National and International Policies for Tropical Rain Forest Conservation — A Quantitative Analysis for Cameroon*

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Abstract. This paper provides a numerical general equilibrium assessment of policies to reduce tropical deforestation in Cameroon. Market failure — mainly in the form of national and international externalities — and policy failures — such as highly distorted product markets — are identified as major sources of overexploitation. The ecological effects of deforestation control are shown to depend crucially upon its impact on land use patterns whereas its efficiency effects hinge on the manner in which a specified set-aside target is achieved. If the international community wants to ensure a higher level of protection of these forests, and to do so within a market-based system, the provision of conditional financial resources is necessary.

Key words. (JEL): Environmental management (Q2), computable general equilibrium models (D58), Cameroon.

1. Introduction

There is a consensus among resource economists that the tropical forests are excessively exploited (e.g. Pearce, 1990; Repetto, 1988). The overutilization results from two main factors driving a wedge between private and social costs of forest use: *market failure* and *policy failure*. Market failure is a consequence of the fact that tropical forests do not only supply timber and land for agricultural conversion but also provide ecological benefits, which because of their public good properties or lacking property rights to not enter the individual decision making process. Some of these ecological benefits, such as the stabilization of the water cycle and the protection of soils against erosion and nutrient losses, affect only populations in the tropical countries, while others, notably the fixing of carbon and the provision of habitat for a large share of the world's biological diversity, accrue to the whole world. Hence, local as well as global externalities have to be considered. Moreover, the pressure on tropical forests is frequently exacerbated by ecologically harmful government activities (Repetto, Gillis, 1988). These policy failures range from subsidized regional development programmes to general biases in the trade regime in favor of resource intensive production.

Since different factors contribute to the suboptimal forest utilization and since different economic sectors, particularly agriculture and forestry, use

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forest resources, a *policy package* is required, which should combine the removal of domestic distortions, national environmental policy measures and international measures. The present paper quantitatively investigates the effects of such policy measures on the structure, economic efficiency and the utilization of forest resources of the Cameroonian economy. The objective is to sort out policy packages, which simultaneously protect tropical forests and stimulate an efficient resource allocation. For this purpose, a computable general equilibrium (CGE) model was developed, which — contrary to a partial equilibrium approach — captures the economy-wide repercussions of sectoral policies and hence allows for conclusions about structural responses and the change in land use patterns.

The remainder of the paper proceeds as follows. Section 2 describes the pattern of forest use in Cameroon and its economic importance, reviews the underlying policies and outlines possible improvements in the policy environment. Section 3 explains the main features of the CGE model employed in the empirical analysis and shortly discusses the numerical specification of the model. Section 4 presents the results of the policy simulations for Cameroon. The conclusions of the paper are summarized in section 5.

2. The Cameroonian Case

2.1. DEFORESTATION AND ITS ECONOMIC IMPACT

In the mid-1980s, 16.5 million ha or 40 percent of the land area of Cameroon was covered by closed tropical forests. At an estimated annual rate of deforestation for agricultural use of 100,000 ha (Table I), the resource would be depleted in about 150 years, assuming no behavioural change is taking place. In addition, large parts of the forest are opened up by the forestry sector.[1] The wood clearance per harvest of 6 m^3/ha is small compared to the average stand of timber of 280 m^3/ha in virgin forest (FAO/UNEP, 1981), but on average there are less than six years between two harvests on the same area. That rotation period is by far too short for the forest to regenerate, especially as several of the remaining trees are damaged at each harvest.[2]

In terms of biomass reduction, the agricultural sector accounts for 90 percent of the destruction of the Cameroonian rain forest (Table I). As the soil productivity on converted areas is very low, the land is mainly cultivated in the form of shifting cultivation. Since shifting cultivation is nearly exclusively done by small farmers, for whom the costs of opening up new primary forests are too high, the forestry sector acts as a pace-maker for agricultural conversion by providing the necessary infrastructure (Amelung and Diehl, 1992, pp. 19ff.). Hence, the actual responsibility of the sector for the problem of deforestation is far greater than its contribution to the reduction of biomass.

Table I. Key characteristics of deforestation in Cameroon 1976–1986

Average annual deforestation[a] (in 1,000 ha)	100
Thereof (percent):	
Perennial crops	30
Annual crops	70
Shifting cultivation	95
Permanent cultivation	5
Sectoral share in the reduction of biomass[b] (percent)	
Forestry	10
Agriculture	90
Other sectors	0

[a] Only including the total wood clearance for agricultural purpose ("deforestation"). No account is taken of the degradation of the rain forest, i.e. the selective felling of trees. — [b] 1981–1985; the degree of biomass reduction takes into account that forestry only damages parts of the forest, whereas the agricultural sector converts the whole area.

Source: Amelung, Diehl (1992), WRI (1990), FAO (1988).

Long-run ecological considerations are running contrarily to the economic significance of tropical forest resources for the agricultural and forestry sector. In the 1980s, forestry and the wood processing industry[3] accounted for about 10 percent of all export revenues, so that these sectors were a major source of foreign exchange for Cameroon, following directly after coffee, cocoa and oil (World Bank, 1989). The importance of the timber industry is still increasing, as the export prospects for coffee, cocoa and oil are falling because of declining world market prices and decreasing production. The agricultural production on converted forest land contributed less than 2 percent to total output during the 1980s, but the employment effect is supposed to be much higher, because mainly small farmers are working on former tropical areas, who do not have access to modern technology (Amelung and Diehl, 1992, p. 122).

The importance of the tropical forest as an economic resource has to be weighed against its ecological functions. A destruction of these functions could negatively impact on the long-run growth potential of the economy, particularly by reducing agricultural productivity. In most instances, short-sighted governments tend to ignore such long-run considerations.

2.2. THE POLICY ENVIRONMENT

Among the wide range of factors that might play a role in determining the rate of deforestation, we consider exchange rate and trade policy, land tenure and agricultural pricing policy as well as forestry policy to be of high importance in the Cameroonian context.[4] These policies will be shortly reviewed in the following.

(a) *Exchange Rate and Trade Policy*

Cameroon's exchange rate policy is externally restricted by its membership in the franc-zone. The franc-zone is a currency union between France and 13 West and Central African states, in which the nominal exchange rate has now been fixed at 50 CFA-francs per French franc for more than 40 years.[5] At this parity, the CFA-franc is fully convertible vis-à-vis the French franc. Until the early 1980s, fairly low inflation rates in the CFA-zone guaranteed that the real exchange rate remained at a competitive level. But devaluations of the currencies of neighboring competitors like Ghana and Nigeria and the strength of the French franc vis-à-vis the US dollar since 1985 led to significant appreciations of the real effective exchange rates in some member states of the CFA-zone, particularly in Cameroon and Côte d'Ivoire, who have relatively substantial trade with the United States (Boughton, 1991). Milner (1990) estimates that Cameroon had a currency overvaluation of 12 percent in 1986.[6]

Like many other countries in Sub-Saharan Africa, Cameroon pursued an import-substitution strategy since Independence. The consumer goods and food processing industries are highly protected against import competition, whereas there are lower import restrictions for intermediate and capital goods as well as for most primary products (Devarajan and Rodrik, 1991). The measures taken include tariffs as well as quantitative restrictions like the requirement for import licences. Moreover, Cameroon's exports are subject to export duties, which are highest for traditional exports, while the majority of manufactured exports is exempted (Milner, 1990). Altogether, the Cameroonian trade policy has always created a substantial anti-export bias, which has been reinforced by the currency overvaluation in the 1980s.

(b) *Agricultural Policy*

Cameroon's economy is still fundamentally based on agriculture (World Bank, 1989). The sector accounts for about 20 percent of GDP and provides employment for nearly three-quarters of the population. Apart from the transitory oil boom in the early 1980s, cocoa and coffee have always been the main sources of foreign exchange earnings for the country. 93 percent of Cameroon's agricultural output is produced by smallholders, and consists of various food crops, coffee, cocoa and cotton. The remaining 7 percent is comprised of rubber, palm oil, sugar, tobacco and bananas from mostly state-owned industrial plantations.

