, the regional and sectoral aspects provide the background for an appropriate formulation of policy alternatives and the model used for policy analysis.

III. A General Equilibrium Model for Analyzing Conservation Policies in Brazil

The open economy static general equilibrium model constructed for policy analysis (see the Appendix) emphasizes the real sector, with parameter values chosen to reflect the Brazilian economy. The general theoretical structure which underlies this analytical framework is the multisector, general equilibrium model system developed by Dervis et al. (1982), which in turn has its origin in Johansen (1960).[7] This basic model was modified according to the regional and sectoral characteristics of the Brazilian economy which are relevant for analyzing anti-deforestation policies.

Most importantly, the model considers the Brazilian economy as consisting of three regions, where two regions (I and II) produce only primary products and the third region produces only manufactured products and services. Region I represents the Amazon while region II

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[6] Estimates of pasture land in Legal Amazonia are biased downward by the omission of Goiás. Goiás, however, is a major cattle-producing state and much of this industry is located in its southern region. Hence, including it here would have greatly exaggerated the area of pasture in the Legal Amazon.

[7] One characteristic of this class of models is the fairly firm rooting in conventional microeconomic theory: Producers minimize costs subject to certain technology constraints, while consumers maximize utility subject to a budget constraint. Another trait is the detailed attention devoted to intersectoral linkages.

contains all primary production outside the Amazon; in both regions, the primary sector is disaggregated into six producing sectors. In effect, we may think of these regions as two primary producing countries having extremely close economic ties both with each other and a third country represented by the Brazilian secondary and tertiary sectors. The two primary regions differ only with respect to the proportions in which the six primary sectors are represented in each; with region I containing a relatively high concentration of timber, livestock, and mining. In view of the fact that accessible production data was only available at the state level, region I (the Amazon) was given a sectoral structure that reflects the primary composition of the Northwest region comprising the North region (Rondônia, Acre, Amazonas, Roraima, Pará, Amapá) and the states of Maranhão, Mato Grosso, and Goiás, while Region II comprises the primary production in the remaining states. With this regional classification, region I accounts for about 16 percent of the total value of agricultural production in Brazil in 1980, for about 27 percent of total livestock production, 21 percent of total timber production, and 31 percent of mining. These primary sectors contribute only about 1.8 percent to Brazil's GDP while the primary sectors in region II contribute about 9.5 percent.

The commodities produced in Brazil consist of eleven goods differentiated by their degree of tradability. The sectoral classification employed here is based on an aggregation of 90-industries-136-commodities input-output table provided by IBGE (1989) and is explained in the Appendix. It is assumed that the technology employed in each primary sector is the same across regions, that each sector produces an identical good in both regions, and that there are no commodity trade barriers between both regions. Hence, the primary goods of each region are perfect substitutes and the law-of-one price obtains across regions. However, domestically produced goods and similarly classified goods produced in the rest of the world are taken to be imperfect substitutes.

The primary factors of production have been classified into five types: labor – subdivided into mobile workers, rural workers, and urban workers[8] –, capital, and land. Mobile workers are assumed to

[8] Rural workers comprises agricultural workers and small landowners or "minifundistas" who own a plot of land as well as "garimpeiros". What distinguishes them from mobile labor, is that they are tied to the land and earn, in addition to their wage income, a share of profits. Urban workers, or organized labor, are employed only in the manufacturing sectors and the government.

be mobile both between regions (though not internationally) and sectors. This means, essentially, that mobile workers receive the same wage, independently of the sector and region in which they are employed. Rural workers are also mobile between regions. However, their sectoral mobility is restricted to primary sectors while urban workers are assumed to be mobile across secondary and tertiary sectors. As a consequence, rural workers in both regions receive a uniform wage independent of the primary sector in which they are employed. Also, urban workers in each secondary and tertiary sector receive the same wage. Land is assumed to be in abundant supply at fixed rental rates. However, rental rates may differ between regions but not between sectors in any region.

Physical capital is both sectorally and regionally immobile in the short run, and totally mobile (sectorally and regionally) in the medium run. This means that in the short run sectoral capital stocks are exogenously fixed, while their rates of return are determined endogenously. In the medium run, the sectoral and regional capital stocks are endogenously determined subject to the condition of equal rates of return in each sector. Hence the model considers two closures, denoted as the short-run and the medium-run solution.[9]

Several items have been placed on the list of exogenous variables in both model closures:

– Net capital flows and, hence, the balance of capital and current account are exogenous, while the exchange rate is determined endogenously. This allows to model Brazil's capital constraint without explicitly incorporating the financial sector into the model.

– The total capital stock of the economy is held constant. In the short run, this is consistent with the previous assumption of sectoral and regional capital immobility. In the medium run, this constraint serves to bring out more clearly the capital-redistribution effects of various policies across regions and sectors.

– The producer price index is held constant. The model focuses entirely on the real sector with money regarded simply as a 'veil' along traditional classical lines. This means that all real variables depend only on relative prices.

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[9] The term "long run" is reserved to cover the situation (not considered in this paper) where all types of labor become perfect substitutes, e.g., where they are totally mobile regionally, sectorally, and occupationally.

– The land rental is fixed exogenously because land is assumed to be in abundant supply, leaving land usage to be determined by demand.

The model is written as a set of four groups of structural equations (see Appendix):

(1) Eqs. (1)–(7) give the domestic price vectors obtained by setting pure profits from all activities to zero, i.e., perfectly competitive conditions are assumed to prevail.

(2) Eqs. (8)–(14) describe the supply side of the model.[10] To capture the fact that land rentals differ inside and outside the Amazon, the model allows for distortions in land markets.[11] Eqs. (11) and (12) give the constant-elasticity-of-substitution import aggregation (Armington) functions and the corresponding sectoral import demands, which depend on relative prices and the substitution elasticities. Analogously, eqs. (13) and (14) describe the constant-elasticity-of-transformation export transformation functions and the corresponding sectoral export supplies depending on relative prices and the transformation elasticities (see Table A3).

