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Title: A Policy Preference Function Analysis of the Forest Sector in the Côte d'Ivoire

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The main objective of this study was to offer an alternative methodology for forest sector modeling in developing economies. To this effect, a policy preference function was developed and estimated using data from the forest sector of the Côte d'Ivoire.

The justification for this alternative framework for forest sector analysis is twofold. First, forest sector policies in developing countries are often guided by the results of market-simulating studies. Although these market-based planning models are valuable, they fail to take into account the political economic environment in which the planning of the forest sector takes place. This omission may partially explain the poor performance of many forest industrial projects in the Third World. Second, policy evaluations based solely on economic efficiency criteria are incomplete in general, and more specifically so in the setting of developing economies. As Rausser (1990) points out, the integration of both economic and political factors is

essential in understanding and formulating recommendations for governments in developing countries in order to achieve real economic policy reforms.

This study formulated the problem facing public forestry policy makers in terms of expected discounted welfare maximization, subject to a set of stochastic constraint equations describing the forest economy. The revealed-preference-inverse-control technique was used to estimate the model. Marginal utilities and utility elasticities were derived that indicated that private profit, government revenues, and reforestation have intrinsic values to forestry policy makers in the Côte d'Ivoire. Employment and foreign exchange earnings and savings did not appear to be directly valued. The interpretation is that public policy makers compromise on employment and foreign exchange earnings in order to achieve their revenue, profit, and environment protection objectives. Large sample standard errors were computed for the PPF parameter estimates. Although the individual policy preference weights did not appear to be measured with much accuracy, a subsequent hypothesis test (Chi-square test) rejected, at the 1% level, the hypothesis that all the estimates of the objective function parameters equal zero. The implication is that although individually the estimates of the PPF parameters may not be measured accurately, they do, when taken together, suggest that the elements specified in this model are useful in explaining the behavior of forestry policy makers in the Côte d'Ivoire.

The model was validated using a validity test that focuses on the predictive ability of the model. The validated PPF was then used to evaluate alternative policy scenarios over a short planning horizon during which the estimated PPF weights can be assumed constant.

A Policy Preference Function Analysis of the Forest Sector in the Côte d'Ivoire.

By

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DEDICATED TO

My wife, Rosalie and my brother, Clément
for their love and support without which
this task would not have been accomplished.

A POLICY PREFERENCE FUNCTION ANALYSIS OF THE FOREST SECTOR IN THE COTE d'IVOIRE

CHAPTER I

INTRODUCTION

1.1 The Problem

Once there was a great hope that forestry, because of its strong forward and backward linkages to other sectors of the economy would offer an excellent opportunity for tropical countries to develop their own capital bases (Hirschman, 1958; Westoby, 1962; FAO, 1967). International donor agencies encouraged capital intensive industrial programs in the 1960s and early 1970s. But today the contribution of forestry to socio-economic development in the Third World remains unsatisfactory (Repetto and Gillis, 1988; Vincent and Binkley, 1991; Grut et al. 1991); and there has been a wasteful destruction of forest resources (Ross and Donovan, 1986; Vincent and Binkley, 1991). These ills are often attributed to (1) government macroeconomic policy spillovers (i.e. policies designed for other objectives but which negatively affect the forest sector), (2) government failures to capture enough economic rent from forest industries (Page et al., 1976; Grut et al., 1991), (3) failure of the government to set appropriate (i.e., revenue maximizing, and forest resource saving) forest sector policies (Page, 1974 and 1976; Vincent and Binkley, 1991; Grut et al., 1991;).

Repetto and Gillis (1988) report: "Governments [in tropical countries] have typically sold off timber too cheaply, sacrificing public revenues while encouraging rapid logging exploitation. The terms of many timber concession agreements and revenue systems have encouraged wasteful, resource depleting logging." For example, in Ghana, total forest revenues collected in 1988 from all forest fees were some $0.5 million, equal to about $0.38/m3, and less than 0.5% of the delivery price of logs at processing plants (World Bank 1988); in Guinea the stumpage fees were set at less than 1% of the value of the sawnwood on the local market (Grut et al., 1991); while in Côte d'Ivoire the total amount of stumpage fees collected in 1986 was about CFAF750 million, or $0.58/m3 (World Bank, 1990).

However, to argue that forestry policies consistently are in error because they do not transfer maximum economic rent from private firms to the government, one must hold either that the government is the guardian of social preferences, and as such it can deliberately strive to achieve first best solutions in its forest-based industrialization efforts; or that direct private investment in a developing country's forest sector is a matter of take it or leave it. The first reason ignores the conflicting objectives of the interest groups involved in the forest sector. The second assumes away the possibility of bargaining as an instrument to accommodate these conflicting objectives. Policy decision making in the forest sectors of developing countries must be best understood and analyzed within a bargaining framework. As Rausser (1990) pointed out, throughout the Third World, the integration of both political and economic forces is essential in understanding and prescribing roles for the public sector in order to achieve economic policy reforms.

Forest sector planning models for developing countries have been traditionally presented as some form of supply and demand analysis used to forecast timber product requirements in a given country or region, predict the impacts of alternative forest development strategies, or estimate how much investment should be devoted to timber production and wood processing (Buongiorno,1991; Adams, 1985; Haynes and Adams, 1991). Forestry sector policies in developing countries are often developed using the results of these market-simulating models (Buongiorno, 1991). Although these market-based planning models are valuable, they fail to take into account the political economic environment in which the planning of the forest sector takes place. This omission may partially explain the poor performance of many forest industrial projects in the Third World (Harou, 1991).

This research effort seeks to analyze the forest sector of developing countries using an alternative modeling approach: The Policy Preference Function (PPF) framework. A fundamental premise of this approach is that observed policies are the outcome of an implicit optimization process involving, directly or indirectly, all the interest groups in the sector. The model is applied to a major West African timber producing country, the Côte d'Ivoire.

1.2 The Economic Setting

The setting for this study is that of open, capital-short developing economies seeking to develop efficient and sustainable forest-based industries that can contribute significantly to overall socio-economic development. These economies are adequately endowed with stocks of tropical forests mostly controlled by the state. To attract and maintain the necessary capital and technology for a successful forest-based industrialization, governments in these countries adopt policies that provide incentives for direct (foreign and/or domestic) private investments. These stylized economies are commonly found in Africa, Latin America and South Asia (FAO,1967; Enabor, 1971; Tuinder, 1978; Page, 1974, 1976; Page et al., 1976; Othman, 1986). There are significant variations from one country to another in the choice of policy instruments to achieve forestry development objectives. However, a high degree of commonality prevails so that tropical countries can benefit from each other's experience.

It is the intent of this study to understand how groups such as governments and private firms who represent different economic interests can work together in spite of their differences. Indeed the objectives of these two groups are quite different and even conflicting in many ways. For example, a government may want to develop a domestic processing industry by restricting raw log exports. This objective may conflict with the objective of a private logging firm trying to maximize profits by supplying quality logs to satisfy increasing demands abroad. Clearly, some kind of agreement (implicit or explicit) must be reached if the industrial development of the forest sector is to be realized. This is a situation where political and economic markets are integrated. First-best solutions would be difficult, if not impossible, to achieve. The full achievement of one objective can only be accomplished at the expense of another. The government's desire to increase employment may not be fully realized if the profit maximizing producer (capital and technology owner) hires labor according to the marginal productivity distribution rule,[1] or insists on using expatriate workers rather than local labor. Trade-offs among the different interest groups concerned with the policy process are inevitable. Thus, policies formulated in this context should be viewed as pareto optimal outcomes resulting from a bargaining process involving government policy makers and private domestic and foreign enterprises.

More often foreign direct investment is identified with the import of capital to complement local resources. This view, which is referred to in the theoretical literature on direct foreign investment as the Neo-classical theory of foreign

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[1]According to the marginal productivity theory of distribution the profit maximizing firm will use labor up to the point where the wage rate is equal to the value of the marginal product of labor. This profit maximizing level of employment may fall short of the level expected by the government.

investment (Jenkins, 1976), implies that any proposal from a foreign corporation that, on a cost-benefit analysis, shows a positive net present value, should be undertaken. The implied alternative is no foreign investment and therefore no project. In contrast, the bargaining model presented above implies that a positive net present value is not a sufficient condition for accepting the investment for two reasons: (1) the alternative may not be no project but investment by another (foreign) company, or undertaking the project without direct foreign investment; (2) it may be possible, through negotiation, to increase the net present value of the original project (Jenkins, 1976). Moreover, the foreign or domestic capitalist has the options of directly investing in another country, or investing in another sector of the economy. Clearly, the situation is not a matter of take it or leave it, as the neo-classical model implies, but involves the negotiation of a package that includes a great number of distinct elements such as profit remission, royalty payments, tax treatment, tariff protection, local content requirements, export earnings, training of local labor, and the like.

1.3 Objectives and significance of the Study

The broad objective of this study is to understand the policy selection process in the forestry sectors of developing countries with special attention to the Côte d'Ivoire as a case study. This is important for predicting future policy paths, and evaluating alternative policy reforms.

Recent assessments of the success of the Tropical Forest Action Plans (TFAP) have revealed an urgent need for policy reforms (Ross and Donovan, 1986; Winterbottom, 1990). Ross and Donovan (1986) argue that an improved plan should include, among other components, cross-sectoral reviews of government policies and long-term assistance in policy development and planning. For such policy reviews and planning assistance to be successful, however, a change in approach is needed. Most national TFAPs, based mainly on forestry sector reviews, simply justify increased investment in the sector--a focus too narrow to adequately assess the root causes of the poor performance of forest-based industrial projects (Winterbottom, 1990). A new approach that integrates the economic and political forces operating in the forest sector is needed to understand the preferences of the interest groups involved and to formulate better policies for effective forest sector development. Successful reforms must alter the forces that condition government policy selection. Unless this framework is adopted, policy reform proposals from an outside government or international body will fail because such reforms will be nothing but "temporary reactions to external demands and, once those demands abate, the political-economic system will likely return to its previous policy equilibrium" (Rausser and Foster, 1990).

Government forestry policies are not always implemented as officially stated. They are most often statements of intention for the sector (Enabor and Umeh, 1991;

Marchés Tropicaux et Mediterranéens, 1971). Policies actually observed fall short of policies officially planned. Any attempt to understand the policy formulation process by directly interviewing policy makers is therefore doomed to failure; since what is said is not always what is done or observed. A systematic analysis that makes explicit the importance (weights) that government policy makers attach to the objectives of the interest groups concerned with forestry policies is needed. This study pursues the following specific research objectives:

1. Develop and estimate a policy preference function to explain and predict the behavior of policy makers in the forest sector of the Côte d'Ivoire.