The Cameroonian agricultural sector was highly regulated until the end of the 1980s (World Bank, 1989).[7] For all major crops, the government set producer prices, regulated marketing, and set profit and distribution margins. The pricing policy towards food crops was dominated by the striving for self-sufficiency. Domestic producers were protected against foreign competitors by a combination of guaranteed prices, import duties and import quotas. In the export crops sector, the system of fixing prices independently of world market trends imposed heavy taxation on farmers, until world market prices for cocoa and coffee sharply declined after 1985. In 1983, for example, producer prices for cocoa and coffee were 67 and 65 percent below their world market equivalents (Lele, 1990).

In addition to price incentives, non-price factors play a crucial role for the profitability of agricultural production (Krishna, 1982; Beynon, 1989). Among these the security of land tenure is of high importance, because it determines in how far farmers — especially smallholders — have access to credits which would enable them to buy fertilizer and other inputs.[8] In Cameroon only about 2 percent of the owned land is held by title and thus can be used as a collateral (IRG, 1992). As a consequence, investment in productivity enhancing measures remains low. This is particularly a problem for farmers on converted tropical forest land, who because of the poor soil quality are forced to shift into new areas very frequently. Moreover, the insecurity of tenure provides a strong incentive for scattered plantation of tree crops to claim ownership of land.

(c) *Forest Policy*

Virtually all the forests of Cameroon are publicly owned, whereas logging is nearly exclusively carried out by the private sector, predominantly by foreign firms (Djophant and Tchounkoue, 1992). Concession licences can be obtained for 5 years only, and under cumbersome and lengthy procedures (World Bank, 1989). Concessionaires face a very complex taxation system containing numerous area taxes, stumpage fees and export taxes (Fultang, 1992), but the total of all forest revenues from all forest fees falls by far short of capturing the resource rent accruing to the concessionaires.[9] For 1973/74, Repetto (1988, p. 18) reports rents between 7 and 61 US dollar per m^3, depending on the value of the species and the costs of transporting the logs to the market. In expectation of high excess profits, domestic and foreign firms are induced to invest in rent-seeking activities and to acquire concessions over vast forest areas (Repetto, 1988). This does not only mean that resources are wasted for unproductive activities, but also that deforestation by shifting cultivators is encouraged, because the forestry industry has little incentive to control encroachment if it has excess area.

Low forest fees also act as an implicit subsidy for the wood processing industry by providing cheap log inputs. This leads to a waste of wood and discourages investment in human capital and new equipment, because sawmills and plywood mills have an incentive to substitute cheap logs for other inputs, labor and capital (Grut *et al.*, 1991). More directly, domestic processing is promoted by a requirement to process at least 60 percent of the log volume from concessions locally. This regulation can distort domestic production (Grut *et al.*, 1991). Usually the more valuable logs are exported, while the less valuable species are the ones that end up being processed domestically. As a result of this distortion, domestic processing becomes less efficient. Currently, the Cameroonian government is even considering an outright log export ban.

With respect to the conservation of forest ecosystems, the Cameroonian government has announced the ambitious target to set aside 20 percent of the national territory in national parks and wildlife reserves (IRG, 1992).[10] At present, only 5 percent of the total national area falls under protective schemes and most of the parks and reserves are not sufficiently protected against encroachment. Only the parks and reserves receiving additional outside assistance, such as the Korup National Park, fair better.

2.3. PROPOSED POLICY CHANGES

Any policy package for a better management of tropical forests should contain measures to correct for market failure at the local and global level as well as measures to correct for ecologically harmful government activities.[11] Moreover, we argue that even such distortions which might be regarded as environmentally friendly — e.g. the taxation of agricultural exports — should be removed in order to achieve efficiency gains and to approximate a first-best starting point for the application of environmental policy measures.

The local externalities of deforestation can be split up into a "user cost" and an "environmental externality" component (Barbier *et al.*, 1992). User costs denote the foregone future returns of using a resource today. The creation of adequate property rights ensures that the producers internalize these user costs. The external environmental costs of forest exploitation, such as watershed degradation and soil erosion, can be internalized by means of price and quantity policies.

The definition and enforcement of property or user rights is the basic precondition for individuals to include sustainability considerations into their decisions. Missing or ill-defined property rights encourage short-run profit maximization and thus lead to the overexploitation of resources. In order to avoid this, the contractual arrangements for timber concessionaires have to be improved. One possibility is to base the duration of logging concessions for the Cameroonian forests, the majority of which is state-owned, on the regeneration period of about 30 years, whereas the licenses are currently given for 5 years at maximum (World Bank, 1989). Other arrangements, such as conditioning the continuation of short-term contracts on "sustainable" harvesting practices or even the outright sale of the land, could also be applied (Barbier *et al.*, 1992). Moreover, the licences should be tradable to provide an incentive for the concessionaires to maintain the value of their timber stands (Repetto, 1988). For the agricultural sector, it is important that land titles on converted forest areas are secure and transferable and that the land can be used as a collateral in borrowing for improvements.

Once having reached the long-run privately efficient use of forest resources by the provision of property rights, the remaining external environmental costs can be internalized by imposing a tax. The first-best solution is a tax on the use of tropical forest land, because it is levied — as suggested by the theory of domestic distortions (Corden, 1974) — exactly at the point where the externality occurs. Since logging is ecologically less harmful then agricultural conversion and since the cultivation of tree crops like coffee and cocoa causes less damage than the cultivation of food crops like rice and cassava (Repetto, 1989), there is a rationale for varying tax rates.

Another possibility to narrow the gap between private and social costs of deforestation is to fix upper limits for the use of forest resources. The government could prescribe concessionaires not to cut trees until they have reached a certain age. The objective of such a selective logging regime is to account for the renewability of the tropical rain forest, thereby making a sustainable forest management possible.[12] A further option for the government is to directly set aside areas, e.g. by establishing new national parks. National parks should be located on areas with rich biodiversity and low quality soils, which are not suitable for economic use. In order to achieve this allocation, the government has to carry out a detailed land use planning.

Theoretically, the local external environmental costs of deforestation should be internalized by employing a tax or a quantity measure in order to achieve an economic optimum. However, since the ecological costs of deforestation can only be estimated with high uncertainty and since damages may be irreversible, a safe minimum standard may, in practice, be a more adequate reference point for policy measures (Pearce and Turner, 1990, pp. 317ff.).

If all external costs of deforestation are accounted for, the timber concessionaire is still making an economic rent. The government can capture all or part of this rent through fees and taxes. The auctioning of licences is a means of capturing virtually all the rent, provided that the government ensures competition (Grut *et al.*, 1991). Competitive bidding has two further advantages compared to the present discretionary allocation of licences. First, it avoids the lengthy administrative process of choosing among competing applicants. Second, it allocates concessions to those applicants to whom they are most valuable. Moreover, the Cameroonian government should remove the domestic processing requirement for logs or at least replace it by an export tax, which is more efficient and additionally generates revenues (Repetto, 1988).[13]

With respect to foreign trade, Cameroon should move towards a more neutral incentive structure between exported and import-competing as well as between tradable and non-tradable goods. The former can be achieved by means of a trade liberalization, whereas the latter requires a real devaluation of the CFA Franc in order to correct for the present overvaluation of the currency which works in favor of the non-tradables sector.

For the internalization of the global external costs of deforestation, i.e. climate change and the loss of biodiversity, two broad categories of instruments are available: import restrictions for tropical hardwood and international compensation payments for the conservation of tropical forests (see, for instance, Barbier *et al.*, 1992).

Compensation payments build on the cooperation between industrial and tropical countries, as they rely on complementary national resource policy measures. Contrary to development aid, they should not be interpreted as a grant but as a payment for an environmental service (Amelung and Diehl, 1992). The theoretical reference point for the amount of money spent is the gap between the economic losses for the developing country caused by the implementation of a resource policy and the ecological benefits accruing to the developing country through the conservation of its forests (Amelung, 1991). The actual payments will, however, crucially depend on the bargaining power of the parties involved in the treaty, because both the local and global ecological benefits of conservation can only be calculated with high uncertainty. Furthermore, it has to be decided how the transfers should be used. In order to be effective in compensating the net losers of environmental protection, the transfer must contain some kind of conditionality, e.g. the prescription that the funds have to be invested in the creation of new employment opportunities outside the tropical forest.[14]

Import restrictions for tropical hardwood have the advantage that they can be applied directly without any prior bargaining. However, their ecological effectiveness is not guaranteed. A necessary condition for import restrictions to be effective is that the tropical country — as Cameroon does — exports a large share of the forestry output. This has to be weighed against the fact that in Cameroon the forestry sector is only a minor user of tropical forest resources compared to agriculture. It cannot be excluded that as a result of lower forestry profitability the conversion of land for agricultural use will increase to such an extent that the outcome for the tropical forest will be worse than without any policy intervention (Braga, 1992).[15] Import restrictions have at least three additional disadvantages. First, they have adverse distributional consequences by shifting nearly all the costs of adjustment to the tropical countries. Second, they make any complementary protective measures in the tropical countries unlikely. Finally, import restrictions are inferior to national resource policies from a welfare theoretic point of view, because they imply additional deadweight losses by distorting consumption (Braga, 1992).