(3) Eqs. (15)–(20) describe the final demands for commodities by households, firms, government, and the rest of the world.[12] With respect to the last of these, it is assumed that Brazilian producers face

[10] Underlying these equations is the assumption that producers minimize costs subject to a nested, three tier, constant-rate-of-substitution production function. At the highest tier, a Leontief technology is assumed, with fixed proportions between intermediate inputs and an aggregate of primary factors. At the second tier, CES functions describe the substitution prospects between domestic and foreign-produced intermediate inputs and Cobb-Douglas functions describe the substitution possibilities between the three primary factors (capital, land and aggregate labor). At the third tier, Cobb-Douglas functions describe the substitution prospects between different types of workers.

[11] This is represented by the region-specific parameter α_{if} that measures the extent to which the marginal revenue product of land in the Amazonian primary sectors deviates from the average rental across all Brazilian primary sectors.

[12] These equations were derived using the following postulates:

- Households choose consumption to maximize an additive nested utility function subject to an aggregate budget constraint. The nests of commodity categories involve CES functions describing the substitution possibilities between domestic and imported sources of each category. Leisure is not considered as a choice variable.
- Investment spending is modeled (somewhat rudimentarily) by assuming fixed coefficients. Total investment is determined endogenously by the sum of domestic and foreign savings, and is allocated across industries in such a way as to equate expected rates of return.
- Real government expenditures are held constant and fall entirely on services.

a downward-sloping demand curve for their exports.[13] On the import side, however, the 'small-country' assumptions prevail, so that Brazil faces an exogenously given vector of imported goods prices.

(4) Eqs. (21)–(24) provide the conditions for the clearing of factor and commodity markets, trade balance, and the savings-investment identity. Since the financial sector is ignored in this model, money or bond finance of government activities are not considered. The government must finance its expenditures entirely through taxes.

All in all, the quantification of the model has been matched to both the essential structural characteristics of the Brazilian economy and to the analysis of macroeconomic, sectoral, and regional policies which affect deforestation directly or indirectly. Such policies are simulated in the following.

IV. Simulation of Macroeconomic, Sectoral, and Regional Policies

Removing Macroeconomic Mismanagement

The effects of macroeconomic mismanagement can be simulated by assuming that the net capital inflow recorded by the underlying 1980 SAM is reduced to zero.[14] This is a quite reasonable procedure in the case of Brazil because macroeconomic mismanagement contributed to the fact that Brazil was among the countries which have been severely hit by the outbreak of the debt crisis leading to credit rationing and overvalued exchange rates. Continued macroeconomic mismanagement – consistent with Brazil's muddling-through strategy since that time (Funke et al. 1992) – also contributed to the fact that Brazil is still credit constrained while Latin America reform countries reemerged on international capital markets. Hence, the need to devalue the (real) exchange rate in order to restore external equilibrium can largely be attributed to macroeconomic mismanagement. The relevant question is whether or not the devaluation process encouraged an increased land use in the Amazon. If so, this gives an indica-

[13] This follows from the fact that foreigners (like consumers in Brazil) differentiate between Brazil's supply and the rest of the world's supply. If Brazil wants to increase its world market share of a commodity, it must lower the dollar price of its own product.

[14] The Brazilian input-output table for 1980 records a trade deficit of 220.7 billion cruzeiros or 2 percent of GDP which is financed by foreign capital inflows (see Appendix Table A2). Thus, eliminating these capital inflows represents a sizeable foreign exchange "crisis".

tion of how much of the rain forest could be conserved by macroeconomic reform, i.e., by easing the devaluation pressure and relaxing the credit constraint.

With open access to land, the change in the land use pattern and the extent of deforestation is determined by the demand for land. This is reflected in Table 2 which reports the sectoral, regional, and macroeconomic results of macroeconomic mismanagement. First of all, we notice that the devaluation affects the sectoral outputs of primary products uniformly across both regions, leading to an expansion and increasing land use in all primary sectors. This result obtains in the short as well as in the medium run. The basic reason is that these sectors produce tradable final goods or raw materials used in the production of tradable manufactured goods and, hence, benefit directly or indirectly from the increase of the relative prices for these products due to devaluation. Differences in the magnitude of the expansion between primary sectors stem from differences in export orientation, import dependence, and trade elasticities.[15]

Cash crops, and to a lower extent, food crops are either directly exported or processed in the highly export-oriented food manufacturing sector and, therefore, expand their production. By contrast, the production of other agricultural products increases only slightly because the backward-linkage effect resulting from the expansion of the food manufacturing sector is partly offset by reduced domestic absorption resulting from the devaluation. The production of timber and livestock are also affected to a lesser extent than crop production by the devaluation. About 95 percent of the timber production is consumed domestically and about 90 percent of domestic supply is either processed by the domestic consumer goods industry or used in the domestic construction industry (which is included in services in the model). Thus, there are two opposing effects on timber production. Increasing demand from abroad and the domestic manufacturing sector is partly offset by reduced demand from the domestic nontradable construction sector which reduces its production as a result

[15] Not surprisingly, the largest percentage increase in output is registered by the domestic mining sector. Mining is the most export-oriented sector having the highest ratio of exports to domestic supply (see Appendix Table A3). Moreover, the sectoral import share of mining is large implying relatively large demand increases for the domestic product in order to compensate for relatively small reductions in imports. Finally, the domestic demand for mining is not price sensitive because these products are exclusively used as intermediates (with fixed input-output coefficients) in domestic production.