2. Use the estimated model to (a) test the commonly held belief that forest-based industrial development in developing countries results in huge profits to private companies with no significant benefits to the local people and the government; (b) simulate policy responses to changes in the economic environment (e.g., reduction in tropical raw log supply that could result from tropical timber boycotts; and increases in tropical forest products export charges).

3. Use the results obtained to evaluate tropical forestry policy reforms in the Côte d'Ivoire.

To achieve these objectives, a policy preference function (PPF) will be estimated econometrically in the context of an optimal control model. It is assumed that public policy makers in tropical developing countries seek to obtain control of their forest resources by pursuing a set of policies that reflect not only public development objectives but also those of the private companies operating in the forest sector. It is also assumed that the extent to which an interest group's objectives are accommodated in the policy process depends on the relative bargaining position of that group. For example, a government which has a very high level of unemployment but a low level of external debt, may be in a stronger position to insist on domestic processing of raw logs than a government with a high level of external debts and moderate unemployment level (assuming that domestic processing increases employment, but reduces foreign exchange earnings and savings; and that raw log exports generate just the opposite effects).

PPF is a structural framework that embraces the objectives and decision rules of the government as well as the other interest groups (Rausser and Foster, 1990; Love et al., 1990). The control model will optimize the multi-attribute PPF under economic and environmental constraints. The estimated PPF will serve to simulate policy responses to changes in the economic and political environment such as international boycotts of tropical timber (as a reaction to tropical deforestation), timber supply shortage, and increases in forest fees. The simulation results will provide guidance in evaluating policy reforms.

1.4 Literature Review

Forest sector planning models have evolved from the so-called "gap model" to market equilibrium models. Gap models typically attempt to quantify the gap between the potential demand for and supply of different forest products over time at current price levels. Aggregate consumption and production at the national level are often considered, and, for a given price level a gap between consumption and production is forecast. Next, policies and programs are proposed to fill the gap. Market equilibrium models, on the other hand, are characterized by a supply and demand adjustment process, that endogenously determine both prices and quantities.

The best examples of gap models come from the United States (US) Forest Service where they were first developed and used (USDA Forest Service, 1958, 1965, 1977). The methodologies used in the U.S. influenced the sector analyses conducted in the FAO studies on the European and African timber trends and prospects (FAO, 1967, 1964). The flexibility of this method in accommodating different levels of data availability is its key advantage. For this reason the gap modeling approach is the most popular method used in developing countries where extensive statistics on forest sector and trained professionals are limited (Harou, 1991). Examples of these include FAO and World Bank studies on the forest sectors of Malaysia, Indonesia and Nigeria summarized by Buongiorno (1991); and Enabor and Umeh (1991).

These gap type models are valuable in appraising forest resource bases, forecasting future resource requirements, and providing the rationale for alternative policies for better management of forest resources. However, since they take no account of the policy formulation process, policy recommendations based on these models may be misleading or ineffective in bringing about real policy reforms.

Much of the evolution of forest sector models was stimulated by the change in the focus of policy discussions from defining policy needs in terms of quantity shortfalls to identifying policy needs in terms of price impacts (Haynes and Kaiser, 1991; Harou, 1991). Also the rapid changes in commodity prices in the mid 1970s and the concern about the effectiveness of various policies to alter selected price trajectories led analysts to shift from gap models to market equilibrium models.

Adams and Haynes (1980) distinguished three types of market equilibrium models: (1) non-spatial market models, where only one region is considered; (2) quasi-spatial equilibrium models, where goods flow from one region to another region; (3) spatial equilibrium models, where various spatially isolated markets compete between themselves. Market equilibrium models have been developed and successfully used in developed market economies, especially in North America.[2] It is hoped as forestry statistics and technical expertise improve in developing economies, market equilibrium models could develop and replace the basic gap models.

[2]The Timber Assessment Market Model (TAMM) is perhaps the best known examples of Market Equilibrium Models. TAMM is a model of the U.S. forest sector and has been developed to assist in the analysis of long-term trends in resource use and status. It provides long-term projections of consumption, production, and prices of forest products and the growth and inventory of the forest resource under externally specified conditions on policy and the economic environment surrounding the forest sector.

Some analysts, however, have already applied the market equilibrium modeling approach to developing economies. These include the Vincent study (1987) on Japan-South Sea trade in forest products, and the Adams study (1985) on the African-European trade in tropical logs and sawnwood. Both of these studies are spatial equilibrium models designed to address trade issues such as the effects of trade barriers and exchange rates on trade patterns as they relate to national welfare. Both market equilibrium models and gap models ignore the political economic environment so critical to the understanding of the forestry policies observed in developing tropical countries.

In addition to these models, many case studies on forest-based industrialization in the Third World are also found in the literature. Page (1974) concludes that Ghana's effort to promote domestic processing by Ghanaians themselves has reduced the generation of economic surplus. Page (1976) finds that Ghana's plywood mills and sawmills are socially more profitable than furniture mills. He explains this difference by indicating that government pricing policies are more pronounced in secondary processing than in primary processing. But Page does not explain these observed differences in government policy toward the two subsectors. Ewing and Chalk (1988) propose operational strategies for tropical forest industries with no reference to the policy formation process. Douglas (1983) stresses that industrial forestry projects in developing countries are unprofitable. The World Bank's 1978 "Forest Sector Policy Paper" also observes the unprofitability of forest industries and recommends a shift away from forest-based industrialization and toward nonindustrial projects such as social forestry and agroforestry. Recently, Vincent and Binkley (1991) review the economic theory relevant to understanding the efficient development of the forest sector, using three tropical countries--Peninsular Malaysia, Ghana, and Chile-- to illustrate their points. They observe that forest-based industrial development in the tropics is largely unsuccessful because of public policy failures. They conclude that for forest industrial projects to still have a role to play in World Bank programs they must be freed from past policy problems including inappropriate macroeconomic and sector-specific policies. They made no mention, however, of the political environment within which forestry policy decisions are taken. More recently, Grut, Gray and Egli (1991) observe that in most African countries forest fees (stumpage rates, area-based fees, export tax rates) are considerably below the value of the standing timber. They propose that forest fees be raised or adjusted using international forest product commodity prices. They fail, however, to examine the political feasibility of such policy recommendations.

All the studies mentioned above underline the poor performance of the forest industries in developing nations, and stress the need for policy reforms. However, such assessments are incomplete since they consider only economic efficiency as evaluation criterion. The political dynamics of policy formulation are ignored. Also needed is an analytical framework where political and economic forces are integrated, where social power structure and objectives of various interest groups in addition to the government's own preferences are reflected. Such a framework exists in the recent literature on agricultural policy analysis.

Agricultural policy analysts has recently come to realize that public decision making must be treated as a bargaining process between governmental policy makers and special interest groups affected by particular decisions (Love et al., 1990). The economic rationale underlying this process is that government policy generates rents through its ability to enforce market regulations (Rausser and Freebairn, 1990). It is assumed that the underlying political process leads all interest groups including the government to adopt some forms of rational behavior in their attempt to appropriate these rents. The final policy choice actually observed is thus the outcome of the underlying bargaining process. The criterion function that summarizes the preference structures of all the interest groups involved in the selection of alternative levels of given policy instruments has been defined as a policy preference function (PPF) (Rausser and Freebairn, 1990). This function is not concerned with individual utilities, as in the utilitarian welfare function, but with measurable quantities. As Rausser and Freebairn put it "PPF exists and manifests itself in observable economic actions. Much like the consumer preference function, it may be revealed by policy actions and hence is 'observable'."

1.5 Organization of the Study

The remainder of this thesis is organized as follows. Chapter 2 reviews (i) the importance of the forest sector of the country under study in relation to economic development, and (ii) the forest sector policies pursued by public policy makers. The review will lead to the identification of the major objectives set by the different economic agents involved in forest sector development. Finally, attributes will be assigned to the objectives identified above. In Chapter 3 the theoretical framework used in this study will be developed. This development will follow three stages. First, a conceptual model integrating political and economic forces in action in the forest sector will be structured. Second, the performance functions of the interest groups will be specified. Third, the estimation procedure of the policy preference function (PPF) will be investigated. Chapter 4 will present and discuss the empirical results of the model. Chapter 5 is concerned with hypotheses testing, model validation, and the use of the model for policy evaluation. Finally, summary and conclusions are drawn in chapter 6.

CHAPTER II

FOREST SECTOR POLICIES IN THE COTE d'IVOIRE

This chapter is developed in five sections. The purpose of section 2.1 is to establish the importance of the forest sector in the economy of the Côte d'Ivoire. This will lead to the review, in section 2.2, of the country's forestry policies. Section 2.3 will identify the major objectives pursued by the different interest groups in the forest sector. Next, in section 2.4, attributes will be assigned to each of the objectives identified in section 2.3. Finally, section 2.5 will summarize the main points of the chapter.

2.1 Importance of the Forestry Sector

Forests are resource that play a multiple role. In their raw state they provide fuel and crude building materials, they are inputs for various wood-processing industries, and they constitute a protective resource. In the latter role, they help to maintain soil quality, stabilize hillsides, modulate climate and seasonal flooding, protecte waterways and marine resources from accelerated siltation, and promote ecological diversity and wildlife conservation. Without minimizing the protective role, this section concentrates on the productive uses of the forests, which in view of the need for economic development, seem the most valued in developing countries.

2.1.1 Forestry in the Economy

Forestry and forest industrial enterprises contribute substantially to the national economy of the Cote d'Ivoire. In the early 1970s the forestry sector represented on average 7% of gross domestic product (GDP), 8% of total wages, 8% of total tax revenue, and about 25% of total exports (Tuinder, 1978). As in most developing countries, the forest land is mostly state-owned. The logging and wood-processing industries, however, are dominated by private enterprises working under a system of concessions granted by government through its empowered agency, the Ministry of Forestry. Because of the capital intensity of logging activities and the link between logging and processing capacity located abroad, the logging industry is mostly foreign-owned.

Wood products export led all other exports from the Cote d'Ivoire in 1969 with an export value of 35,236 million CFA, and today, rank third after cocoa and coffee in earning foreign exchange for the country.