In the following, the aforementioned policy measures will be empirically analyzed with respect to their consequences for the economy and the use of tropical forest resources. But first, the main characteristics of the model have to be described.

3. The Model

3.1. THEORETICAL STRUCTURE

The model we use in the empirical analysis is a standard CGE model as described in Dervis *et al.* (1982), extended by a forestry submodel along the lines of Dee (1991b).[16] A major advantage of the multisectoral approach is that it captures the implications of environmental and economic policy instruments for land use patterns. This is important, because the question of whether forests should be logged, or left as protected areas, or cleared entirely for agricultural use, is primarily a question of land use patterns. The forestry submodel enables us to examine the conventional forestry policy measures like resource taxes, secure property rights, selective logging regimes, and the setting up of national parks.

The treatment of the forestry sector is closely related to the forest economics literature. The traditional economic problem is to find the rotation period[17] that maximizes the present value of net returns from the current and all future harvests, at given timber prices, harvesting costs, interest rates and physical growth characteristics of trees (Bowes and Krutilla, 1985). While the traditional model does not take into account the environmental services provided by the forest, we do so by constraining harvests via the introduction of a minimum harvest age T^* (Nguyen, 1979). By means of such a selective logging regime the government can ensure that a certain minimum timber stock remains after each harvest. In the modified model, foresters choose the optimal harvest age T so as to maximize

$$PV(T) = \frac{RR \cdot e^{-r(T-T^*)}}{1 - e^{-r(T-T^*)}}, \tag{1}$$

where PV is the present value of net returns per hectare, RR is the net return per hectare per rotation, $T - T^*$ is the rotation period, and r is the discount rate applied by the concessionaire. The first-order condition of the maximization problem is given by

$$RR' = \frac{r \cdot RR}{1 - e^{-r(T-T^*)}}, \tag{2}$$

$$\text{with } RR = (P_x \cdot HV - RC) \cdot (1 - t_F) \tag{2a}$$

$$\text{and } RR' = \partial RR/\partial T = P_x \cdot \partial HV/\partial T \cdot (1 - t_F), \tag{2b}$$

where HV denotes the volume of timber harvested per hectare per rotation,

P_x the output price of timber, RC the harvest costs per hectare per rotation, and t_F a factor tax on forest land.

The interpretation of the first-order condition is that foresters should harvest at the age T, or, equivalently, choose the rotation period $T - T^*$, at which the marginal increase in net revenues from further growth of the forest (RR') just equals the opportunity cost of delaying the harvest. The opportunity cost is the potential interest income foregone on the delayed receipt of harvesting revenues. The correction term $1/(1 - e^{-r(T-T^*)})$ accounts for the fact that not only the current harvest but also future harvests are postponed, if the rotation period is extended.[18]

Equation (2) reveals that an increase in the discount rate, which may be attributed to more insecure property rights for concessionaires, raises the opportunity costs of letting trees grow and hence leads to a shorter rotation period. A rise in the timber output price raises both the marginal revenues from further growth and the opportunity costs. Using the definitions (2a) and (2b), one can see that, with positive harvesting costs, the increase in RR is stronger than that in RR' so that the rotation period shortens. Finally, higher harvesting costs reduce opportunity costs, leading to an extension of the rotation period.

The physical growth of trees is described by a logistic functional form (Fig. 1).[19] Initially, trees grow very rapidly. Slower growth sets in as the stand matures, until growth stops when the climax state (MV) is reached. At any chosen rotation period, the physical growth characteristics of trees determine the volume of timber than can be harvested per hectare per rotation. This can be discerned from Fig. 1. Assume that the initial rotation period was $T_o - T^*$. This corresponds to a harvest size of $TV_o - SV$, where TV denotes the volume of timber per hectare before the harvest, and SV the minimum volume of timber that has to be left as a result of the minimum harvest age T^*. Now assume that the forestry sector is forced to shorten the rotation period to $T_1 - T^*$. As a consequence, the harvested volume per rotation is reduced to $TV_1 - SV$.

Logging technology is described by a Leontief function which combines land and a non-land input bundle consisting of capital, labor and intermediate inputs at the top of a multi-level production function. It is assumed that the bundle of non-land inputs is fixed per rotation, which gives rise to a form of increasing returns to scale (Dec, 1991b). Within the input bundle, substitution possibilities between labor and capital and between imported and domestically produced intermediates are allowed.

Since the harvest volume HV above is defined per hectare per rotation, it has to be translated into annual output for the entire forest in order to make the forestry submodel compatible with the rest of the model. Assuming that the harvest per rotation is equally distributed over the years of the rotation period, annual timber output X from the whole harvested area B is

$$X = HV \cdot B/(T - T^*). \tag{3}$$

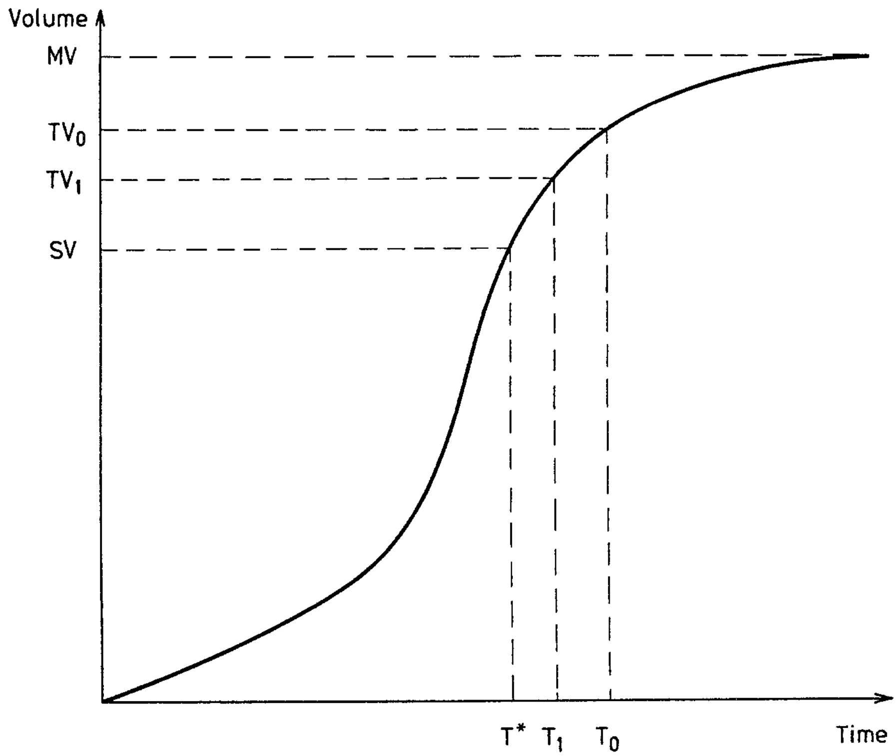

Fig. 1. Logistic growth curve of trees.

The rest of the model follows conventional lines. Domestic supply of all sectors except forestry is given by a constant-returns Cobb-Douglas production function, using labor of different occupations, forest and non-forest land (in agriculture), and sector-specific capital, which is fixed in the short run. A Leontief function combines the aggregate of primary factors and intermediate inputs. The producers in each sector choose their demand for labor (and land in agriculture) and their output so as to maximize profits at the given wage rates, factor taxes, land prices, commodity prices and capital stocks.

Regarding foreign trade, Cameroon is assumed to be a small country not able to influence world market prices. While this is in accordance with classical trade theory, we deviate from its assumptions in some other respects. First, domestically produced goods and imports of the same product category are regarded as imperfect substitutes. The substitution possibilities for domestic consumers are described by a CES (Constant Elasticity of Substitution) function (Armington, 1969). In a similar way, differences in quality between domestically consumed and exported commodities are described by a CET (Constant Elasticity of Transformation) function (Powell and Gruen, 1968). Finally, we specify Cameroon's exports of some sectors as facing a constant elasticity demand function. This formulation takes account of the fact that as the domestic price of a commodity rises (falls) relative to the world market price, export demand may fall (rise) although the country is still a price-taker.