Table 2 – *The Effects of Trade Balance Adjustment by Devaluation*[a]

	Short run		Medium run	
	Region I	Region II	Region I	Region II
Sectoral outputs				
(1) Food crops	3.41	3.41	2.74	2.74
(2) Cash crops	3.93	3.93	4.73	4.73
(3) Other agricultural products	0.12	0.12	0.92	0.92
(4) Timber	0.98	0.98	1.34	1.34
(5) Livestock	1.42	1.42	1.27	1.27
(6) Mining	7.77	7.77	7.25	7.25
(7) Manufactured food	2.23		1.52	
(8) Consumer goods	1.75		0.94	
(9) Intermediates	1.47		1.98	
(10) Capital goods	−0.74		1.36	
(11) Services	−0.56		−0.96	
Factors				
Land use				
(12) Food crops	5.13	5.13	3.43	3.43
(13) Cash crops	6.32	6.32	5.43	5.43
(14) Other agricultural products	1.77	1.77	1.74	1.74
(15) Timber	3.47	3.47	2.41	2.41
(16) Livestock	3.55	3.55	1.85	1.85
(17) Mining	20.10	20.10	7.89	7.89
(18) Regional land input	5.28	4.68	2.89	3.07
(19) Regional employment of mobile labor	10.64	8.98	4.65	4.43
(20) Regional employment of rural labor	1.25	−0.27	0.18	−0.04
(21) Land rental	0.00 (EX)		0.00 (EX)	
(22) Rate of return to capital	−1.83		−0.60	
Macroeconomic variables				
(23) Exchange rate	17.21		6.09	
(24) Real GDP	0.09		0.02	
(25) Domestic price of imports	17.21		6.09	
(26) Domestic price of exports	12.15		3.66	
(27) Dollar price of exports	−4.64		−2.34	
(28) Imports (volume)	−7.14		−9.85	
(29) Exports (volume)	15.29		9.81	
(30) Trade balance	−100.00		−100.00	
(31) Producer price	0.00 (EX)		0.00 (EX)	

[a] All figures refer to percentage changes; (EX) means that the variable in question is exogenously determined.

Source: Own calculations based on the model described in the Appendix.

of lower relative prices. The net effect is a 1 percent increase of domestic timber production. A similar result emerges in the livestock sector which is nearly exclusively oriented toward the domestic market. Forward linkages to the expanding food manufacturing sector encourage cattle ranching. However, reduced demand for breeding as a result of missing foreign exchange offsets partly this expansionary effect.[16]

Although the sectoral impact is the same in both regions, the overall regional impact will not be the same simply because the primary sectors are represented in different proportions in both regions and there are strong factor price effects that have a differential impact across sectors, depending on the difference in relative factor intensities. This is clearly reflected in the effects on regional factor allocation (rows (18) to (20)). In general, devaluation reduces domestic wages. However, the wage rate for rural labor increases because all primary sectors benefit from devaluation and these sectors are the sole users of rural labor. Rural labor which is intensively used in the primary sectors outside the Amazon is attracted into the more export-oriented primary sectors in the Amazon. These reallocation effects are more moderate in the medium run because higher trade substitution elasticities provide room to adjust by import substitution rather than by export expansion. As a result, more factors are retained in the import substituting sectors outside the Amazon.

With open access to land, both in the short and medium run, land usage is determined by demand. Because of the expansion of all primary sectors, i.e., all land-using sectors, land use increases inside and outside the Amazon. Thus devaluation of the exchange rate, necessary to adjust the trade balance, by improving the competitiveness of Brazil's exports and import substitutes accelerates the exploitation of Brazil's rain forest. The pressure to convert tropical forests is somewhat reduced in the medium run when there is more room for trade substitution both, on the demand and the supply side, and capital can be reallocated between different activities and regions of Brazil. Increasing substitution possibilities in domestic absorption imply that imports can now more easily be replaced by domestic

[16] As for other sectors, there are two important opposing effects: Industries producing close import substitutes or exportables will benefit from increasing prices due to devaluation. However, to the extent that an industry depends on imported intermediate (such as capital goods sector) and has restricted possibilities to pass on increasing costs for imported intermediate inputs (such as the service sector), it will experience a decline in its output. Whether an industry expands or contracts then primarily depends on which of the two effects is predominant.

substitutes. Moreover, improved trade transformation possibilities mean individual sectors can more easily reallocate factors into export production.[17] As a result, the dominating intermediate and capital goods sectors expand their production, thereby easing somewhat the pressure to expand agricultural production and deforestation.

The policy implications of these simulations are straightforward. To the extent that the devaluation process was caused by macroeconomic mismanagement, this has added to the increase of land use in the rain forest area of Legal Amazonia. Hence, macroeconomic reform, most notably inflation reduction and fiscal consolidation, cannot only be expected to put the economy at a stable (positive) growth path but also to reduce the dynamics of deforestation considerably. However, it is not reasonable to assume that deforestation could be stopped without additional direct microeconomic policy measures which have to be discussed in the following.

Equalizing Fiscal Incentives among Sectors

As shown in Section II, cattle ranching and crop production are the main driving forces behind the rapid conversion of forest land in the Amazon. This is not only the result of market failure but policy induced to a large extent. Brazil's income tax laws virtually exempt agriculture and livestock and convert them into a tax shelter. Corporate profits are taxed at a rate of only 6 percent. Combined with generous depreciation provisions, the tax on corporate agricultural profits can be as low as 1.2 percent. On the other side, corporate profits from other activities are subject to a tax rate between 35 and 45 percent.

The implication of this tax treatment is that private and corporate investors will undertake projects in agriculture, even though the projects have a lower economic return than nonagricultural projects. Therefore, the demand for land by corporations and individuals in high income tax brackets increases, resulting in a faster expansion of agriculture into frontier areas. It also provides incentives for the accumulation of large land holdings. Moreover, the market price for land

[17] This is also reflected in the wide range in the implied aggregate import demand and export supply elasticities (with respect to the average user price of imports and the average supply price of exports which can be calculated from rows 25–26 and 28–29 in Table 2) in the short and medium run. The import demand elasticity varies betweeen 0.4 and 1.7 whereas the export supply elasticity lies between 1.1 and 2.3.

becomes too high for the poor to buy, even if given credit. This encourages them to move to the frontier in search of uncleared land.