Employment in the forest sector represents about 9% of the total industrial work force in the Côte d'Ivoire. Wood-processing activities have been the most employment generating sub-sector, accounting for 93% of the total forest-based employment volume. The distribution of the labor force in the forest industrial sector by nationality is: 55% Ivorians (nationals of the Côte d'Ivoire); 40% Africans, non-Ivorians; 5% non-Africans. Although non-African workers represent only a tiny proportion of the forestry labor force, they receive over 1/3 of the total rent payment to labor (Pretzsch, 1990).

2.2 Forest Sector Policies

Côte d'Ivoire's forestry policies have been quite stable through time. The fundamental policy is to combine foreign capital (which is lacking in the country) with local labor and forest resources (which abound locally). So, forestry, which is a highly capital-intensive operation, has depended largely upon private foreign investments. The highly mechanized timber industry, almost wholly in European hands, has been (and is still to a large degree) financed privately from abroad or out of retained earnings (Stryker, 1974). Table 1 below shows the structure for accumulated forestry investments in nine African countries as of 1981. Except for Ghana, all the countries selected indicate a clear dependance on foreign investments for the industrial development of their forest sectors. For example, as of 1981, in the Côte d'Ivoire, foreign investment in the forest sector represented 79% of total accumulated forest sector investment. The percentages were even higher in Liberia and Congo (85%), and in the Central African Republic (92%).

In the Côte d'Ivoire, as in most developing countries, the highly mechanized and privately owned timber industry is heavily dependent, however, on public investments in infrastructure, which determine the areas in which companies can profitably operate. The major means of attracting foreign capital was the formulation of a rather liberal investment incentive scheme as well as an absence of restrictions on repatriation of profits.

Table 1. Accumulated Forest Sector Investment in Selected African Countries, 1981 (in million U.S. Dollar)

Selected African Countries	Total	Foreign	Domestic
Liberia	146.90	124.87	22.03
Côte d'Ivoire	703.80	558.80	145.00
Ghana	382.60	175.45	207.15
Cameroon	701.12	365.41	335.71
Congo	185.80	157.20	28.60
Central African Republic	105.00	92.21	12.79
Zaïre	149.47	95.03	54.44
Nigeria	1,553.60	932.16	621.44
Total	4,462.82	2,888.38	1,574.44

Source: Gillis, 1988

In order to encourage the timber companies to expand production in the postwar period the colonial government reduced export taxes, lowered import tariffs on equipment, granted subsidies for the use of the railroad, guaranteed loans from commercial banks, and engaged in various other supporting policies including the provision of an improved transportation infrastructure. As in most tropical developing countries, there was the hope in the Côte d'Ivoire that the forward and backward linkages of forest product industries could provide real opportunities for industrial development. Log processing prior to export was particularly viewed as a major avenue that could greatly add value to timber resources. So, on December 20, 1965, the Government of the Côte d'Ivoire published a forestry code that called for the development of a viable forestry industry on a sustaining basis (Tuinder, 1978; Marches Tropicaux, 1971). Subsequently, local processing, which had oscillated around 25 percent of total production since 1960, was targeted to increase to 37 percent in 1975 and 42.5 percent in 1980. The actual levels of domestic processing in 1975 and 1980 represented respectively, 39% and 38% of total raw log output. To stimulate domestic processing, export of unprocessed wood products was discouraged by a tax penalty: the average total tax on exported logs being about CFAF2,500-5,000 per cubic meter; for processed wood in roundwood equivalent it is about CFAF750-1,500 per cubic meter. This tax penalty, however, did not affect raw log export significantly. So, as a further incentive, the government forest service established quotas for logs to be supplied by logging firms to local processing plants. Logging firms have to deliver two units to local processing plants for every three units exported. For the logging companies with large concessions, local deliveries must equal exports (Tuinder, 1978). Still because of the higher returns and the more attractive cash flow associated with log export market, logging companies were reluctant to process logs voluntarily. To satisfy government quota requirements, logging firms sorted their productions by quality, supplied the less known species to local processing plants, and exported the more commercially valuable species. By 1967 the tax laws were changed so as to provide further incentive for domestic processing. Wood processing was made a "priority industry" meaning that timber companies, which invested considerably in processing capacities, benefited from governmental measures exonerating them from taxes for a specified period of time up to 25 years. The purpose of this long term fiscal agreement is to promote a profitable domestic wood-processing subindustry. A study of the Côte d'Ivoire's timber industry conducted in the mid-1960s revealed, however, that exporting unprocessed logs was considerably more profitable and contributed more government revenue and foreign exchange per unit of capital investment than did exporting processed wood products. Although the new tax legislation of 1967 decreased the relative private profitability of exporting raw logs, it is unclear whether this did anything to increase the social profitability of exporting processed timber products. Nevertheless, as Stryker (1974) pointed out, there may be a social gain from processing associated with backward and forward linkages of forest industries quite apart from fiscal linkages. Backward and forward linkages relate to increased capacity utilization or new investments in other sectors as a result of timber processing activities. Backward linkages, generated by the demand for intermediate inputs of goods and services in the process of timber industrial activities, have been found by Stryker to be weak in the Côte d'Ivoire. Forward linkages, on the other hand, are much more important as sales of timber to local sawmills and other processing activities accounted for 42 percent of total log production (Stryker, 1974). Fiscal linkages are in the Côte d'Ivoire the most important effects of the expansion of the timber industry as timber taxes have contributed in an important way to government revenues. A recent study established that of all West African countries, Côte d'Ivoire has been able to command by far the highest export taxes on logs (World Bank, 1990).

2.3 Major Forestry Development Objectives

An objective generally indicates the direction in which one is striving. The forestry policies reviewed above reveal that the most fundamental objective pursued by the forestry authorities in the Côte d'Ivoire is the development of a viable forestry sector that could contribute to overall socio- economic development. To be useful for an empirical analysis, however, the meaning of this overall objective is defined in more detail through the following sub-objectives:

1. Expand foreign exchange earnings and savings from forest products trade.
2. Increase employment in the forest sector.
3. Expand government forest revenues.
4. Increase the rate of reforestation.

The objective "Expand foreign exchange earnings and savings" is to be differentiated from the objective "Expand government revenue". The former objective involves international transactions such as import and export, but the later is entirely locally generated.

Also important is the set of objectives of the private firms operating in the forestry sector. The behavior of these private firms indicate that they are mostly interested in maximizing the return on their capital investments. Thus forestry policy makers in developing countries must also keep in mind the following private sector objective:

5. Maximize profits.

In the Côte d'Ivoire the private firms operating in the forest sector are mostly foreign-owned, although a number of local entrepreneurs also exist. Thus, in order to accommodate the conflicting interests in the forestry sector, the Cote d'Ivoire has to deal primarily with foreign companies. This situation contrasts with the situation in other tropical countries such as Ghana where a great number of marginally profitable local firms coexist with a few large, more efficient foreign companies (see Table I above). This study will make the simplifying assumption that the private sector is homogenous, meaning that ownership does not change the economic behavior of the firms. In other words, private foreign and domestic firms have the same objective and behave the same way so as to maximize profits.

2.4 Assigning Attributes to Objectives

The next task is to identify for each of the objectives attributes that clearly indicate the degree to which the associated objective is achieved. To be useful in an empirical analysis, an attribute must be both comprehensive and measurable. An attribute is comprehensive if, by knowing its level in a particular situation, one has a clear understanding of the extent that the associated objective is achieved. An attribute is measurable if it is reasonable both (a) to quantify it, and (b) to assess the decision maker's preferences for different possible levels of the attribute, for example, in terms of monetary value (Keeney and Raiffa, 1976).

2.4.1 Foreign Exchange Earnings and Savings.

The earnings and savings of foreign exchange in the forestry sector can be accomplished through a variety of actions such as reducing outflows of capital and profits, limiting use of imported inputs, and expansion of local production through increasing export earnings, substituting local production for imports, and increasing productive efficiency (which could lower domestic prices and result in expanded consumption). However, the reductions of outflows of capital and profits, and the limitation of use of foreign inputs are not feasible in developing countries where capital and other productive factors (machinery and technology) are scarce, and where profits remission must be guaranteed to attract and maintain foreign capital. In Cote d'Ivoire, as in most developing countries, "export expansion" and "import substitution" are the most likely attributes for the objective "expand foreign exchange earnings and savings." Gross export earnings and the value of imports substituted are important elements in determining total foreign exchange availability; however, their consideration in isolation can lead to a very exaggerated picture of foreign exchange benefits. Net benefits or "retained value" (i.e., what is left after transfer of profits abroad) is what counts. "Net export earnings" and "value of import substituted" are measurable and comprehensive enough to constitute suitable attributes for the foreign exchange objective.

2.4.2 Employment

The employment objective can be measured by the number of people employed in the forest sector of a country, foreign nationals excluded. This attribute is adequate because it is comprehensive and measurable.

2.4.3 Government revenue

An attribute for the "government revenue" objective is "payments to government" out of the total economic rent generated from tropical timber exploitation. These payments include concession fees, export taxes, royalties, and corporate income taxes (Binkley and Vincent, 1991; Page et al., 1976). This attribute is comprehensive and measurable, therefore, it is suitable.

2.4.4 Reforestation

A reasonable attribute for this environmental objective could be total expenditure devoted annually to the artificial regeneration of the forest resource, or the total area of land reforested each year. The total area reforested yearly is used in this study because it is available and does not involve monetary adjustment.

2.4.5 Profit maximization

Private firms operating in the forestry sectors of developing countries (and developed economies for that matter) are assumed in this study to be profit maximizers. Therefore, profits measured in monetary unit is a logical attribute for the objective "maximize profits". Knowing the profits for logging and wood-processing operations in a country would indicate how much the objective of the private firms in the sector is achieved. A number can be assigned to profits. Thus, "profits" is a comprehensive and measurable attribute for the objective "maximize profits".

2.5 Summary

This chapter has summarized the forestry policies, and objectives of the interest groups concerned with the policy implementation process in the forest sector of the Côte d'Ivoire. It was pointed out that, in this country, as in most developing tropical countries, forest lands are controlled by the state while capital and technology are privately owned. It was also pointed out that the state and the private sector have different and conflicting objectives that need to be reconciled through bargaining (albeit implicit) if any joint venture combining their different endowments is to take place in the forest sector.