In the household sector, we assume there is only one representative consumer who buys consumer goods according to fixed expenditure shares. This demand system can be derived from the maximization of a Cobb-Douglas utility function. Government demand for final goods is defined using fixed shares of aggregate real spending on goods and services. The sectoral allocation of investable funds is determined by exogenously given share parameters. These share parameters are fixed within one period, but are allowed to adjust over time (see below). Inventories are a fixed proportion of sectoral supply.

In order to solve the CGE model, market clearing equations for the product and factor markets as well as macroeconomic equilibrium conditions for the balance of payments and the savings-investment balance must be specified. Supply and demand in product markets is equilibrated by the adjustment of sectoral prices. For the factor markets we assume that the supply of each factor is exogenously fixed.[20] Market clearing requires that total factor demand equals supply, and the equilibrating variables are the average factor prices. While sectoral capital stocks are assumed to be fix within each period, all labor categories are intersectorally mobile, agricultural land is mobile across all agricultural activities and forest land across all forest land using activities. Forest land moves towards the use in which the discounted returns to land are greater. Returns to forest land therefore adjust until their discounted values are equalized across sectors. With foreign savings set exogenously, equilibrium in the balance of payments is achieved via adjustments in the real exchange rate. As the nominal exchange rate is fixed in Cameroon, changes in the real exchange rate are the result of movements in the absolute price level. Finally, aggregate investment is the endogenous sum of private, government and foreign savings, i.e. the model is "savings-driven". This is the so-called "neoclassical" model closure (see, for instance, Robinson, 1989).

Despite the intertemporal treatment of forestry the model can be solved within a comparative static framework. Our model is nevertheless dynamic[21] as it contains equations governing the growth of primary factors over time. While the total supply of labor and land is adjusted exogenously, sectoral capital stocks are built up according to a simple investment model. In this investment model, the sectoral allocation of investable funds is adjusted as a function of the relative profit rate of each sector compared to the average profit rate in the economy. Sectors with higher-than-average profit rates will get a larger share of the investable funds than their share in aggregate profits. An important advantage of such a dynamic formulation is that it allows to investigate the growth effects of different allocations of international transfer payments. To take an extreme example: if the money is exclusively spent for consumption purposes, this will cause mainly Dutch Disease effects, if it is invested this will enhance the production capacity and thus lay the ground for the creation of new employment opportunities.

3.2. NUMERICAL SPECIFICATION

The theoretical model was calibrated to a consistent data set for the year 1980, which is assumed to represent a benchmark equilibrium of the Cameroonian economy. Data from different statistical sources had to be adjusted and a number of parameters, such as those of the above mentioned CES and CET functions, had to be fixed (Mansur and Whalley, 1984).[22] The underlying data base is given in Thiele and Wiebelt (1993). Table II provides a summary of the most important structural features of the Cameroonian economy. We distinguish 11 sectors of production, 5 of which are directly — food crops, cash crops and forestry — or indirectly via strong backward linkages to the primary sectors — wood processing and consumer goods which includes food processing — involved in forest exploitation. Column (1) describes the structure of production across sectors. It reveals a typical composition of output in developing countries where agriculture and services provide more than 60 percent of GDP. The importance of intermediate inputs in each sector is indicated by the per unit value added in column (2). High value added ratios, e.g. for food crops and forestry, indicate small backward linkages. By contrast, the manufacturing sectors exhibit generally the lowest value added rations suggesting high backward linkages.

The next three columns provide information about each sector's trade orientation. Column (3) indicates that cash crops and forestry are the most export-oriented sectors in the economy. On the import side, the typical pictures emerges when one considers both the share of imports in domestic absorption (which indicates the degree of import "orientation") and the share of imported inputs in total intermediate inputs (which indicates the degree of import "dependence"). The manufacturing sectors are the most import-oriented sectors and all sectors are highly import-dependent.[23] Construction and public services are the only non-traded sectors, yet 45 and 19 percent of their inputs are imported. The import substitution and export transformation elasticities in columns (6) and (7) indicate that the extent of product differentiation due to differences in quality and the degree of product heterogeneity is higher for non-traditional manufacturers and services than for agricultural products and the more traditional consumer goods. Finally, the export demand elasticities in column (8) reflect the ease with which foreign users can substitute domestic products. Here, agricultural commodities are less substitutable than other goods.

Once having constructed a consistent data set, one can compare the

Table II. Sectoral Characteristics of the Cameroonian Economy, 1979/80

Sector	Composition of output (percent) (1)	Per unit value added (2)	Exports/ Gross output (percent) (3)	Imports/ Absorption (percent) (4)	Imported/Total intermediates (percent) (5)	Import substitution elasticity (6)	Export transformation elasticity (7)	Export demand elasticity (8)
Food crops	17.0	0.94	1.4	0.8	10.9	1.50	1.50	1.0
Cash crops	5.5	0.42	94.0	55.9	22.0	0.90	0.90	1.0
Forestry	1.5	0.62	75.7	0.02	20.1	0.40	0.40	4.0
Wood processing	1.0	0.38	39.1	9.1	15.5	0.50	0.50	4.0
Consumer goods	9.8	0.28	15.4	25.5	23.4	1.25	1.25	4.0
Intermediates	13.7	0.34	36.1	44.7	35.0	0.50	0.50	4.0
Base materials	1.8	0.38	30.7	67.7	50.0	0.75	0.75	4.0
Capital goods	0.5	0.69	37.3	95.4	50.2	0.40	0.40	4.0
Construction	9.0	0.45	—	—	45.2	—	—	4.0
Private services	31.7	0.72	13.3	12.2	12.9	0.40	0.40	4.0
Public services	8.5	0.66	—	—	19.3	—	—	4.0
Sum/Average	100.0	0.61	18.2	22.6	24.3			

Source: Thiele, Wiebelt (1993), Condon *et al.* (1987).

equilibrium prices for each period (or the actually traded quantities, if prices are exogenously given), which in turn determine the allocation of resources and the use of tropical forests. The effects of different policy measures are analyzed by running model simulations. This means that exogenous variables are changed and a new sequence of equilibria is computed. Policy appraisal then proceeds on the basis of pairwise comparison of counterfactual and benchmark equilibria. Despite of the incorporation of dynamics the solutions generated by the model should be interpreted as medium term results. To capture the long-run implications of measures to cope with deforestation, an extension of the model is required. For example, one has to keep track of the negative stock effects that deforestation has an agricultural productivity (Devarajan, 1990).

4. Empirical Results

This section presents the simulation results for the policy measures discussed in Section 2.3 and shows how single measures can be combined to obtain consistent policy packages.

4.1. RESOURCE POLICIES

We assume that the target of the Cameroonian government is to achieve a specified increase in the volume of standing timber. For concreteness, the target for each policy measure is set at 5 million m^3, equivalent to about 20 percent of the biomass losses caused by one year's deforestation and degradation. Altogether, we distinguish four different resource policy instruments.

The first is an increase in the length of forest leases so that concessionaires have an incentive to take account of the user costs of short-run harvesting and hence to harvest the stand at the private long-run efficient level. This has been modeled as a reduction of the discount rate, which concessionaires apply to calculate their returns from forestry, by 30 percent. A lower discount rate simply implies that future revenues get a higher weight as a result of more secure property rights.

The objective of the remaining three instruments is to deal with the environmental externalities of deforestation. The first option we consider is an increase in the stipulated minimum harvest age of trees by 8 years in order to make forestry more sustainable. The second option is a direct set-aside in the form of a national park. The increase in national parks has been modeled as a reduction in the total area of forest land available for forestry and agriculture by 220,000 ha. The final option is a tax on income from forest land to put a value on the unpriced ecological benefits that harvesting and conversion destroys.[24] This might be called the Pigouvian solution. As the ecological damage varies according to land use patterns, the tax rates are varied accordingly, i.e. 10 percent for forestry, 20 percent for export crops and 25 percent for food crops.