Several authors (e.g., Binswanger 1991; Repetto 1988; Reis and Margulis 1991) have, therefore, suggested to eliminate fiscal incentives for agriculture in general. The effects of such a measure are simulated in the model by equalizing the net subsidy rates on value added across sectors.[18]

The results of this simulation are reported in Table 3. It shows that an equalization of value-added subsidy rates is effective to the extent that it reduces overall land use in the Amazon (row(18)). Moreover, it shifts relative land use from agriculture to mining and forestry because these sectors are currently taxed. However, the area of forest affected by mining is generally small compared with that cleared for cattle ranching. The most serious mining-related problem is mercury pollution, not deforestation. As regards the forestry sector, the increase in relative land use could further improve the effectiveness of the policy measure. Contrary to cropping and pasture, forestry does not necessarily contribute to the greenhouse effect. Contributions to the increase or decrease of atmospheric carbon comes only from reductions or increases in the forest size. In a steady-state forest, the contributions of carbon to the atmosphere from decay of dead trees offsets extraction of carbon from the atmosphere by new, growing trees (Cline 1991). A steady-state forest policy would, however, require additional policy measures.[19]

Table 3 shows that the equalization of value-added subsidy rates also has unintended side effects. First, row (18) reveals that there is also a significant reduction of land use in region II which is even larger than in region I. Second, real GDP declines, with equal regional percentage output losses in all primary sectors. This is reflected also in the decrease of national land input. Only those sectors expand which produce timber, mining products, consumer goods and intermediates. These exceptions can be traced back to the fact that these sectors are currently taxed.

Generally, the efficiency gains resulting from the reallocation of labor in the short run and of labor and capital in the medium run are not large enough to compensate for the production losses caused by

[18] The uniform net subsidy rate is set at the average of the observed rates so that the effect on the fiscal balance is neutral.

[19] The effects of improving forest policies have been analyzed for the cases of Cameroon (Thiele and Wiebelt 1993) and Indonesia (Thiele 1995).

Table 3 – *The Effects of an Equalization of Value-Added Subsidy Rates across Sectors*[a]

	Short run		Medium run	
	Region I	Region II	Region I	Region II
Sectoral outputs				
(1) Food crops	−0.27	−0.27	−0.39	−0.39
(2) Cash crops	−0.33	−0.33	−0.62	−0.62
(3) Other agricultural products	−0.27	−0.27	−0.35	−0.35
(4) Timber	0.08	0.08	0.15	0.15
(5) Livestock	−0.23	−0.23	−0.31	−0.31
(6) Mining	0.35	0.35	0.87	0.87
(7) Manufactured food	−0.21		−0.29	
(8) Consumer goods	0.37		0.54	
(9) Intermediates	0.04		0.11	
(10) Capital goods	−0.17		−0.40	
(11) Services	−0.01		−0.01	
Factors				
Land use				
(12) Food crops	−0.32	−0.32	−0.41	−0.41
(13) Cash crops	−0.42	−0.42	−0.64	−0.64
(14) Other agricultural products	−0.33	−0.33	−0.38	−0.38
(15) Timber	0.04	0.04	0.12	0.12
(16) Livestock	−0.33	−0.33	−0.32	−0.32
(17) Mining	0.64	0.64	0.87	0.87
(18) Regional land input	−0.18	−0.26	−0.17	−0.30
(19) Regional employment of mobile labor	−0.07	−0.20	−0.01	−0.20
(20) Regional employment of rural labor	0.11	−0.02	0.16	−0.03
(21) Land rental	0.00 (EX)		0.00 (EX)	
(22) Rate of return to capital	0.06		0.06	
Macroeconomic variables				
(23) Exchange rate	−0.07		0.08	
(24) Real GDP	−0.02		−0.02	
(25) Domestic price of imports	−0.07		0.08	
(26) Domestic price of exports	0.00		0.08	
(27) Dollar price of exports	0.09		0.00	
(28) Imports (volume)	−0.04		−0.04	
(29) Exports (volume)	−0.10		−0.01	
(30) Trade balance	0.00 (EX)		0.00 (EX)	
(31) Producer price	0.00 (EX)		0.00 (EX)	

[a] All figures refer to percentage changes; (EX) means that the variable in question is exogenously determined.

Source: Own calculations based on the model described in the Appendix.

the reduction of land input. The mixed result of the equalization of value-added subsidy rates, i.e., the sectoral policy, mostly stem from the fact that output losses emerge not only in the Amazon but also in the primary sectors outside the Amazon. This suggests the implementation of more focused policy instruments.

Improving Regional Taxation of Land

In order to avoid deforestation, it is not the conservation of land per se, which is desired, but rather the preservation of the Amazonian forest.

An important insight obtained from the traditional literature on optimal intervention is that policy measures should be applied at the closest possible point to the objective sought, so that other unintended effects on the rest of the economy are kept to a minimum (Bhagwati and Ramaswani 1963; Corden 1974; Johnson 1965). In other words, any distortions arising on account of, say, the existence of externalities or public goods are best dealt with through measures directly applied to the source of the distortion in order to avoid new by-product (or upsetting marginal conditions) elsewhere in the economy. By this principle alone, the previously examined equalization of value-added tax or subsidy rates would clearly be suboptimal as a means of achieving the objectives sought. A regionally focused policy aimed at the land market would therefore be a more direct route toward meeting that objective than would be a sectoral policy aimed at equal treatment of agricultural and manufacturing sectors.

Table 4 presents the effects of an aggregate tax of 10 percent levied on land use and uniformly applied across all primary sectors in the Amazon. In order to avoid repercussions resulting from the redistribution between private sectors and the public sector, the additional tax revenues are distributed to households. By neglecting distributional shifts, the results can be compared with those achieved in the previous simulation.