The Côte d'Ivoire adopted policies that were relatively liberal and internationally oriented. Logging and wood-processing firms were mostly foreign-owned. Long term agreements were made between the government and companies with a considerable amount of capital invested in the domestic processing industry. Logging output was to supply both domestic and international markets. Profit remission and fiscal incentives were used to attract and maintain private direct investments in the domestic wood-processing sub-industry.

Government objectives are identified as: expansion of foreign exchange earnings and saving, increased employment, expansion of government revenues, and reforestation. Private firms operating in the forest sector are assumed to be motivated by profit maximization. Each of these objectives was assigned an attribute which is a performance measure indicating the extent to which the objective is achieved. The suitability of the attribute was based on two properties. Comprehensiveness, refers to the appropriateness of the attribute on theoretical grounds (i.e., does it convey the needed information, regardless of whether it can be obtained?) Measurability, refers to practical consideration (i.e., can the necessary information be assessed?)

CHAPTER III

THE THEORETICAL FRAMEWORK

The previous two chapters argued that fruitful analyses of the behavior of forestry policy makers in developing countries must be formulated in terms of a bargaining framework that formalizes trade-offs between conflicting objectives, so that the observed forestry policy measures can be viewed as resulting from an (implicit) optimization process. In this chapter, the bargaining process will be made more explicit in mathematical terms; and assuming that a structure exists for the preferences of the different interest groups in the forestry sector, a policy preference function will be elaborated to make explicit the preference structure.

3.1 Conceptualizing the Bargaining Process[3]

To motivate the implicit bargaining process that produces the concession fees and royalty levels observed in developing countries' forestry sector, let us consider the following model.

[3]This section follows closely the model by Sutinen. However, while Sutinen's modeling objective was to characterize optimal path of exhaustible natural resources, this study adapts the model to a welfare type of analysis.

3.1.1 Assumptions

(1) two sets of agents exist in the forest sector: the government which owns the forest resource, and the private firms which own the capital and technology necessary for forestry operation. All firms are assumed to have identical preferences.

(2) government has a utility function $U(R_t)$, where U'>0, $U''<0$, and R_t represents government revenue collected from the firm's operations. The representative firm has a utility function $V(\Pi_t)$, with V'>0, $V''<0$. The firm's income (profits) in period t is given by $\Pi_t = p_t y_t - w_t y_t - r_t y_t$, where y_t is the total timber harvested in period t by the firm, p_t is the market price of timber in period t, w_t is per unit cost of harvest, and r_t is price of the right to harvest one unit of timber resource (payment to the state per unit of the resource harvested).

(3) The demand for timber is assumed given by $p_t = d_t(q_t)\mu_t$, where q_t is the quantity of timber demanded in t, with $d'<0$, and μ_t is an error term identically and independently distributed, with mean value $\overline{\mu_t} = 1$, so that expected value of p_t, noted $E(p_t)$, is given by $E(p_t) = \overline{p_t} = d(q_t)E(\mu_t) = d(q_t)$.

(4) No inventory is held. Thus, total harvest is equal to total demand at each time period. That is $y_t = q_t$

3.1.2 The Negotiation Model.

Let the per-unit payment to the state be structured as follows:

$$r_t = \alpha_t p_t + \beta_t$$

where $0 \leq \alpha_t \leq 1,\ \beta_t \geq 0$. When $\alpha_t = 0$, then $r_t = \beta_t$, the deterministic resource rental price (average concession fee set independently of the stumpage value of timber removed).

The bargaining is over the level of α_t and β_t. This bargaining is pursued to the point at which neither party can be made better off without the other being made worse off. The negotiated levels α_t^* and β_t^*, therefore, result from the following maximization problem:

Maximize $\quad \int_0^T E[U(R_t)]\, e^{-\delta t} dt$

Subject to $\quad \int_0^T E[V(\pi_t)]\, e^{-\delta t} dt = \int_0^T e^{-\delta t} \bar{V}(t)\, dt,$

where $\bar{V}(t)$ is some level of utility at least as great as the minimal level necessary to keep the firm in the forest industry, and R_t and π_t now are defined respectively as $R_t = (\alpha_t p_t + \beta_t) q_t$, and $\pi_t = p_t q_t - w_t q_t - (\alpha_t p_t + \beta_t) q_t$.

The Hamiltonian for this problem is

$$H = e^{-\delta t} E[U(R_t)] + \mu e^{-\delta t} \{E[V(\pi_t)] - \bar{V}(t)\}$$

The first order conditions that determine α_t^* and β_t^* are

$$\frac{\partial H}{\partial \alpha_t} = e^{-\delta t}[E(U'p_t)q_t - \mu E(V'p_t)q_t] = 0,$$

$$\frac{\partial H}{\partial \alpha_t} = e^{-\delta t}[E(U')q_t - \mu E(V')q_t] = 0$$

3.1.3 Firm's demand for concessions

Given the negotiated arrangements α_t^* and β_t^*, the firm's demand for concessions (exploitation rights) is obtained by maximizing the firm's expected present value of profits:

$$\int_0^T e^{-\delta t}E[V(\pi_t)\,dt$$

This yields the following first order condition

$$e^{-\delta t}E[V'.(p_t - w_t - \alpha_t p_t - \beta_t)] = 0 \quad ,$$

which, rearranged, gives the following concession demand function

$$(1) \qquad \alpha_t^* \overline{p_t} = \overline{p_t} - \frac{(w_t + \beta_t^*)E[V']}{E[V'\mu_t]}$$

Totally differentiating equation (1), and assuming a constant level of expected utility, yields the following marginal rate of substitution between α_t and β_t for the firm:

$$(2) \qquad \frac{d\beta_t}{d\alpha_t}\Big|_{\bar{V}} = -\frac{E[V'p_t]}{E[V']} < 0$$

from which the following second order condition is derived.

$$(3) \qquad \frac{d^2\beta_t}{d\alpha_t^2}\Big|_{\bar{V}} = \frac{E[V''.\,(p_t + \frac{d\beta_t}{d\alpha_t})^2 q_t]}{E[V']} < 0$$

Equations (2) and (3) imply a concave indifference curve illustrated in Fig.3.1 below, where the arrow indicates direction of higher expected utility.

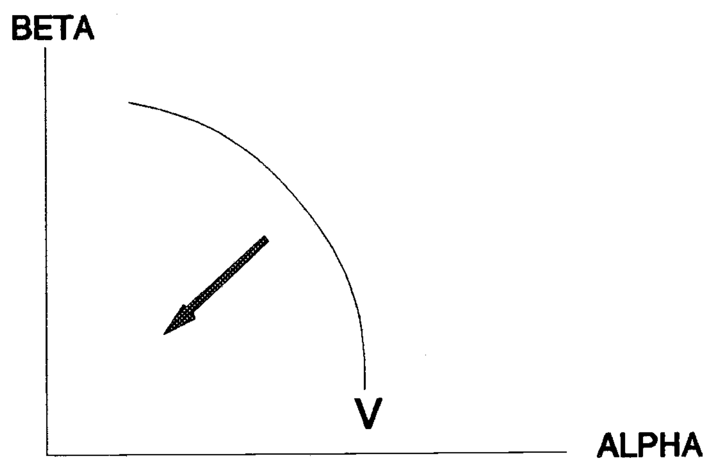

FIG.3.1 FIRM'S INDIFFERENCE CURVE

3.1.4 Government's supply of concessions

The concession rights supply function is obtained by solving the following problem:

Maximize $$\int_0^T e^{-\delta t} E\{U[(\alpha_t p_t+\beta_t)\, q_t]\}dt$$

Subject to $$\int_0^T q_t dt \le \overline{Q}$$

where $\overline{Q_t}$ is the total timber harvested in period t.

The Hamiltonian for this problem is

$$H=e^{-\delta t}E[\,U((\alpha_t p_t+\beta_t)\,q_t)\,]+\lambda(\bar{Q}-q_t)$$

and
$$\frac{\partial H}{\partial q_t}=e^{-\delta t}E[\,U'.\,(\alpha_t p_t+\beta_t)\,]-\lambda=0$$

This first order condition implies that

$$E[U'.\,(\alpha_t p_t+\beta_t)\,]=\lambda e^{\delta t}$$

or
$$\alpha_t\overline{p_t}E[U'\mu_t]=\lambda e^{\delta t}-\beta_t E[U']$$

which finally gives the following concession supply function:

(4)
$$\alpha_t\overline{p_t}=\frac{\lambda e^{\delta t}-\beta_t E[U']}{E[U'\mu_t]}$$

Again at constant level of expected utility the trade-off between α_t and β_t gives the following marginal rate of substitution

(5)
$$\frac{d\beta_t}{d\alpha_t}\Big|_{\bar{U}}=-\frac{E[U'p_t]}{E[U']}<0$$

which yields the following second derivative

(6) $$\frac{d^2\beta_t}{d\alpha_t^2}\Big|_{\bar{U}} = -\frac{E[U''.(p_t+\frac{d\beta_t}{d\alpha_t})^2 q_t]}{E[U']} > 0$$

Equations (5) and (6) define a convex indifference curve illustrated in Fig.3.2 below, where the arrow indicates direction of increasing expected utility.

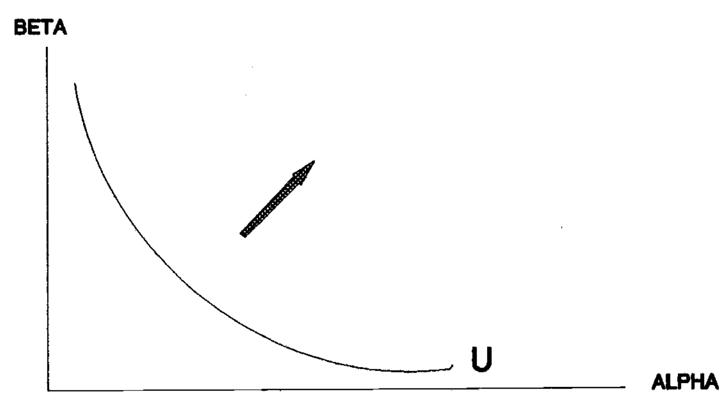

FIG.3.2 GOVERNMENT 'S INDIFFERENCE CURVE

Now for the private firm and the government to work together in developing the forest sector, it is necessary that a common ground acceptable to both parties be found. This is the equilibrium point where the firm's marginal rate of substitution between α_t and β_t is equal to that of the government. Symbolically, this means that

$$\frac{d\beta_t}{d\alpha_t}\Big|_V = \frac{d\beta_t}{d\alpha_t}\Big|_U$$

This equilibrium condition describes a contract curve illustrated in fig.3.3 below.