Table III shows the impact of each resource policy on real GDP, aggregate exports, and the domestic price level as well as on sectoral production, exports and producer prices. It is striking that all policies induce a considerable reduction of forestry's production and exports, leading to increasing domestic producer prices.[25] Wood processing is heavily penalized by increasing input costs because of its strong backward linkages to the forestry sector.

Table III. Economic Consequences of Resource Policies in Cameroon (percentage change)[1]

Policies	30 percent reduction of discount rate in forestry	8 year increase in minimum harvest age	220,000 ha converted to national parks	Sector-specific factor tax on income from forest-land
Indicators	simulation 1	simulation 2	simulation 3	simulation 4
Real GDP	−0.2	−0.3	−0.3	−0.4
GDP deflator	0.0	0.3	0.3	−0.7
Total exports	−0.5	−1.4	−1.1	−0.8
Sector production				
Forestry	−4.4	−14.0	−10.0	−15.2
Wood processing	−3.8	−9.8	−6.8	−8.6
Food crops	−0.1	−0.1	−0.2	−0.7
Cash crops	−0.3	−0.2	−0.2	1.3
Sectoral prices				
Forestry	11.2	23.5	15.9	11.0
Wood processing	2.3	10.8	7.2	5.8
Food crops	0.1	0.2	0.2	0.3
Cash crops	0.0	0.2	0.2	−0.6
Sectoral exports				
Forestry	−10.0	−15.6	−11.2	−19.0
Wood processing	−6.5	−13.5	−9.5	−11.8
Cash crops	−0.1	−0.2	−0.3	1.4

[1] All policies are calibrated to produce an increase in standing timber of about 5 million m^3 compared to the reference situation.

Source: Own calculations based on the CGE model.

The change in the annual forestry activity level is determined by three variables (see Equation 3):

- the rotation period;
- the volume of timber harvested per hectare per rotation; and
- the area of land devoted to forestry.

The forestry sector adjusts these variables in different ways depending on the specific policy measure (Table IV).

When the discount rate is lowered (simulation 1), this reduces the opportunity cost of letting trees grow so that there is an incentive for concessionaires to extend the rotation period. Since the subsequent increase in the harvested volume per rotation does not fully compensate for the more infrequent harvests, the net result is a reduction in annual output and a rise in the timber price. As gross harvest revenues increase, because the rise in the timber price is stronger than the decline in harvests, and annual harvesting costs decrease, because the rotation period is extended, forestry net revenues and the stock value of land increase. This provides the price signal to attract additional land into forestry and thereby eases off the initial output reduction.[26] The reallocation of forest land contributes significantly to the achievement of the ecological target as it implies that the planned conversion of some forest areas does not take place. Furthermore, it has only minor effects on agricultural output and prices because forest land is only a small fraction of total agricultural land.

The primary impact of an increase in the minimum harvest age (simulation 2) is that foresters have to wait for trees to grow larger before they harvest them, i.e. the rotation period is shortened exogenously. This change in the logging regime reduces the opportunity costs of forest growth by making earlier future harvests possible. As a consequence, concessionaires increase the age at which they actually harvest the trees. On balance, the rotation period is extended. The change in the volume of timber harvested per rotation is the result of two offsetting factors. First, at any given minimum

Table IV. Consequences of Resource Policies for the Use of Forest Land (percentage change)

Policies	30 percent reduction in discount rate of forestry	8 years increase in minimum harvest age	220,000 ha converted to national parks	Sector-specific factor tax on income from forest-land
Indicators	Simulation 1	Simulation 2	Simulation 3	Simulation 4
Use of forest land				
in agriculture:				
Food crops	−19.3	−19.2	−18.8	−20.9
Cash crops	−18.6	−18.1	−17.8	−15.7
in forestry:	1.2	1.4	−9.9	−15.2
Rotation period	10.3	5.8	−7.3	1.1
Harvest per rotation	4.7	−9.6	−7.4	1.1

Source: Own calculations based on the CGE model.

harvest age, the increase in the actual harvest age leads to a higher harvest volume (see Fig. 1). Second, the increase in the minimum harvest age reduces the harvestable timber volume by stipulating a higher amount of timber (SV) that has to be left after each harvest. In Cameroon, the second effect dominates the first and hence the harvest per hectare per rotation falls. An explanation for this result provides the Cameroonian peculiarity that, because of very small and selective harvests, the timber volume in logged forests (TV) is very close to the maximum timber volume in virgin forest (MV).[27] This implies an extremely low growth rate of trees so that delaying harvest does not yield much additional timber. Both, the lower and less frequent harvests are translated into a decline in annual output and a rise of the timber price. The negative output effect is partly offset by an increase in the area of land devoted to forestry via the same mechanism as described for simulation 1.

The establishment of a national park (simulation 3) initially reduces the area available for forestry activities. As a consequence, annual output declines, pushing up the price of domestically produced timber. The higher output price provides an incentive for concessionaires to undertake more frequent harvests, because it raises the opportunity costs by more than the marginal revenues of forest growth (see Section 3). The shorter rotation period, in turn, leads to smaller harvests per rotation. On balance, annual production falls and the output price increases. With gross revenues increasing more than annual harvesting cost, a rising stock value of forest land attracts land from agriculture thereby cushioning the output reduction in forestry.

A general taxation of forest land (simulation 4) forces up the price of forest land in forestry as well as in agriculture and thus leads to a reduced demand for this factor in both sectors.[28] As the frequency and the intensity of harvests adjust only marginally and compensate each other, the decline in annual output of the forestry sector is solely due to the reduction of forest land use.

The output losses in forestry and wood processing lead to moderate reductions of real GDP in the range of 0.2 to 0.4 percent, depending on the policy choice. Because of the weak linkages to other sectors there are only minor real adjustments in the rest of the economy. On the demand side, exports have to carry the major burden of adjustment. This is because forestry and wood processing are highly export oriented and because the export demand for forest products is very elastic. The sharp decline in exports of the timber industry would impose a significant constraint on the Cameroonian economy, especially in a situation in which export prospects for coffee, cocoa and oil are discouraging and the country has to look for alternative foreign exchange sources. Moreover, the wood industry is a relatively labor-intensive industry in which Cameroon may have a comparative advantage (World Bank, 1989).

Basically, the ecological target can be realized by each of the resource policies analyzed above. Considering the fact that the main problem in Cameroon is the short rotation period and the damage caused by frequent harvests, the best solution from an ecological point of view is to extend logging concessions. This would encourage concessionaires to take into account the regenerative capacity of the forests. Moreover, this measure has the lowest side effects on production and exports in the timber industry.

4.2. TRADE POLICIES

In section 2, we identified the agricultural pricing policy and the trade regime in general as main obstacles for greater efficiency in the Cameroonian economy. A trade liberalization to improve the competitive edge of the country may increase the use of tropical forest resources compared with the status quo, if it leads to a reallocation of resources to the agricultural sector. Consequently, it has to be analyzed whether there is a trade-off between efficiency and ecological objectives. We do this by examining two different policy measures: first, an elimination of import tariffs and export taxes on agricultural goods, and second, a general abolition of import tariffs.

Table V shows the impact of these policies on some important macro-

Table V. Consequences of Trade Liberalization for the Economy and the Use of Forest Resources (percentage change)

Policies	Agricultural liberalization	Across-the board liberalization	Across-the board liberalization *plus* reduction of discount rate
Indicators	simulation 5	simulation 6	simulation 7
Real GDP	0.2	1.1	0.9
Real exchange rate[a]	0.4	−16.7	−16.7
Total exports	7.1	10.0	9.5
Total imports	1.1	5.6	5.5
Standing timber (absolute change in million m^3)	−2.4	2.6	7.5
Use of forest land			
in agriculture:			
Food crops	−0.4	−14.8	−33.4
Cash crops	31.8	−1.1	−19.7
in forestry:	−0.5	0.5	1.7
Rotation period	−0.3	−7.1	3.2
Harvest per rotation	−0.3	−6.7	0.5

[a] An increase (decrease) in the real exchange rate indicates an appreciation (depreciation).

Source: Own calculations based on the CGE model.

economic aggregates and the use of forest resources. Generally, trade liberalization will increase real GDP with the extent depending on the structure of the economy, the structure of protection, and the extent of liberalization. If the liberalization is restricted to agricultural markets (simulation 5), the efficiency gains are very small, while they amount to more than one percent, if import tariffs are eliminated across-the-board (simulation 6). As indicated by higher import and export flows, liberalization induces a shift of resources towards tradables.