We observe that land taxes, by increasing net production costs to producers in the Amazon, disencourage overall economic activity in that region, while in general causing economic activity in the primary sectors outside the Amazon to expand. Because of the small share of Amazonian primary activities in the total economy, the regionally focused policy has no repercussions to the manufacturing sectors and services. Mobile factor resources are drawn from region II to be ab-

Table 4 – *The Effects of a 10 Percent Tax on Land in the Amazon (except forestry)*[a]

	Short run		Medium run	
	Region I	Region II	Region I	Region II
Sectoral outputs				
(1) Food crops	−0.61	0.07	−0.95	0.12
(2) Cash crops	−0.57	0.18	−0.95	0.33
(3) Other agricultural products	−1.68	0.25	−1.84	0.28
(4) Timber	0.08	0.08	0.13	0.13
(5) Livestock	−0.47	0.04	−0.39	0.03
(6) Mining	−0.94	0.16	−1.00	0.13
(7) Manufactured food	−0.04		−0.05	
(8) Consumer goods	0.02		0.02	
(9) Intermediates	0.00		−0.01	
(10) Capital goods	0.00		−0.01	
(11) Services	0.00		0.00	
Factors				
Land use				
(12) Food crops	−2.60	0.39	−3.37	0.50
(13) Cash crops	−2.91	0.58	−4.06	0.82
(14) Other agricultural products	−4.10	0.64	−4.55	0.72
(15) Timber	0.62	0.62	0.74	0.74
(16) Livestock	−2.94	0.43	−4.06	0.61
(17) Mining	−6.33	1.06	−7.19	1.14
(18) Regional land input	−2.89	0.55	−3.65	0.69
(19) Regional employment of mobile labor	3.30	−0.66	2.51	−0.54
(20) Regional employment of rural labor	3.26	−0.70	2.51	−0.54
(21) Land rental	0.03		0.02	
(22) Rate of return to capital	0.00		0.00	
Macroeconomic variables				
(23) Exchange rate	0.04		−0.01	
(24) Real GDP	0.00		0.00	
(25) Domestic price of imports	0.04		−0.01	
(26) Domestic price of exports	0.01		0.01	
(27) Dollar price of exports	0.00		0.00	
(28) Imports (volume)	−0.01		0.02	
(29) Exports (volume)	0.01		0.00	
(30) Trade balance	0.00 (EX)		0.00 (EX)	
(31) Producer price	0.00 (EX)		0.00 (EX)	

[a] All figures refer to percentage changes; (EX) means that the variable in question is exogenously determined.

Source: Own calculations based on the model described in the Appendix.

sorbed in the Amazon (mobile labor and rural labor in the short run, inclusive capital in the medium run) and partly compensate for the output losses resulting from releasing land. In the short run, the reduction of land use in the Amazon by the regional policy could have offset about two thirds of the increase resulting from the macroeconomic distortion (Table 2). In the medium run, a tax on Amazon land more than compensates for the increased deforestation following the devaluation. Furthermore, the macroeconomic impact of these taxes is negligible both in the short and medium run if the tax proceeds are redistributed to the private sector. Finally, the land tax program leads to a sizeable reduction in deforestation in the Amazon if compared with the sectoral program of the previous section without hampering economic activity in the primary sectors outside the Amazon.

V. Summary

The "deforestation problem" in Brazil, as with most questions of national concern, consists of a variety of interrelated issues, of which this paper has identified a regional, sectoral and macroeconomic dimension. To make a balanced assessment of the impact of particular policies aimed at correcting this problem, a sufficiently disaggregated model is required to handle these separate aspects simultaneously. The general equilibrium model developed here draws attention to various important effects and linkages, which in retrospect are fairly easy to explain, but would have been overlooked in a more aggregated or partial equilibrium framework designed only to address a single dimension of the problem at a time.

The results from the macroeconomic experiment bear out the expectation that a devaluation of the exchange rate, necessary for reducing aggregate demand, improves the competitiveness of Brazil's export-oriented and import-substituting industries but encourages the exploitation of the rain forest. Hence, macroeconomic reform could be expected to reduce the environmental pressure considerably by dampening the dynamics of deforestation.

This gives two conclusions. First, macroeconomic reform is complementary to conservation policies. Second, continued or even increasing macroeconomic mismanagement could easily counteract conservation policies. Therefore, if not for other reasons, macroeconomic reform is urgently required in order to provide an adequate framework for microeconomic conservation policies to be effective.

The simulation results for these policies show that their costs in terms of real GDP are rather negligible or zero. However, the results emerging from the simulation of a sectoral policy aimed at equal fiscal incentives for agricultural and manufacturing activities shows that such a policy would have only a minor impact on land use in the Amazon. In contrast, a regionally focused program of land taxes in the Amazon was shown to achieve a significant reduction of land use for agricultural purposes without obstructing economic development. That is, a regional land tax program would be preferable because of its effectiveness and its efficiency.

These simulation results also have interesting repercussions for international environmental initiatives. It is argued, e.g., by Cline (1991, p. 377), that OECD countries could find it more cost-effective to compensate Brazil for reduced Amazon agricultural production than to achieve carbon reduction in their domestic energy sectors. The results of this paper generally do not support the assumption that compensation payments are necessary at all. Most importantly, the proposed land tax system would reduce the land input in Amazonia by about three and a half percent without any losses in real GDP. Moreover, the (static) losses reported in the case of revising macroeconomic mismanagement have to be interpreted with considerable care. First, dynamic gains could not be captured by the comparative-static model. Second, improved capital markets could not be considered because of the emphasis on the real sector. Third, macroeconomic reform will be necessary anyway if Brazil does not want to allow economic and social pressures to increase and to loose another decade of economic development. Finally, recent macroeconomic reforms in developing countries, e.g., Argentina, showed that consistent reforms need not to be contractionary. The problem is rather to consolidate an industrial expansion. Each of these arguments devalues the claims for compensation payments.

Appendix

Data Set

This appendix describes the data base to which the Brazilian model has been calibrated. Table A1 summarizes the aggregation scheme by which the 136 commodities of the input-output table provided by IBGE were converted into the 11 sectors used in our model.

The latest available figures for the Brazilian input-output table are for the year 1980 (published in 1989). Table A2 outlines the SAM underlying the model and provides a macroeconomic view of the Brazilian economy in 1980. Finally Tables A3 and A4, respectively, describe the sectoral structure of demand and of production costs together with estimates of the substitution and transformation elasticities.

Table A1 – *Sector Classification*

Sector		Input-output table commodity classification number
1	Food crops	01006–01008, 01011
2	Cash crops	01004–01005, 01009–01010, 25101
3	Other agricultural products	01012
4	Timber	01001–01003, 14101
5	Livestock	01014–01017
6	Mining	02101–03201
7	Manufactured food	26101–31301
8	Consumer goods	14201–15302, 22101–24201
9	Intermediates	16101–21201, 32101–32903, 04101–07202
10	Capital goods	08101–13401, 01013
11	Services	33101–45101

Source: IBGE (1989).