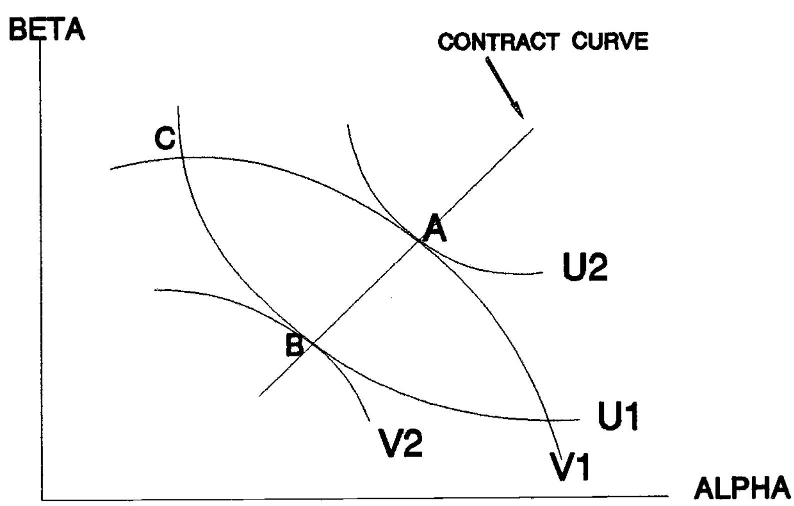

FIG.3.3 CONTRACT CURVE AND EQUILIBRIUM

The argument that forest industries in Third World countries do not add to national welfare is illustrated in figure 3. Let $V1$ and $U1$ be, respectively, the firm's and the government's utility levels before forest exploitation. Suppose now that the (implicit) bargaining between these two interest groups starts at point C where the two initial utility levels cross. If point A is the outcome of the bargaining process, then the state (public sector) captures the total benefits (economic rents) of the forestry project. A foreign logging firm may be willing to stay at A if, for example, this allows the firm to maintain the supply of quality logs to parent companies or business partners abroad. Point B in contrast would be where the private sector captures totally the economic rents. Note however that the situation is still pareto optimal, and a government may be willing to be at point B as long as the forest operation generates other indirect benefits in the economy as a whole (e.g., forward and backward linkages). The argument that forest-based industrial projects in developing countries perform poorly, therefore, corresponds to point B.

Analysts argue that for forest industrialization to add to economic development, governments in developing countries must re-adjust their forest pricing and concession policies so as to capture higher economic rent (Page et al. 1976; Grut et al., 1991). In terms of the above conceptual bargaining model, the analysts' argument means that the levels of α_t and β_t must be raised so that equilibrium occurs at a point close to A. This runs counter to what economic theory would lead one to believe based on the existing structure of forest industries in developing countries. Basic economic theory tells us that the presence of economic rent within an industry for an extended period of time indicates that the industry is non-competitive, meaning among other things that forces on the supply and demand sides are not in balance. The demand for tropical forest concessions was until recently concentrated in the hands of a few large foreign companies that have the capital, technology and manpower necessary for forest exploitation. These multinational corporations have also adequate information about the supply side of the market. For example, they know (1) that tropical forests can be rented either from South America, South East Asia, or Africa; (2) that in most of these regions capital and technology (which are important factors in forest development) are lacking; and (3) that governments in these countries are desperately seeking these missing elements to promote industrialization. The supply side of the market for forest concessions, on the other hand, is characterized by a large number of developing countries working independently to develop their forest sectors. They have only scant information about the extent of the demand for concessions. As a result, in most tropical countries, government pricing and concession policies seem to be designed to respond to and accommodate the demand for concessions (Grut et al., 1991). Granting concessions becomes for these countries a way to bring industry and development to remote and underdeveloped regions. Therefore, to argue that concession fees and royalty levels can be raised significantly above their current levels, one must hold that the government has a stronger bargaining position than the firms. This appears unrealistic.

Another interesting question is the following: why do governments in developing countries continue to accept a deal that does not benefit them in terms of economic rents? The answer to this question is empirical, and could be assessed within the policy preference function framework, by estimating the weights (or importance) that government policy makers in developing countries attach to the objectives of the interest groups in the forest sector.

3.2 The Conceptual Policy Preference Function Model

The discussion in the last chapter (1) defined the government and the private companies as the two interest groups in the forest sector of developing countries; (2) identified the expansion of foreign exchange, employment, government revenue, reforestation, and the maximization of profits as the major objectives guiding forestry development; and (3) assigned attributes or performance measures to each of these objectives. This section develops a conceptual policy preference function model to enforce systematic thinking about which objectives are valued and how these objectives tradeoff against each other. Three steps will be followed in the specification of the model:

(1) Specification of the general structure of the model

(2) The mathematical formulation of the PPF

(3) Specification of the equations describing the forestry economic environment.

3.2.1 General Structure of the PPF Model[4]

Let $S_{it}(x_t, z_t; g_t)$ represents the performance measure of the i^{th} interest group (i=1,2) at time t, where x_t represents a vector of policy variables; z_t represents other endogenous variables; and g_t represents exogenous variables. The well-being of an interest group, therefore, is influenced, among other things, by the levels of policy instruments selected by the government policy makers. Policy instruments most commonly used in developing countries include quota on log exports, royalty rates, logging output control, and export taxes on log and processed products. The use of these policy instruments, however, differs from one country to another. For example, in Ghana, royalty rates are set so as to allow less efficient local firms to stay in operation.[5] The Côte d'Ivoire does not have such a political obligation to local firms, however, it does apply partial restriction on raw log exports.

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[4] This section follows closely the work by Love et al., 1990.

[5] In the post-independence period successive governments have emphasized Ghanaianization of the timber industry. Concessions policies and subsidy measures were used to increase Ghanaian ownership of timber firms (Page, 1974). Medium-term credit and loans of capital equipment were provided to Ghanaian firms at below commercial rates. This resulted in a proliferation of small forest firms which could not efficiently operate without continuous public assistance.

Governments in developing countries are assumed to select levels of x_t so as to maximize a policy preference function whose arguments are the weighted performance measures of the interest groups in the forestry sector. Letting k_i represents the weight that policy makers attach to the performance measure of the i^{th} interest group, the PPF can be generally specified as follows:

(7) $$W_t = W_t[k_{it} * S_{it}(x_t, z_t; g_t)], \quad i=1,2$$

where the subscript t indicates that the function may change over time. Since a resource industry is being considered, the model has to be dynamic in order to capture the intertemporal nature of the resource problem (Hotelling, 1931; Fisher, 1981).

In making decisions as to the level of raw logs to produce, royalty rates to set, domestic processing to undertake, and export taxes on log and processed products, government policy makers face linear constraints in production, processed timber marketing, employment generated, and environmental considerations. Since these activities involve a great deal of uncertainty, the problem facing public policy makers has to be formulated in terms of expected discounted welfare maximization, subject to a set of constraint equations describing the stochastic economic environment, i.e.,

(8) $$Max._{x_t} \quad W = E\{ \sum_{t=1}^{\infty} \lambda^t \, W_t[k_{it}*S_{it}(x_t, z_t; g_t)]\}$$

(9) Subject to $Z_t = F(x_t, z_t; g_t) + v_t$

where E is the expected value operator conditional on information at time t=1, and λ is the social discount rate of time preference. F(.) represents the forest economy at time t and has a structure that incorporates the policy variables (Love et al., 1990). The uncertainty in the constraints (equation 9) is specified as an additive error term v_t independently and identically distributed. As Love et al. point out there are two potential sources of uncertainty in the policy preference function framework: one source comes directly from the random nature of the political optimization process. This is the uncertainty in predicting the effects of policy instrument variations on the performance measures. The other source results from using the constraints to transform policy instruments and economic variables into performance measures. These two sources of uncertainty are assumed independent. Consequently, errors emanating from the stochastic specification of the constraint equations are independent of errors coming from the political process.

The performance measures S_{it}, $(i=1,2)$ can be specified further by letting S_{1t} measure the private sector performance, and S_{2t} represent the public sector performance measures. Then, from the discussion in Chapter two, the following correspondence can be established:

$S_{1t} = \pi_t =$ profit realized by private firms from forest activities. $S_{2t} = (GR_t, L_t, FE_t, R_t)$, where GR_t is government revenues collected from private firms' forest operations; L_t represents the employment level generated; FE_t stands for foreign exchange earnings and savings resulting from forest industrial development; and R_t represents the reforestation objective. S_{2t}, thus, is a four-dimensional vector attribute, so that the policy preference function (7) can be written as a five-dimensional welfare function:

(10) $$W_t = W_t(\pi_t, FE_t, GR_t, L_t, R_t)$$

where the weights have been omitted temporarily.

The policy preference function (equation (10)) is assumed to satisfy the following mathematical conditions:

(11a) $$\frac{\partial W_t}{\partial \pi_t} > 0, \quad \frac{\partial^2 W_t}{\partial \pi_t^2} < 0$$

(11b) $$\frac{\partial W_t}{\partial GR_t} > 0, \quad \frac{\partial^2 W_t}{\partial GR_t^2} < 0$$

(11c) $$\frac{\partial W_t}{\partial L_t} > 0, \quad \frac{\partial^2 W_t}{\partial L_t^2} < 0$$

(11d) $$\frac{\partial W_t}{\partial FE_t} > 0, \quad \frac{\partial^2 W_t}{\partial FE_t^2} < 0$$

(11e) $$\frac{\partial W_t}{\partial R_t} > 0, \quad \frac{\partial^2 W_t}{\partial R_t^2} < 0$$

Conditions (11a through 11e) above imply that the preference function is assumed concave (i.e., increasing in its arguments but at a decreasing rate.)