In order to analyze the effects that liberalization has on the use of tropical forests, one has to look at its impact on the sectoral allocation of resources (Table VI). The elimination of import tariffs on food crops and cash crops induces domestic users to shift part of their demand towards imports as the domestic price increases relative to the import price. However, the decline in demand for domestically produced agricultural goods is small, because imports rise from a very low base. Because of better substitution possibilities the increase in imports is somewhat higher for food crops than for cash crops. As decreasing domestic demand lowers the domestic price, there is a secondary repercussion on the demand for exports. Exports will increase, the extent depending on the transformation elasticity and the exports demand elasticity. The removal of export taxes for cash crops greatly improves their competitiveness in world markets and pushes up export sales, although the expansion is limited by the relatively inelastic export demand.

These are the *direct effects* determining the initial response in the deregulated markets. In order to estimate the final resource shift in the economy, we must also take into account the *economy-wide effects*. In the present case, the

Table VI. Resource Pull Effects of Trade Liberalization (percentage change)

Policies	Agricultural liberalization simulation 5			Across-the-board liberalization simulation 6		
Sectors	output	exports	imports	output	exports	imports
Food crops	−3.6	3.9	32.1	−2.4	4.3	11.8
Cash crops	18.6	19.3	18.4	8.9	9.2	9.5
Forestry	−0.5	−0.5	0.3	0.9	1.0	5.2
Wood processing	−0.3	0.0	−0.6	0.4	4.7	1.9
Consumer goods	1.4	2.2	−0.3	2.5	14.9	24.0
Intermediate goods	2.9	3.4	0.7	7.4	16.3	4.8
Base materials	2.5	3.0	1.1	5.1	12.1	4.4
Capital goods	2.6	3.4	0.5	5.1	9.4	4.1
Construction	0.5	—	—	1.7	—	—
Private services	1.8	2.0	1.8	1.3	4.9	−3.9
Public services	−8.1	—	—	−5.9	—	—

Source: Own calculations based on the CGE model.

main economy-wide repercussions result from the fact that taxes on agricultural exports make a significant contribution to the government budget and that their elimination reduces government expenditures substantially. Since the demand for public services predominantly stems from the government, this sector contracts and releases labor to other sectors, especially to manufacturing. Other channels for economy-wide effects are less important. Real wages do not change dramatically. The real exchange rate remains almost constant (see Table V), because the pressure to devalue exerted by the elimination of tariffs and the resulting deterioration of the trade balance is neutralized by the improvement of the trade balance following the removal of export taxes. Intermediate input costs do not play a dominant role because of agriculture's weak linkages to the rest of the economy. There are two exceptions: first, via food processing there is a strong forward linkage to consumer goods of food crops, and second, there is a backward linkage to intermediate goods of cash crops via the purchase of fertilizer. Lower domestic prices for domestically produced and imported food crops as a result of zero tariffs lower the production costs of consumer goods whereas higher domestic prices for cash crops as a result of tariff and export-tax abolition stimulate fertilizer demand and production.

Altogether, the change in the use of tropical forests is dominated by the direct effects, which lead to a moderate contraction of food crops and a substantial expansion of cash crops. This implies a reallocation of forest land from forestry and food crops to cash crops (see Table V). As a consequence, the volume of standing timber declines compared to the reference situation, because additional forest areas are converted for agricultural use. The forestry sector faces only minor adjustment needs. With harvesting cost and revenues being roughly unchanged, foresters have no incentive to alter the rotation length and, hence, the harvested volume also remains at its initial level. The small output reduction in forestry is the result of the reallocation of forest land.

If import tariffs are eliminated across-the-board, domestic users substitute imports for domestically produced goods in all tradable sectors except private services, which does not received any import protection in the reference situation. The agricultural sectors and consumer goods show the highest growth rates of imports because of relatively good substitution possibilities and — in the case of consumer goods — a high initial protection level. For the manufacturing sectors with high import shares, increasing imports correspond to substantial decreases in domestic demand, so that they are most heavily penalized by the direct effects of the trade liberalization.

This picture changes, however, when the economy-wide repercussions are taken into account. First, abolishing tariffs reduces intermediate input cost throughout the economy. This stimulates production in those sectors having strong backward linkages and a high share of imported in total intermediate use, i.e. predominantly in manufacturing. Second, the real exchange rate has to depreciate by 16.7 percent,[29] thereby inducing a reallocation of resources towards traded goods. The real depreciation favors cash crops and the manufacturing sectors while it hurts the nontradable sectors and food crops, which can almost be treated as an additional nontradable sector. Forestry does not fit into this pattern. While being highly trade oriented, the sector cannot expand significantly in the presence of a more competitive exchange rate, because it exhibits a very low supply elasticity[30] so that increasing demand only leads to a large increase in the domestic price. Finally, the removal of trade restrictions lowers domestic real wages, which again works in favor of sectors producing export goods and import substitutes and hence being exposed to international price competition. A further repercussion is due to the government's loss of tariff revenues. While we assume that the government raises household taxes in order to maintain a certain supply of public goods, there is a moderate reduction in real government expenditures. As a consequence, resources are shifted from the public to the private sector.

On balance, cash crops and the manufacturing sectors are the winners of trade liberalization. The predominant factor explaining the expansion of cash crops is the devaluation of the CFA Franc. The manufacturing sector benefits from the elimination of import tariffs, because the costs for intermediate inputs decline sharply whereas the output prices for domestic goods are not decreasing to the same extent as the prices of imports because of limited substitution possibilities in domestic demand. The final resource shift corresponds to an increase in the volume of standing timber which is mainly due to two reasons: First, the removal of import tariffs provides an incentive for the manufacturing sector of absorb additional resources. Second, the steep increase in the timber price attracts land to the forestry sector, i.e. agricultural conversion is reduced. A further effect of the price increase is that foresters shorten the rotation period (see section 3), whereupon the harvested timber volume per rotation decreases.

Summing up, a general trade liberalization not only raises real GDP but also eases pressure on the tropical forests. Hence, it overcomes the trade-off between efficiency and ecological objectives. It has, however, one negative ecological side-effect by further shortening the rotation period which is already extremely short in Cameroon. A preferable option would be to combine a general trade liberalization with long-term logging concessions as is illustrated in Table V (simulation 7). Such a policy mix would on the one hand encourage a sustainable use of tropical forests and, on the other hand, promote exports and economic growth, thereby improving the long-run development potential of Cameroon without any outside support.

4.3. INERNATIONAL MEASURES

This section deals with two basic options which industrialized countries have to affect the level of tropical forest exploitation (see subsection 2.3). First, we consider an import ban of Cameroon's logs and processed timber, the most restrictive among the foreign policy measures which may be applied. Second, international transfer payments are investigated. The results of the simulations are presented in Table VII.

As it seems unrealistic that an import ban works perfectly, we assume in simulation 8 that Cameroon is, after the introduction of the ban, still able to sell 10 percent of its previous tropical hardwood exports to outsiders who do not obey the ban. Nevertheless, the decline in exports leads to dramatic output losses in forestry and wood processing. Forestry suffers more than wood processing, because there is almost no domestic demand for the sector's output – except from the forward linkage to wood processing –, which could substitute for the foregone exports. The high share of exported timber thus makes, the ban rather effective as concerns forestry activity. The use of forest land in forestry is more than halved,[31] while the rotation period and the harvested volume per hectare per rotation remain constant. The

Table VII. Consequences of International Measures for the Economy and the Use of Forest Resources (percentage deviation from the base run)

Policies	Import ban of Cameroonian wood and wood products	Compensation payments (used for investment)	Compensation payments (used for consumption)	Compensation payments (used for investment) *plus* national park
Indicators	simulation 8	simulation 9	simulation 10	simulation 11
Real GDP	−1.4	0.3	−0.4	0.0
Real exchange rate	−5.6	3.5	8.0	2.9
Aggregate exports	−0.9	−1.8	−3.7	−2.6
Sectoral output				
Food crops	−0.9	0.5	0.9	0.3
Cash crops	4.6	−0.2	−4.0	−2.0
Forestry	−53.7	−0.1	−0.2	−10.7
Wood processing	−20.0	0.0	−0.1	−5.4
Volume of standing timber (absolute change in mill. m^3)	1.0	−0.6	−0.9	4.3
Use of forest land in agriculture:				
Food crops	−1.8	3.7	5.7	−11.5
Cash crops	5.8	−0.6	−1.2	−17.2
in forestry:	−53.7	−0.1	−0.2	−10.9
Rotation period	0.0	−0.1	−0.1	−4.4
Harvest per rotation	0.0	−0.1	−0.1	−4.2

Source: Own calculations based on the CGE model.

effectiveness of the ban in slowing down the activity in the timber industry imposes considerable costs on the Cameroonian economy, as is indicated by a decline in real GDP of more than one percent.