Table A2 – *Social Accounting Matrix, 1980 (billion cruzeiros, current prices)*

Expenditures / Receipts	Activities	Commodities	Factors	Households	Government	Capital account	Rest of world	Totals
Activities		24,753.1			–77.8		1,248.9	25,924.2
Commodities	14,415.2			7,404.5	1,273.4	3,233.3		26,326.4
Factors	10,267.8							10,267.8
Households			10,021.6					10,021.6
Government	1,241.2	103.7						1,344.9
Capital account			246.2	2,617.1	149.3		220.7	3,233.3
Rest of world		1,469.6						1,469.6
Totals	25,924.2	26,326.4	10,267.8	10,021.6	1,344.9	3,233.3	1,469.6	

Source: IBGE (1989).

Table A3 – *Structure of Demand in Brazil, 1980 at producer prices (billions cruzeiros)*

Sector of origin i	Intermediates V_i	Private consumption C_i	Government consumption G_i	Investment Z_i	Absorption Q_i	Imports cif M_i	Import tariffs TM_i	Exports fob E	Export subsidies TE_i	Domestic production X_i
1	275.062	19.463	–	19.964	314.489	71.045	−42.500	17.502	−3.071	300.375
2	279.167	55.705	–	−16.045	318.827	–	–	133.834	−55.754	396.907
3	212.397	218.879	–	−11.452	419.824	14.880	2.700	22.246	−3.868	420.622
4	273.694	34.849	–	−4.982	303.561	3.525	1.000	17.144	−0.293	315.887
5	397.225	65.013	–	142.190	604.428	2.253	0.900	0.992	−0.132	602.135
6	676.093	–	–	–	676.093	508.296	−43.700	98.039	−4.284	305.252
7	669.557	1,266.230	–	23.326	1,959.113	33.170	8.160	244.334	−7.463	2,154.654
8	925.626	758.562	–	40.261	1,724.449	20.051	4.190	98.132	−0.864	1,797.476
9	4,563.177	821.085	–	118.758	5,503.020	349.063	74.000	173.306	−4.819	5,248.444
10	1,122.970	478.857	–	897.549	2,499.376	283.747	87.960	185.109	2.845	2,315.623
11	5,020.262	3,685.879	1,273.419	2,023.778	12,003.338	183.616	−11.016	258.235	−0.092	12,066.849
Sum	14,415.230	7,404.522	1,273.419	3,233.347	26,326.518	1,469.646	103.726	1,248.873	−77.795	25,924.224

	V_i/Q_i	C_i/Q_i	G_i/Q_i	Z_i/Q_i	$(M_i+TM_i)/Q_i$	$(E_i+TE_i)/X_i$	σ_i^a	τ_i^b
1	87.46	6.19	–	6.35	9.08	4.80	1.42	3.9
2	87.56	17.47	–	−5.03	–	19.67	1.42	3.9
3	50.59	52.14	–	−2.73	4.19	4.37	1.42	3.9
4	90.16	11.48	–	−1.64	1.49	5.33	5.03	3.9
5	65.72	10.76	–	23.52	0.52	0.14	1.22	3.9
6	100.00	–	–	–	68.72	30.71	0.50	2.9
7	34.18	64.63	–	1.19	2.11	10.99	0.31	2.9
8	53.68	43.99	–	2.33	1.41	5.41	3.15	2.9
9	82.92	14.92	–	2.16	7.69	3.21	3.05	2.9
10	44.93	19.16	–	35.91	14.87	8.12	3.55	2.9
11	41.82	30.7	10.61	16.86	1.62	2.14	2.00	0.7
Average	54.76	28.13	4.84	12.28	5.98	4.52		

[a] Interpolated from data in Shiells et al. (1986) and Dixon et al. (1982). There is a close symmetry between the aggregation defined by Shiells et al. and the manufacturing sectors in our model. Where there is no close symmetry between their classification and the sectors in the Brazil model, elasticities from representative sectors in their tables (grain for food crops, cash crops, and other agricultural products; pulp for timber; miscellaneous food preparation for livestock; and footwear for consumer goods) were selected. For services and mining, elasticity estimates for the Australian ORANI model, as reported in Dixon et al. (1982) were used. – [b] In principle, the more homogeneous the product, the larger the value of the elasticity of transformation. It is further assumed that traded services are much less homogenous than average and that agricultural and forestry products are more homogenous than average.

Source: Own calculations based on IBGE (1989).

Table A4 – *Structure of Production Costs in Brazil, 1980 (billion cruzeiros, current prices)*

Sector	Total production costs	Intermediate input costs	Indirect taxes	Value added
1	300.375	150.527	−21.335	−1.711
2	396.907	240.754	9.703	−2.146
3	420.622	184.175	21.233	−2.029
4	315.887	178.384	8.309	0.061
5	602.135	281.752	0.012	−3.202
6	305.252	130.107	6.353	1.659
7	2,154.654	1,473.019	296.485	−2.835
8	1,797.476	1,136.821	121.521	6.263
9	5,248.444	3,450.169	452.577	2.575
10	2,315.623	1,459.810	196.481	−8.799
11	12,066.849	5,729.169	174.539	−14.505
Total	25,924.224	14,415.230	1,265.878	−24.669

	Factor income	Factor income shares		
		labor	capital	land
1	172.894	22.14	7.79	70.08
2	148.596	23.42	15.32	61.26
3	217.243	26.52	7.35	66.14
4	129.133	35.03	12.99	51.98
5	323.573	22.14	23.36	54.50
6	167.133	27.91	50.46	21.63
7	387.958	40.83	59.17	–
8	532.871	48.29	51.71	–
9	1,343.123	45.00	55.00	–
10	668.131	62.86	37.14	–
11	6,177.103	51,59	48.41	–
Total	10,267.785	47.93	45.88	6.19

Source: Own calculations based on IBGE (1989) and IBGE (1985).