3.2.2 Mathematical Form of the PPF

Nobody knows the exact functional form of the preference function. For the empirical analysis to proceed, however, it is necessary to specify an appropriate functional form for the function. In this study a quadratic utility function is postulated for convenience under the simplifying assumptions that (1) the marginal utility of one argument variable is independent of the level of others, and (2) it is tolerable to regard government forestry policy decisions as separable from other government concerns. In other words, the performance measures are assumed utility independent and separable but time additive. Under these conditions, the following quadratic form is specified for the policy preference function:

$$\begin{aligned} W_t = {} & E[\textstyle\sum_{t=1}^{\infty} \lambda^t (k_1 \pi_t + k_2 FE_t + k_3 GR_t + k_4 L_t + k_5 R_t + k_6 \pi_t^2 \\ & + k_7 FE_t^2 + k_8 GR_t^2 + k_9 L_t^2 + k_{10} R_t^2 + k_{11} \pi_t FE_t + k_{12} \pi_t GR_t \\ & + k_{13} \pi_t L_t + k_{14} GR_t FE_t + k_{15} GR_t L_t + k_{16} GR_t R_t)] \end{aligned} \tag{12}$$

3.2.3 Empirical Specification of the Constraints

The policy preference function specified above as equation (12) is to be maximized by the public policy makers subject to a set of constraints representing the forest economy. In the previous section, a theoretical representation of the constraints was given as equation (9) reproduced here as equation (9')

$$Z_t = F(x_t, z_t; g_t) + v_t \tag{9'}$$

This section attempts to provide an empirical specification of the constraint structure describing the forest sector. As mentioned above, in making decisions as to the levels to set for the control variables, policy makers in developing countries face constraints in government revenue collection, employment generation, prices they receive for raw logs and processed timber products exported, and reforestation efforts.

3.2.3.1 Government revenue constraint equation

One of the factors measuring the performance of the public policy makers is the total amount of revenues collected from private firms operating in the forest sector. These revenues are fiscal in nature and depend on the levels of forest fees, and taxes on logs and timber products.

In Côte d'Ivoire, for example, forest fees paid by concessionaires are of two types: (1) area tax, and (2) logging tax. The area tax is a tax on concession area, and is paid yearly on the total concession area held by concessionaires. The rate has been fixed at 10 CFA F/ha/year (Grut, Gray, and Egli, 1991). Logging tax, on the other hand is calculated on the volume of wood that has been felled and marketed, based on the declarations of loggers. The tax varies according to species and it is paid by (1) the forwarding agent for export logs, and (2) the user (mill) for logs that are processed in the Country. As an incentive for domestic processing of timber, the logging tax on export logs is higher than the tax on logs locally processed. Unlike raw log tax where the calculation is based on the declaration of the loggers, tax on processed products are calculated at the port, on the volume of processed products actually delivered. The following equation is postulated to define the government revenues constraint:

$$(13) \qquad GR_t = \varrho H_t + T^e_{1t} q^e_{1t} + \tau^d_{1t} q^d_{1t} + T^e_{2t} q^e_{2t}$$

where, ϱ is area tax rate; H_t is the total area of forest under concession at time t; q^e_{1t} is the quantity of log exported at time t; q^d_{1t} is the quantity of logs domestically processed at time t; q^e_{2t} is the quantity of processed products exported at time t; and τ^d_{1t} is the tax rate on logs sent to local mills for processing; while T^e_{1t}, T^e_{2t} are respectively the tax rates on raw log and processed products exports.

3.2.3.2 Employment Constraint Equation

Another factor measuring the performance of the policy makers in developing countries is the extent of employment directly generated as a result of forestry development. Logging, domestic processing of timber, and reforestation are all directly employment-generating activities. Employment can also be generated indirectly in other sectors of the national economy as a result of forestry operations. However, because of the difficulty in isolating these indirect effects of forestry development, this study concentrates only on the employment directly generated. Assuming that employment generation is linearly related to (1) the total output of logging operations, (2) the capacity of wood-processing plants (measured in terms of the quantity of raw logs processed yearly), and (3) reforestation expenditures, the following employment equation is postulated:

$$(14) \qquad L_t = \alpha_0 + \alpha_1 q_t + \alpha_2 q_{1t}^d + \alpha_3 R_t + \varepsilon_{1t}$$

where, L_t is the volume of employment (measured in number of workers) at time t; q_t is total quantity of raw logs produced at time t; q_{1t}^d is the quantity of raw logs allocated to domestic processing plants at time t; R_t is a measure of reforestation activities; ε_{1t} is a random error term identically and independently distributed. α_i $(i=0,1,2,3)$ are parameters to be estimated. The expectation is that $\alpha_1, \alpha_2, \alpha_3$ will be positive, meaning that increased logging, processing, and reforestation activities generate more employment.

3.2.3.3 Reforestation Constraint Equation

Tropical forest depletion has become increasingly a worldwide concern, especially in industrialized nations where the effects of deforestation are being studied more intensively, and where most of the financing capital for forest development in the tropics originate. Policy makers in developing countries can no longer exclude the issue from their development concerns. Reforestation efforts, which are currently at their minimum in most developing nations, are expected to increase in importance in the years ahead. Thus, the following reforestation equation is included in the constraint set facing forestry policy makers:

$$(15) \qquad R_t = \beta_0 + \beta_1 R_{t-1} + \beta_2 q_t + \beta_3 \mathbf{T}_{1t} + \varepsilon_{2t}$$

where current reforestation effort (R_t) is linearly related to past reforestation effort (R_{t-1}), logging activities (q_t), and government forest revenues, particularly the portion that comes from log export tax $(\mathbf{T}_{1t})$. ε_{2t} is a random error term assumed independently and identically distributed. β_0, β_1, β_2, β_3 are parameters to be estimated. It is expected that (1) the larger the volume of timber harvested, the larger the reforestation effort $(i.e., \beta_2 > 0)$; (2) the greater the government forest revenues, the greater the reforestation effort $(i.e., \beta_3 > 0)$; and (3) the government will increase this year's reforestation efforts if last year's efforts were inadequate; and will reduce current reforestation expenditures if last year's expenditures were excessive. However, given the high rate of forest lands conversion into agricultural activities, and the intensive logging so typical to the Côte d'Ivoire, it is also possible that the level of reforestation efforts will never be excessive. In that case, reforestation this year could be positively related to past reforestation efforts. Thus, β_1 could be positive or negative.

3.2.3.4 Price Expectations Constraint Equations

In making decisions as to the proportion of raw logs to export out of total production, policy makers must form expectations about the export prices of raw logs and processed products. Given the uncertainty and difficulties of finding outlets abroad for domestically processed timber products, price expectations are crucial constraints in forestry decision-making. However, because of the high cost of the type of information needed for rational expectations formation, and because of the inherent lack of capital for research in developing countries, export price expectations are formulated on the basis of whatever information past prices reveal at the time expectations are formed.

(16a) $$P_{1t}^{e} = \gamma_0 + \gamma_1 P_{1t-1}^{e} + \gamma_2 P_{1t-2}^{e} + \varepsilon_{3t}$$

(16b) $$P_{2t}^{e} = \mu_0 + \mu_1 P_{2t-1}^{e} + \mu_2 P_{2t-2}^{e} + \varepsilon_{4t}$$

where, P_{1t}^{e}, P_{1t-1}^{e}, P_{1t-2}^{e}, are current and lagged export prices of raw logs; and

P_{2t}^{e}, P_{2t-1}^{e}, P_{2t-2}^{e} are current and lagged export prices of processed wood products. γ_i, μ_i, $(i=0,1,2)$ are parameters to be estimated. ε_{3t}, ε_{4t} are random error terms distributed identically and independently with zero means and constant variances.

3.2.3.5 Profit Constraint Equation

Profits realized by private firms operating in the forest sector constitute another constraint policy makers in developing countries have to account for in their forestry development decisions. Since these profits are essential not only to attract and maintain private (foreign) companies in the sector, but also to guarantee revenues for the public treasury, policy makers have set levels of policy variables so as to assure profitability. Profits are defined as follows:

$$(17) \quad \pi_t = (P_{1t}^{e}-T_{1t}^{e})\, q_{1t}^{e} + P_{1t}^{d} q_{1t}^{d} + (P_{2t}^{e}-T_{2t}^{e})\, q_{2t}^{e} + P_{2t}^{d} q_{2t}^{d} - m_1 q_t - m_2 (q_{2t}^{e}+q_{2t}^{d})$$

where, π_t is the total profit at time t; p_{1t}^{e} and q_{1t}^{e} are respectively log export price and quantity at time t; T_{1t}^{e} is log export tax at time t; P_{1t}^{d} and q_{2t}^{d} are respectively the price and the quantity of raw logs allocated to local processing plants at time t; p_{2t}^{e} and q_{2t}^{e} are respectively sawnwood export price and export quantity at each time period; while T_{2t}^{e} is sawnwood export tax at time t; P_{2t}^{d} and q_{2t}^{d} represent respectively the price and the quantity of sawnwood on the local market at time t; m_1 is the unit cost of raw log production; q_t is the total quantity of logging output at time t; m_2 is the unit cost of wood-processing operation; $(q_{2t}^{e}+q_{2t}^{d})$ is the total output of processed products sold abroad and on the local market at time t.

3.2.3.6 Foreign Exchange Earnings/Savings Constraint

Forest-based industrial activities have significant impacts on the foreign exchange position of developing countries. Foreign exchange earnings and savings depend essentially on (1) earnings from exports of raw logs and processed products, (2) savings from import substitutions, and (3) losses from outflows of capital and profits resulting from imports and payments abroad. These earnings, savings and losses can be approximated by the sum of net export earnings (i.e., gross export earnings minus transfers abroad) and the value of import substitution (measured as a fraction of total transactions in processed products within the domestic market).

$$(18) \qquad FE_t = \theta_1 (P_{1t}^{e}q_{1t}^{e} + P_{2t}^{e}q_{2t}^{e}) + \theta_2 (P_{2t}^{d}q_{2t}^{d})$$

where, θ_1 is the fraction of gross export earnings retained as net export earnings; θ_2

is the proportion of total local transactions representing import substitutions; $(P_{1t}^{e}q_{1t}^{e} + P_{2t}^{e}q_{2t}^{e})$ is gross export earnings; $(P_{2t}^{d}.q_{2t}^{d})$ is total sales of processed products on the local market.

Evidence reported in the literature indicates that, in most developing countries, (1) net export earnings are probably as low as 25% of gross export earnings, while the rest is dissipated in payments abroad (Page, 1976; Pretzsch, 1990); and (2) a large proportion of the processed products (sawnwood in this study) sold on the local market accounts for import substitutions (Contreras-Hermosilla and Gregersen, 1991). Again another assumption will be made here concerning the import substitution portion of local transactions on processed wood products. A level of 80% seems to be consistent with evidence in the literature.