The net effect of the ban on the use of tropical forest resources depends on how agricultural conversion changes. This change can be explained by two dominating economy-wide repercussions. First, the income losses in the economy lead to a decreasing demand for domestically produced goods. This effect is particularly relevant for the food-crops sector, which nearly exclusively serves the domestic market, while it does not affect cash crops. Second, the drop in exports causes a real depreciation, which favors cash crops and hurts food crops.

On balance, there is a reallocation of forest land from forestry and food crops to cash crops, i.e. agricultural conversion increases compared to the reference situation. However, the primary effect on land use in forestry dominates so that the volume of standing timber increases by one million m^3. This outcome shows that a high share of exported timber is the crucial precondition for an import ban to be ecologically effective. Hence, the result should be interpreted as country-specific, as there are a number of tropical countries — e.g. Brazil — with much lower export orientation of the forestry industry (Amelung and Diehl, 1992). For those countries, a ban may well be economically *and* ecologically counterproductive.

With respect to compensation payments for the conservation of tropical forests, we presuppose that tropical and non-tropical countries have negotiated an environmental agreement. Then, three basic questions arise for the individual tropical country: how can it reach the specified ecological goal; how much side payments will it receive for the protection of its forests; and how is it going to spend the money. Consequently, one has to analyze a combination of an external transfer and a complementary national resource policy measure.

In simulation 11, it is assumed that the Cameroonian government directly sets aside tropical forest areas and that the amount of compensation payments injected into the economy — 65 million US Dollar (which was the result of simulation 3) — just matches the economic losses resulting from the establishment of a national park.[32] Since the theoretical reference point for transfer payments is given by the difference between economic losses and local ecological gains of forest conservation, this amount constitutes an upper bound. Furthermore, the transfer is assumed to be provided under the general condition that it has to be used for investment in order to create new employment opportunities.[33]

The effects of establishing a national park have already been discussed in Section 4.1. Simulation 9 shows, how the external transfer qualifies these results. As the money is invested and thus adds to the productivity capacity of the economy, the increase in demand exerts only moderate pressure on domestic prices. Nevertheless, the resulting small appreciation and the higher income are sufficient to induce a reallocation of forest land from cash crops and forestry to food crops so that the volume of standing timber declines because of higher agricultural conversion. Hence, the effects of the compensation payment somewhat dampen the effectiveness of the set-aside, but a substantial ecological gain of 4.3 million m^3 biomass at zero economic costs remains (see simulation 11).

If the same amount of money is used for consumption instead of investment (simulation 10), a different picture emerges. The increase in demand forces up domestic goods prices in relation to foreign goods prices as is indicated by a significant increase in the real exchange rate. The price increase causes a decline in real investment so that economic growth is lowered compared to the base run. This result shows that an unconditional provision of transfers is not appropriate to compensate for the losses of environmental protection.

5. Summary and Conclusions

This paper has provided a numerical general equilibrium assessment of policies to reduce tropical deforestation in Cameroon. While it was not feasible to examine every possible method of deforestation control, we did analyze a variety of alternatives which broadly reflect the continuum of national and international policies currently suggested in the environmental and resource economics literature. Generally, the ecological effects of deforestation control are shown to depend crucially upon its impact on forest land use patterns whereas the efficiency effects hinge on the manner in which a specified set-aside target is achieved.

More specifically, the following major results emerge from the simulation analysis:

The ecological target can be realized by each of the resource policies analyzed: prolongation of forest leases; raising the minimum size of trees that can be harvested; establishment of a national park; Pigou-tax on forest land.

Since the main problem in Cameroon is the short rotation period and the damage caused by frequent harvests, the best solution from an ecological point of view is to extend logging concessions. This measure has also the lowest negative side effects on timber production and exports as well as real GDP.

The trade-off between efficiency and ecological objectives can be overcome by a general trade liberalization. However, such a policy leads to a further shortening of the rotation period, thereby reducing its ecological effectiveness.

A preferable option would be to combine an across-the-board liberalization with long-term logging concessions. Such a policy mix would, on the one hand, encourage a sustainable use of tropical forests and, on the other hand, promote exports and economic growth, thereby improving the long-run development potential of Cameroon without any outside support.

An import ban for Cameroonian tropical wood, while being ecologically effective, would place unacceptably high costs on the domestic economy. This result is country-specific, as there are a number of tropical countries — e.g. Brazil — with much lower export orientation of the forestry industry. For these countries, an import ban would be economically and ecologically counterproductive.

If the international community wants to ensure a higher level of protection of tropical rain forests, and to do so in a market-based system, the provision of additional financial resources is necessary to support domestic policies. However, an unconditional provision of transfers is inappropriate to compensate for the economic loses of environmental protection. An ecologically effective and efficient policy mix has to combine domestic resource policies with conditional outside payments used for capacity enhancing investment.

Appendix

Equations, Variables and Parameters of the Model[a] (comparative static version)

Prices

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

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

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

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

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

(6) $P = NGDP/RGDP$

Input demand and Commodity supply[b]

(7) $X_i = a_i^x \Pi_f F_{if}^{\alpha_{if}} \qquad i \neq F$

(8) $F_{if} = \alpha_{if} \cdot P_i^v \cdot X_i/\gamma_{if} \cdot P_f \qquad i \neq F$

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

(10) $Q_i = a_i^q[\delta_i^q \cdot M_i^{-\rho} + (1 - \delta_i^q) \cdot D_i^{-\rho}]^{-1/\rho}; \sigma = \dfrac{1}{1 + \rho}$

(11) $M_i = D_i[P_i^d \cdot \delta_i^q / P_i^m(1 - \delta_i^q)]^{\tau_i}$

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

(13) $E_i = D_i[P_i^e(1 - \delta_i^t)/P_i^d \cdot \delta_i^t]^{\tau_i}$

Market clearing and macro-closure

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

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

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

(34) $S = Z$

Final demand

(14) $C_i^H = \beta_i^H / P_i^q(1 - t^H)(1 - s^H)Y^H$

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

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

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

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

(19) $E_i = e_i(P_i^{\$e}/\overline{P}_i^{\$e})^{-\eta}$

Forestry submodel[c]

(20) $TV = \overline{MV}/[1 - \overline{MV}/\overline{TV}]e^{-g \quad T}$

(21) $SV = \overline{MV}/[1 - \overline{MV}/\overline{TV}]e^{-g \quad T^*}$

(22) $RC_F = P_F^n \cdot VR_F$

(23) $RR_F = [P_F^x \cdot (TV - SV) - P_F^n \cdot VR_F](1 - t_F^B)$

(24) $PV_F = RR \cdot e^{-r(T-T^*)}/[1 - e^{-r(T-T^*)}]$

(25) $P_F^x(1 - t_F^B) \cdot g \cdot TV[1 - TV/\overline{MV}] =$

$r \cdot RR_F/[1 - e^{-r(T-T^*)}]$

(26) $X_F = (TV - SV) \cdot B_F/(T - T^*)$

(27) $V_F^n = \overline{VR}_F \cdot B_F/(T - T^*)$

(28) $P_F^B(1 - t_F^B) = RR_F/(T - T^*)$

(29) $PV_j = P_j^B(1 - t_j^B)/r$

(30) $PV_i = \gamma_i^B \cdot PV$

[a] Endogenous variables of the flow of funds which are calculated include: Total government revenues, total household income, and total investment. Compensation payments are assumed to enter either directly into savings (if used for investment) or are distributed to households and the government, with part of it being

saved and part of it ending up as private consumption. — [b] Equations (10) and (11) give the CES aggregation functions describing how imports and domestic products are demanded and the corresponding import demand functions. Equations (12) and (13) contain the CET transformation functions combining exports and domestic sales and the corresponding export supply functions. — [c] Cf. section 3.1 for a detailed description of this part of the model. Equations (20) and (21) describe the harvestable and standing timber volume per ha as a function of the harvest age and the minimum harvest age, respectively. Equations (22)–(25) describe the optimization problem in forestry. The other equations determine the allocation of mobile forest land between forestry and agricultural sectors.