Equations, Variables and Parameters of the General Equilibrium Model[a] for Brazil

Equations

Prices

(1) $P_i^m = \overline{P}_i^{\$m} \cdot (1-t_i^m) R$

(2) $P_i^e - P_i^{\$e} \cdot (1+t_i^e) R$

(3) $P_i^q = \dfrac{P_i^d \cdot D_i + P_i^m \cdot M_i}{Q_i}$

(4) $P_i^x = \dfrac{P_i^d \cdot D_i + P_i^e \cdot E_i}{X_i}$

(5) $P_i^v = P_i^x \cdot (1-t_i^x) - \Sigma_j P_j^q \cdot a_{ji}$

(6) $P_i^k = \Sigma_j P_j^q \cdot b_{ji}$

(7) $P^x = \Sigma_i \Omega_i \cdot P_i^x$

Input demand and commodity supply[b]

(8) $X_i = a_i^x \Pi_f F_{if}^{\alpha_{if}}$

(9) $F_{if} = \dfrac{\alpha_{if} \cdot (1-t_i^v) \cdot P_i^v \cdot X_i}{\gamma_{if} \cdot P_f \cdot (1+t_{if}^f)}$

(10) $V_i = \Sigma_j a_{ij} \cdot X_j$

(11) $Q_i = a_i^q \cdot [\delta_i^q \cdot M_i^{-\varrho_i} + (1-\delta_i^q) \cdot D_i^{-\varrho_i}]^{-1/\varrho_i}; \quad \sigma_i = \dfrac{1}{1+\varrho_i}$

(12) $M_i = D_i \cdot \left[\dfrac{P_i^d \cdot \delta_i^q}{P_i^m \cdot (1-\delta_i^q)}\right]^{\sigma_i}$

(13) $X_i = a_i^t \cdot [\delta_i^t \cdot E_i^{\omega_i} + (1-\delta_i^t) \cdot D_i^{\omega_i}]^{1/\omega_i}; \; \tau = \dfrac{1}{\omega_i - 1}$

(14) $E_i = D_i \cdot \left[\dfrac{P_i^e \cdot (1-\delta_i^t)}{P_i^d \cdot \delta_i^t}\right]^{\tau_i}$

Final demand

(15) $C_i^H = \dfrac{\beta_i^H}{P_i^q} \cdot (1-t^H) \cdot (1-s^H) Y^H$

(16) $C_i^G = \beta_i^G \cdot \overline{C}^G$

(17) $I2_i = \beta_i^I \cdot X_i$

(18) $DK_j = \dfrac{k_i \cdot Z}{\Sigma_j \cdot b_{ji} \cdot P_j^q}$

(19) $I_i = \Sigma_j b_{ji} \cdot DK_j$

(20) $E_i = e_i \cdot \left(\dfrac{P_i^{\$e}}{\overline{P}_i^{\$e}}\right)^{-\eta}$

Market clearing and macro-closure

(21) $Q_i = V_i + C_i^H + C_i^G + I_i + I2_i$

(22) $\Sigma_i F_{if} = \overline{F}_f^S$

(23) $\Sigma_i \overline{P}_i^{\$m} \cdot M_i = \Sigma_i P_i^{\$E} \cdot E_i + \overline{S}^F$

(24) $S^P + (Y^G - \Sigma_i P_i^q \cdot C_i^G) + \overline{S}^F = Z$

[a] Endogenous variables of the flow of funds which are calculated include: Total government revenues, total household income, and private savings and investment, respectively. Exogenous net foreign capital inflows (trade balance) are directly channeled into savings. – [b] Equations (11) and (12) give the CES aggregation functions for imports and domestically produced goods of the same product category and the corresponding import demand functions. Equations (13) and (14) contain the CET transformation functions combining exports and domestic sales, and the corresponding export supply functions.

Description of Variables

Variable[a]	Description	Variable	Description
P_i^m	Domestic price of imports	P_f	Average factor price
$\bar{P}_i^{\$m}$	World price of imports	V_i	Intermediate input demand
R	Exchange rate	C_i^H	Final demand for private consumption
P_i^e	Domestic price of exports		
$P_i^{\$e}$	World price of domestic exports	Y^H	Total household income
$\bar{P}^{\$e}$	World price of competitive exports	C_i^G	Final demand for government consumption
P_i^q	Price of competitive good	$\bar{C}^G$	Real government consumption
P_i^d	Domestic sales price	$I2_i$	Inventory investment by sector
D_i	Domestic sales of domestic output	DK_j	Investment by sector of destination
M_i	Imports		
Q_i	Composite good supply	Z	Total investment
P_i^x	Output price	I_i	Final demand for investments goods
E_i	Exports		
X_i	Domestic output	$\bar{F}_f^s$	Factor supply
P_i^v	Value added or net price	S^P	Private savings
P^x	Producer price index	$\bar{S}^F$	Net foreign capital inflow
P_i^k	Capital good price	Y^G	Government revenues
F_{if}	Factor demand		
Parameter	**Description**	**Parameter**	**Description**
t_i^m	Import tariff rate	t^H	Household income tax rate
t_i^e	Export subsidy rate	t_{if}^f	Factor tax rate
t_i^v	Value added tax rate	β_i^H, β_i^G	Expenditure shares
t_i^x	Indirect tax rate	β_i^I	Inventory-output ratio
a_{ij}	Input-output coefficients	k_i	Investment destination shares
$a_i^x, \alpha_i^q, a_i^t, e_i$	Shift parameters		
α_{if}	Factor productivity parameters	b_{ij}	Capital composition coefficients
γ_{if}	Factor market distortion parameters	η	Export demand price elasticity
δ_i^q, δ_i^t	Distribution parameters	s^H	Household savings rate
$\varrho(\sigma), \omega(\tau)$	Substitution and transformation parameters (elasticities)	Ω_i	Sectoral production shares

[a] Endogenous variables are denoted by capital letters. Letters with bars are exogenous variables.

References

Amelung, T., and M. Diehl (1992). *Deforestation of Tropical Rain Forests: Economic Causes and Impact on Development*. Kieler Studien, 241. Tübingen: J.C.B. Mohr.