Two other equations [denoted Eqs.(7),(8) below] were added to the number of constraint equations. This adds more structure to the model (making it just identified) and helps the estimation process (see next chapter on model estimation). Their addition, therefore, is more of an econometrics convenience than a theoretical requirement.

The complete structure of the basic model describing the policy problem facing public policy makers in forest-rich developing countries can be represented below as an optimization problem, whereby the expected value of a linear-quadratic PPF is maximized subject to a set of stochastic economic constraint equations.

$$(3\text{-}1) \qquad Max. \quad W_t = E[\Sigma_{t=1}^{\infty} \lambda^t (k_1 \pi_t + k_2 FE_t + k_3 GR_t + k_4 L_t + k_5 R_t + k_6 \pi_t^2 + k_7 FE_t^2 + k_8 GR_t^2 + k_9 L_t^2 + k_{10} R_t^2 + k_{11} \pi_t FE_t + k_{12} \pi_t GR_t + k_{13} \pi_t L_t + k_{14} GR_t FE_t + k_{15} GR_t L_t + k_{16} GR_t R_t)]$$

Subject to:

$$(3\text{-}2) \qquad L_t = \alpha_0 + \alpha_1 q_t + \alpha_2 q_{1t}^d + \alpha_3 R_t + \varepsilon_{1t}$$

$$(3\text{-}3) \qquad R_t = \beta_0 + \beta_1 R_{t-1} + \beta_2 q_t + \beta_3 T_{1t}^e + \varepsilon_{2t}$$

$$(3\text{-}4) \qquad P_{1t}^e = \gamma_0 + \gamma_1 P_{1t-1}^e + \gamma_2 P_{1t-2}^e + \varepsilon_{3t}$$

$$(3\text{-}5) \qquad P_{2t}^e = \mu_0 + \mu_1 P_{2t-1}^e + \mu_2 P_{2t-2}^e + \varepsilon_{4t}$$

$$(3\text{-}6) \qquad q_{2t}^e = \delta_1 P_{2t}^e + \delta_2 T_{2t}^e + \varepsilon_{5t}$$

$$(3\text{-}7) \qquad q_{2t}^d = \psi_0 + \psi_1 q_{1t}^d + \varepsilon_{6t}$$

$$(3\text{-}8) \qquad GR_t = \rho H_t + T_{1t}^e q_{1t}^e + \tau_{1t}^d q_{1t}^d + T_{2t}^e q_{2t}^e$$

$$(3\text{-}9) \qquad \pi_t = (P_{1t}^e - T_{1t}^e) q_{1t}^e + P_{1t}^d q_{1t}^d + (P_{2t}^e - T_{2t}^e) q_{2t}^e + P_{2t}^d q_{2t}^d - m_1 q_t - m_2 (q_{2t}^e + q_{2t}^d)$$

$$(3\text{-}10) \qquad FE_t = \theta_1 (P_{1t}^e q_{1t}^e + P_{2t}^e q_{2t}^e) + \theta_2 (P_{2t}^d q_{2t}^d)$$

$$(3\text{-}11) \qquad P_1^e(0) = P_1^0, \quad P_2^e(0) = P_2^0, \quad R(0) = 0$$

where,

W_t is the value of the objective function at time t,

E = expected value operator conditional on information at time t=1

λ = social discount rate of time preference

π_t = profits in period t

L_t = volume of employment in period t

GR_t = government forest revenues in period t

FE_t = foreign exchange earnings and savings in period t

H_t = total area of tropical forest under concession at time t

ρ = area tax rate

q_t = total quantity of raw logs harvested in period t

q_{1t}^e = quantity of raw logs exported in period t

q_{1t}^d = quantity of raw logs domestically processed at time t

q_{2t}^e = quantity of processed products (Sawnwood) exported at time t

q_{2t}^d = quantity of processed products (Sawnwood) sold locally at time t

τ_{1t}^e = Average tax on logs exported in period t

τ_{1t}^d = Average tax on logs locally processed in period t

τ_{2t}^e = tax rate on processed products exported in period t

R_t = reforestation expenditures in period t

P_{1t}^e = export price of raw logs in period t

P_{2t}^e = export price of processed products in period t

m_1 = unit cost of raw log production

m_2 = unit cost of domestic wood-processing

θ_1 = factor converting gross export earnings into net earnings

θ_2 = fraction of total local sales of wood product accounting for import substitutions.

Equation (3-11) specifies initial conditions for some state variables.

3.3 Policy Preference Function Estimation

Empirical estimations of policy preference functions (PPF) typically derive parameters of reduced form preference functions without explicitly specifying the underlying political structures. The use of reduced forms is required because political variables are generally unobservable. Three estimation approaches have been suggested in the literature (Rausser and Freebairn, 1974): The direct approach, the arbitrary approach, and the indirect approach.

3.3.1 The direct approach

This estimation method is direct because the researcher directly interviews policy makers, asks them questions, and assumes they will reveal their preferences for alternative policy options. This method, unfortunately, may not yield good results since policy makers may not willingly reveal their preferences to outsiders. Also, political statements, even those put in writing, are not always actually honored.

3.3.2 The arbitrary approach

In this approach the estimation of the PPF parameters relies on the researcher's ability to guess at what policy makers value the most. The researcher simply chooses the weights on the basis of his/her own beliefs. Because of its arbitrariness, this estimation method can produce weights that may be difficult to assess by others.

3.3.3 The indirect approach

The indirect approach estimates policy preference weights by assuming that (1) public policy makers are rational and consistent economic agents, and (2) that observed policy decisions are the outcomes of PPF optimizations subject to appropriate constraints describing the policy environment. The second assumption is referred to in the literature as the revealed preference assumption. For that reason, the indirect estimation method is also called the revealed preference method. The estimation of the reduced form PPF using the indirect approach requires one of the following three techniques (Love et al., 1990): The revealed-preference-econometrics technique (RPE), the revealed preference-mathematical-programming technique (RPMP), and the revealed-preference-inverse-control technique (RPIC). RPE uses the first order conditions of the PPF together with the set of economic constraints and the revealed preference assumption to infer the policy weights. RPMP adapts the PPF problem to standard mathematical programming algorithms in order to derive the PPF parameters. RPIC utilizes information from the economic constraints, the revealed preference assumption, and the optimal control rule in feedback form (Love et al., 1990; Chow, 1983) in estimating the parameters of the objective function. Choice between these techniques depends on the policy problem. RPE and RPMP allow single period and multiple period estimation of reduced form parameters in a non-dynamic setting. But RPIC is most appropriate in a multiple period dynamic framework (Love et al., 1990). Therefore, the revealed-preference-inverse-control estimation technique is adopted in this study.

The adoption of the revealed-preference-inverse-control method to estimate the parameters of the objective function requires that the problem as given by Eqs. [3-1] to [3-10] be approximated and written as the following linear-quadratic stochastic programming problem:

(19) $$Max_{x_t}. \quad W = E\{\sum_{t=1}^{\infty} \lambda^t (k_t' Z_t + Z_t' K Z_t)\}$$

subject to

(20) $$Z_t = A Z_{t-1} + C X_t + b_t + \epsilon_t$$

where z_t and x_t are respectively, the vector of state variables and the vector of control variables. More specifically,

$$Z_t' = [\pi_t \; FE_t \; GR_t \; L_t \; R_t \; q_t \; q_{1t}^d \; p_{1t}^e \; p_{2t}^e]$$

$$X_t' = [q_t \; q_{1t}^d \; T_{1t}^e \; T_{2t}^e]$$

ϵ_t is a vector of serially uncorrelated error terms; and k_t, K, C, and b_t are matrices of fixed values.

The linear representation of the equations of motion was made possible by using a first order Taylor-series expansion to approximate the profit constraint, the government revenue constraint, and the foreign exchange constraint equation (see Appendix B for details).

Because the model describing the environment facing the public policy makers is linear and stochastic, and because the objective function is quadratic, the solution to the problem represented by Eqs. [19] and [20] takes the form of a linear feedback control equation where the vector of control variables, X_t is expressed as a linear function of the vector of past values of the state variables (Chow, 1983; Fulton and Karp, 1989; Love et al., 1990); i.e.,

$$(21) \qquad X_t^* = G Z_{t-1} + g_t$$

Note that the optimal feedback rule need not be stationary in the intercept although it is time invariant in G. This can be shown directly from the solution process (Chow, 1983; Fulton and Karp, 1989).

The econometrician's desire is to obtain parameter estimates of the objective function (Eq.[19]), the equations of motion (Eq. [20]), and the optimal control rule (Eq.[21]). However, because the elements of the matrices G and g_t in Eq.[21] are non-linear functions of the parameters of Eqs. [19] and [20], the task facing the econometrician cannot be performed freely (Chow, 1983).

To solve this estimation problem, analysts have used maximum likelihood methods to simultaneously estimate the parameters of Eqs. [19], [20] and [21] (Chow, 1983; Epple, 1983; Hansen and Sargent, 1980). Parameter estimates generated by full information techniques are known for their greater reliability. However, they are also more expensive and complex (Epple, 1983; Chow, 1983; Hansen and Sargent, 1980). Thus, it is not clear for small data sets whether the greater reliability of such estimates justifies the added complexity and cost (Fulton and Karp, 1989). Fulton and Karp also point out that when models are exactly identified, as this one, the benefit in applying full information methods is null.

Chow solves this estimation problem by using a solution method involving the application of least squares method twice. This 2SLS method is not to be confused with the usual 2SLS method used in simultaneous equations estimation. The procedure consists of estimating, in a first stage, the parameters of the equations of motion (Eq.[20]) and the optimal feedback rule (Eq.[21]) by OLS. Then, use the results obtained in the first stage together with the first order conditions for the dynamic optimization problem to derive the parameters of the quadratic objective function. This procedure produces consistent estimates of k_t and K (Chow, 1983; Fulton and Karp, 1989). This seemingly 2SLS method is relative simple, cost effective, and produces consistent estimates. Thus, it is the method used in this research to solve the inverse control problem (Appendix B presents the precise details of the 2SLS procedure).

CHAPTER IV

EMPIRICAL RESULTS

4.1 The Data:

The data used in this study were collected from various sources, including documents from the Côte d'Ivoire's Ministry of Industry, various issues of the FAO Yearbook of Forest Products, and many other FAO forestry papers, including Gray (1983), Grut et al. (1991). The employment series and the series for reforestation activities were not available in some years. The missing data were, however, generated by the author on the basis of the general trend among the data, and footnote information provided by the different data sources. Time series on export taxes on logs and sawnwood were not available at all. They were therefore generated by the author using informations from various sources. Detailed descriptions of the data and data sources are presented in Appendix A.