Variable[a]	Description	Variable	Description
P_i^m	Domestic price of imports	DK_j	Investment by sector of destination
$\bar{P}_i^{\$m}$	World price of imports	Z	Total investment
R	Exchange rate	I_i	Final demand for investment goods
P_i^e	Domestic price of exports	TV	Timber volume per ha
$P_i^{\$e}$	World price of exports	$\overline{MV}$	Max. volume of timber per ha
P_i^q	Price of composite good	$\overline{TV}$	Average stocking rate in logged forests
P_i^d	Domestic sales price	T	Age of logged trees
D_i	Domestic sales of domestic output	SV	Volume of standing timber after harvest
M_i	Imports	T^*	Min. harvest age of trees
Q_i	Composite good supply	RC_F	Harvest costs per ha per rotation
P_i^x	Output price	P_F^n	Price of non-land input bundle
E_i	Exports	$\overline{VR}_F$	Non-land inputs per ha
X_i	Domestic output	RR_F	Net revenue per ha per rotation
P_i^v	Value added or net price	PV_F	Present value of forest land
P	GDP deflator	X_F	Annual timber output
$NGDP$	Nominal GDP	B_F	Demand for land in forestry
$RGDP$	Real GDP	V_F^n	Annual non-land input requirements in forestry
F_{if}	Factor demand	P_i^B	Annual gross returns to forest land
P_f	Average factor price	$PV_i(PV)$	(Average) Present value of after-tax returns to forest land
V_i	Intermediate input demand	$\bar{F}_f^s$	Fixed factor supply
C_i^H	Final demand for private consumption	S	Total (domestic and foreign) savings
Y^H	Total household income		
C_i^G	Final demand for government consumption		
$\bar{C}^G$	Real government consumption		
$I2_i$	Inventory investment by sector		
Parameter	Description	Parameter	Description
t_i^m	Import tariff rate	β_i^H, β_i^G	Expenditure shares
t_i^e	Export subsidy rate	β_i^I	Inventory-output ratio
t_i^x	Indirect tax rate	k_i	Investment destination shares
a_{ij}	Input-output coefficients	b_{ij}	Capital composition coefficients
a_i^x, a_i^a, a_i^T, e_i	Shift parameters	η	Export demand price elasticity
α_{if}	Factor productivity parameters	g	Max. intrinsic growth rate of trees
γ_{if}, γ_i^B	Factor market distortion parameters	t_i^B	Factor tax on forest land
δ_i^q, δ_i^T	Distribution parameters	r	Discount rate
$\rho(\sigma), \omega(\sigma)$	Substitution and transformation parameters (elasticities)	e	Exponential function
t^H	Household income tax rate	s^H	Household savings rate

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

Notes

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1 Other economic activities such as the exploitation of minerals and the generation of energy by hydroelectric power plants are not significantly contributing to deforestation in Cameroon.

2 The African rain forests have an estimated regeneration period of 20 to 40 years (Grut *et al.*, 1991).

3 Logging and the sale of unprocessed timber are ascribed to forestry, whereas sawnwood, plywood and other wood products are ascribed to the wood processing industry.

4 An important underlying factor that exerts pressure on the tropical forest is the high population growth rate in Cameroon. Strategies to reduce the population pressure — which should, among other things, include measures to alleviate poverty — and their impact on deforestation will not be analyzed in this paper.

5 For critical assessments of the franc-zone, see, for example, Boughton (1991) or Schweickert *et al.* (1992).

6 This estimate was based on survey information about the black market exchange rate; the differential between black market and official rate was halved to account for the risk premium involved in unofficial transactions.

7 In 1989, the government of Cameroon and the World Bank agreed on a structural adjustment programme which, among other things, included a deregulation in the agricultural sector.

8 Other non-price factors, such as the provision of infrastructure and research and extension which predominantly fall into the domain of the government, are not analyzed in this paper.

9 The resource rent, or stumpage value, of a standing tree is the difference between the market value of the timber and all the logging, transportation, and processing costs.

10 This target includes the evergreen forest area as well as the savanna zone in the north.

11 We do not claim to cover the full range of policy options for the conservation of Cameroon's forests. In particular our approach is not suitable to analyze policies which try to link conservation with the development needs of local communities. For proposals in this area, see e.g. Winterbottom (1992).

12 Foresters point out that it is possible to manage tropical forests sustainably, but that current management practices for the most part are unsustainable (Bruenig, 1990). About the constraints on sustainable logging in Cameroon, e.g. inefficient sawmill equipment and poor training, see Gartlan (1992).

13 Policies designed to stimulate domestic log processing are usually justified by the tariffs and trade barriers against processed forest products of developing countries or by the infant industry argument. The former justification is, however, not valid for Cameroon, because it delivers nearly all its wood products to the EC, where it receives unlimited duty-free access under the Lomé Convention (Grut *et al.*, 1991). What remains is the infant industry argument, the rationale of which is doubted by many economists (e.g. Baldwin, 1969).

14 Nunnenkamp (1992) discusses various institutional arrangements for compensation payments with respect to their stability and ecological effectiveness.

15 In a theoretical paper, Barbier and Rauscher (1992) identified another possible cause for the ineffectiveness of import restrictions: they reduce the terms of trade of the tropical country which leads to higher deforestation if the country if highly import dependent.

16 A detailed formal description of the model can be found in Thiele, Wiebelt (1993). The model equations are listed in the Appendix.

17 The rotation period is the length of time between two harvests on a specific area (here on one ha).

18 Note that $1/(1 - e^{-r(T-T^*)})$ is equal to the infinite sum $1 + e^{-r(T-T^*)} + (e^{-r(T-T^*)})^2 + \ldots$.

[19] The assumption of a logistic growth curve is common in the literature on renewable resources (e.g. Wilen, 1985; Clark, 1990).

[20] With respect to forest land, the assumption of a fixed aggregate supply seems appropriate for Cameroon, where the access of the forestry sector is restricted by the provision of concessions and where agricultural use is dominated by smallholders who are not able to open up new primary forests.

[21] Our dynamic specification assumes that agents are myopic, basing their decisions on static expectations about prices and quantities. As a consequence, the model can be solved recursively for a sequence of equilibria.

[22] In addition, some physical characteristics of the tropical forest — e.g. the average timber stock in the primary forest (MV) — must be provided in order to make the model operational (Dee, 1991a).

[23] The high import share for cash crops should not be interpreted as indicating import orientation. It is simply the result of an extremely low domestic absorption.

[24] A tax on income from forest land is also a means of capturing a sizeable proportion of the resource rent accruing to foresters (Gray, 1983). Because of the similarity of the results we will not report separate simulations for rent capture.

[25] The fact that the contraction in domestic supply forces up domestic timber prices, although log imports are available, is a result of the Armington assumption of imperfect substitution between domestic and imported commodities.

[26] The 4.4 percent decline in annual output is the net result of a 10.3 percent increase in the length of the rotation period and two offsetting factors, namely a 4.7 percent increase in the harvest volume per rotation and a 1.2 percent increase in the land devoted to forestry: $-10.3 + 4.7 + 1.2 = -4.4$ (Tables III and IV).

[27] The average timber volume in logged forest is 266 m^3/ha as compared to 280 m^3/ha in virgin forests.

[28] In order to simulate the impact of sectorally differentiated land taxes on total land use we assume a perfectly elastic supply of forest land. The results are, therefore, not fully compatible with those of the other simulations.

[29] This devaluation is sufficient to correct for the overvaluation of the CFA Franc (see Section 2).

[30] The low supply elasticity in forestry follows from the Leontief technology which combines land and non-land inputs in fixed proportions. The bottleneck for the supply response is the availability of land, because the forestry sector can only attract additional land as long as the discounted returns are higher than in agriculture.

[31] In this simulation, we assume that the supply of forest land is perfectly elastic in order to analyze the impact of a ban on total land use.

[32] We neglect here the principal-agent problem which may arise, i.e. the possibility that Cameroon does not fulfill its ecological obligations after having received the transfer. Amelung (1991) suggests that a payment in instalments can reduce this problem.

[33] Alternatively, one may formulate more specific conditions, e.g. that the transfers have to be used to finance measures which enhance agricultural productivity outside the tropical forest.

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