Amelung, T., and M. Wiebelt (1995). Ansatzpunkte zur Reduktion der globalen CO_2-Emissionen. *Energiewirtschaftliche Tagesfragen*, Vol. 45, pp. 173–177.

Bhagwati, J.N., and V.K. Ramaswani (1963). Domestic Distortions, Tariffs and the Theory of the Optimum Subsidy. *Journal of Political Economy*, Vol. 71, pp. 44–50.

Binswanger, H.P. (1991). Brazilian Policies That Encourage Deforestation in the Amazon. *World Development*, Vol. 19, pp. 821–829.

Cline, W.R. (1991). Comments (on Reis, Margulis 1991). In R. Dornbusch, J. Poterba (eds.), *Global Warming: Economic Policy Responses*, pp. 375–380. Cambridge, Mass.: The MIT Press.

Corden, W.M. (1974). *Trade Policy and Economic Welfare*. Oxford: Clarendon Press.

Dervis, K., J. de Melo, and S. Robinson (1982). *General Equilibrium Models for Development Policy*. Cambridge: Cambridge University Press.

Dixon, P., B. Parmenter, J. Sutton, and D. Vincent (1982). *ORANI: A Multisectoral Model of the Australian Economy*. Amsterdam: North-Holland.

Funke, N., P. Nunnenkamp, and R. Schweickert (1992). Brazil: Another Lost Decade?: Domestic Policies and Attractiveness for Foreign Capital. Kiel Discussion Papers, No. 188, The Kiel Institute of World Economics. Kiel.

Instituto Brasileiro de Geografia e Estatística (IBGE) (1989). *Matriz de Insumo-Produto Brasil – 1980, Série Relatórios Metodológicos – Volume 7*. Rio de Janeiro.

— (several years). *Annuário Estatístico do Brasil*. Rio de Janeiro.

Johansen, L. (1960). *A Multi-Sectoral Study of Economic Growth*. Amsterdam: North-Holland.

Johnson, H.G. (1965). Optimal Trade Intervention in the Presence of Domestic Distortions. In R.E. Caves et al. (eds.), *Trade, Growth and the Balance of Payments*, pp. 3–34. Amsterdam: North-Holland.

Mahar, D.J. (1989). *Government Policies and Deforestation in Brazil's Amazon Region*. Washington, D.C.: The World Bank.

May, P.H., and E.J. Reis (1993). The User Structure in Brazil's Tropical Rain Forest. Kiel Working Paper No. 565, The Kiel Institute of World Economics. Kiel.

Myers, N. (1980). *Conversion of Tropical Moist Forests*. Washington, D.C.: National Academy of Sciences.

National Institute for Space Research (INPE) (1992). *Deforestation in Brazilian Amazonia*. Sao Jose dos Campos, São Paulo.

Nordhaus, W.D. (1991). Economic Approaches to Greenhouse Warming. In R. Dornbusch, J. Poterba (eds.), *Global Warming: Economic Policy Responses*, pp. 33–66. Cambridge, Mass.: The MIT Press.

Reis, E.J., and S. Margulis (1991). Options for Slowing Amazon Jungle Clearing. In R. Dornbusch, J. Poterba (eds.), *Global Warming: Economic Policy Responses*, pp. 335–375. Cambridge, Mass.: The MIT Press.

Repetto, R. (1988). *The Forest for the Trees? Government Policies and the Misuse of Forest Resources*. Washington, D.C.: World Resources Institute.

Serôa da Motta, R. (1993). Policy Issues Concerning Tropical Deforestation in Brazil. Kiel Working Paper No. 566, The Kiel Institute of World Economics. Kiel.

Shiells, C.R., R.M. Stern, A.V. Deardorff (1986). Estimates of the Elasticities of Substitution between Imports and Home Goods for the United States. *Weltwirtschaftliches Archiv*, Vol. 122, pp. 497–519.

Solow, A.R. (1991). Is There a Global Warming Problem? In R. Dornbusch, J. Poterba (eds.), *Global Warming: Economic Policy Responses*, pp. 7–28. Cambridge, MA: The MIT Press.

Thiele, R. (1995). Conserving Tropical Rain Forests in Indonesia – A Quantitative Assessment of Alternative Policies. *Journal of Agricultural Economics*, Vol. 46, No. 2, pp. 187–200.

Thiele, R., and M. Wiebelt (1993). National and International Policies for Tropical Rain Forest Conservation – A Quantitative Analysis for Cameroon. *Environmental & Resource Economics*, Vol. 3, pp. 501–531.

World Bank (1992). *World Development Report 1992 – Development and the Environment*. Oxford: Oxford University Press.

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Abstract: Stopping Deforestation in the Amazon: Trade-off between Ecological and Economic Targets? – Using a computable general equilibrium model the paper analyzes the regional, sectoral and macroeconomic dimension of Brazil's "deforestation problem". It is shown that macroeconomic reform is not in conflict with conservation policies. Therefore, there is no need for compensation payments but rather for improving the effectiveness of conservation policies by macroeconomic reform. The analysis also shows that regional conservation policies are generally superior to sectoral conservation policies. JEL No. Q2, Q28, C68

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Zusammenfassung: Zur Begrenzung der Tropenwaldrodung im Amazonas: Gibt es einen Konflikt zwischen ökologischen und ökonomischen Zielen? – Auf der Basis eines berechenbaren allgemeinen Gleichgewichtsmodells wird untersucht, inwieweit dem Raubbau am brasilianischen Regenwald durch Korrektur von Politikmängeln auf der regionalen, sektoralen und gesamtwirtschaftlichen Ebene Einhalt geboten werden kann. Die Simulationsergebnisse zeigen keinen Konflikt zwischen ökologischen und ökonomischen Zielen. Es besteht somit im allgemeinen kein Bedarf für Kompensationszahlungen bei der Verfolgung ökologischer Ziele. Es besteht dagegen Bedarf, die ökologische Effektivität tropenwaldspezifischer Instrumente durch makroökonomische Reformen zu verbessern. Dabei ist eine regional ausgerichtete Tropenwaldpolitik einer sektorspezifischen Tropenwaldpolitik grundsätzlich überlegen.