It is important, however, at this point to state that in this study the scope of domestically processed wood-products is reduced to sawnwood only. Other processed products (e.g., veneer sheets, plywood) exist in the forest industry, but their importance is small relative to that of sawnwood. This study assumes that they can be omitted without loss of generality, but with a great gain in simplicity.

4.2 Estimates of the Equations of Motion

Parameter estimates of the constraint equations (Eq.(20) or Eqs.(3-2), (3-3), (3-4), (3-5), (3-6), and (3-7) are presented in Table 2 below.

The employment equation relating the volume of employment to logging, processing and reforestation activities, has coefficients of the expected signs. These estimates indicate that about one job is created for every two thousands cubic meters of raw log produced and also for every hectare of land reforested; while roughly six jobs are created for every thousand cubic meters of sawnwood processed. This is quite consistent with the popular belief that domestic processing of raw log before exports generates more jobs than raw log production.

The coefficient on logging is statistically significant at the 10% level, while the coefficient on processing and the reforestation coefficient are statistically significant at the 1% level for two-tailed tests. The Durbin-Watson statistic is in the inconclusive region.

The estimated reforestation equation shows a positive relationship between current total land area reforested and raw log production, log export charges and past reforestation efforts. This may be an indication that reforestation efforts in the country has never been considered excessive at any time. All estimated coefficients are statistically significant at the 10% level. The Durbin h statistic being less than

1.645 provides an indication that the null hypothesis of no autocorrelation cannot be rejected.

The price expectations equations indicate that an increase in either log export price or sawnwood export price today will cause expected export prices of both products to rise next year. Export prices lagged two periods were omitted from the regression equations because they did not appear to add new information to the estimation process.

Table 2. Parameter Estimates of the Equations of Motion

(3-2)	$L_t = 1407 + 0.65q_t + 5.98q_{1t}^d + 1.22r_{t-1}$ (0.93) (1.95) (5.97) (2.78)	R^2=0.92 DW=1.36
(3-3)	$r_t = 112 + 0.65r_{t-1} + 0.19q_t + 12.35T_{1t}^e$ (.41) (8.31) (2.73) (1.79)	R^2=0.92 h=0.67
(3-4)	$p_{1t}^e = 12.38 + 0.89\,p_{1t-1}^e$ (1.52) (9.76)	R^2 = 0.80 h = 0.365
(3-5)	$p_{2t}^e = 17.35 + 0.94\,p_{2t-1}^e$ (1.21) (11.14)	R^2 = 0.84 h = 0.055
(3-6)	$q_{2t}^e = 9.25\,p_{2t}^e - 132\,T_{2t}^e$ (2.28) (-2.29)	R^2 = 0.92 DW = 1.65
(3-7)	$q_{2t}^d = 78.19 + 0.13\,q_{1t}^d$ (0.56) (1.85)	R^2 = 0.79 DW = 1.60

Note: The values in parentheses are t statistics.

The last two estimated equations in Table 2 are two linear relationships between sawnwood export quantity and sawnwood export tax on one hand and domestic consumption of sawnwood and domestic processing in the other hand. Both equations show a good fit and are included in the system of constraint equations to add more structure to the model thereby reducing the number of variables in the model (see the linearization process of the nonlinear constraint equations in Appendix B). This is more for estimation convenience than theoretical necessity.

4.3 Estimates of the Optimal Feedback Rule

The optimal feedback rule (Eq. [21]) was derived using the structure of the objective function (Eq. [19]) and the equations of motions (Eq. [20]) as constraints. Consequently, the elements of the matrices G and g_t in Eq.(21) are functions of the parameters of Eqs. (19) and (20) (Chow, 1983; Fulton and Karp, 1989). The implication is that if a column of A is zero, the corresponding column of G is also zero. This results in the following linear feedback rules:

$$q_t^* = a_0 + a_1 r_{t-1}^e + a_2 p_{1t-1}^e + a_3 p_{2t-1}^e + e_1$$

$$q_{1t}^{*d} = b_0 + b_1 r_{t-1}^e + b_2 p_{1t-1}^e + b_3 p_{2t-1}^e + e_2$$

$$\mathrm{T}_{1t}^{*e} = c_0 + c_1 r_{t-1} + c_2 p_{1t-1}^e + c_3 p_{2t-1}^e + e_3$$

$$\mathrm{T}_{2t}^{*e} = d_0 + d_1 r_{t-1} + d_2 p_{1t-1}^e + d_3 p_{2t-1}^e + e_4$$

which, when estimated by OLS, yields the results presented in Table 3 below.

Because the feedback rule is not time invariant in its intercept, it was possible to include a Dummy variable in the sawnwood export charge equation in order to account for the recent government decision to increase the export tax on processed products (Ministère de l'Industrie, 1990).

Table 3. Parameter Estimates of the Optimal Feedback Rule

Raw log production equation

$$q_t^* = 3775 + 0.66 r_{t-1} + 13.03 p_{1t-1}^e - 19.57 p_{2t-1}^e \qquad R^2 = 0.66$$
$$(6.95) \quad (3.56) \qquad (0.71) \qquad (-1.79) \qquad DW = 1.36$$

Domestic processing equation

$$q_{1t}^* = 416.72 + 0.19 r_{t-1} - 1.83 p_{1t-1}^e + 4.76 p_{2t-1}^e \qquad R^2 = 0.80$$
$$(2.96) \quad (3.99) \qquad (-0.35) \qquad (1.56) \qquad DW = 1.24$$

Raw log export charge equation

$$T_{1t}^* = 3.85 + 0.004 r_{t-1} + 0.27 p_{1t-1}^e - 0.067 p_{2t-1}^e \qquad R^2 = 0.67$$
$$(0.79) \quad (2.64) \qquad (1.5) \qquad (-0.64) \qquad DW = 1.24$$

Sawnwood export charge equation

$$T_{2t}^* = 0.15 + 0.001 r_{t-1} + 0.02 p_{1t-1}^e + 0.038 p_{2t-1}^e + 5.00 DUM \qquad R^2 = 0.93$$
$$(0.14) \quad (2.58) \qquad (0.46) \qquad (1.58) \qquad (4.85) \qquad DW = 2.38$$

Note: Values in parentheses are t values.

The optimal feedback rule for raw logs production indicates that 66% of logging output variation is related to lagged values of reforestation, log export price, and sawnwood export price. The lagged reforestation coefficient is statistically significant at the 1% level. The coefficient on sawnwood export price lagged one period is also significant but at the 10% level. The coefficient of the log export price lagged one period is not significant. Nevertheless, the estimated equation shows that log export price and reforestation lagged one period both affect positively the optimal level of current period log production; while an increase in sawnwood export price last year decreases current log production.

The optimal feedback rule for domestic processing shows a better fit, with a coefficient of determination equal 80%. Here also the reforestation coefficient and the coefficient on sawnwood export price are both statistically significant at the 1% and 10% respectively; while the log export price coefficient does not appear to be significant. The Durbin-Watson statistic is in the inconclusive region. The coefficients also indicate that an increase in the export price of logs last year discourages domestic processing this year, while reforestation effort and sawnwood export price lagged one period have positive effects on current domestic processing.

The raw log export charge equation indicates that higher log export price and reforestation last period tend to increase log export charge this period. But an increase in sawnwood export price last period decreases current log export charges.

The t-statistics revealed, however, that only the reforestation coefficient and that of log export price are significant at the 1% and 10% levels respectively.

The sawnwood export charge equation suggests that last period reforestation efforts, log export price, and sawnwood export price all have a positive effect on current period sawnwood export charges. All coefficients but the log export price coefficient are significant. A dummy variable was included in the sawnwood export charge equation to account for the 1990 governmental decision to increase the export charges for processed forest products.

4.4 Estimates of the Objective Function Parameters

Using the estimated equations of motion and feedback rules together with the necessary conditions of the dynamic optimization problem, the parameters of the objective function can be determined. The estimated weights are presented below in Table 4 below. Two assumptions have been made in undertaking this estimation: First, discount rates of 6%, 6.5%, and 7% have been used in order to examine the sensitivity of the estimates to the discount rate. Second, as a result of the linearization of the non-linear constraints using a Taylor-series expansion, average values had to be assumed for a number of the variables. The estimated weights in Table 4 below have been calculated using values of \$30/m3 and \$12/m3 respectively for average quantity of log export charge and sawnwood export charge, 2227 and 305 thousand cubic meters respectively for average quantity of log export and average quantity of sawnwood export, \$84/m3 and \$164/m3 for average log export price and average sawnwood export price respectively, and \$30/m3 , \$120/m3, and \$125/m3, respectively for average cost of log production, sawnwood production, and price of sawnwood on the local market. It was estimated that net export earnings in the Indonesian forestry sector in the early 1970s were about 25 percent of gross export earnings (Gray, 1983; Contreras-Hermosilla and Gregersen, 1991). This estimate is assumed, in this study, to hold approximately for most developing countries, including the Côte d'Ivoire.

Statistics on import substitution are not readily available. However, it is widely believed that a large proportion of domestically produced forest products sold in local market represents import substitution (Contreras-Hermosilla and Gregersen, 1991). Based on these information, θ_1, the factor converting gross export earnings into net earnings was set at 25%, while θ_2, the fraction of total local sales of domestically processed forest products accounting for import substitutions was fixed at 80%.

Table 4. Parameter Estimates of the Objective Function

	Discount rate (%)			
	7.00	6.5	6.00	
Coefficient on	Estimate		Estimate	Large sample std errors
Π_t	1.3E+06	1.2E+06	1.2E+07	9.4E+08
FE_t	-1.3E+07	-2.4E+07	-5.9E+07	5.8E+09
GR_t	1.4E+07	4.7E+07	1.1E+08	2.5E+10
L_t	-6.3E+07	-1.2E+08	-1.7E+08	2.2E+10
R_t	2.2E+09	4.1E+09	6.3E+08	1.4E+12
Π_t^2	-10.0987	-10.0979	-10.0970	13.5709
FE_t^2	-44.9250	-44.9210	-44.9180	10.5216
GR_t^2	-86.9460	-86.9330	-86.8900	54.4259
L_t^2	-0.04391	-0.04389	-0.04350	0.38403
R_t^2	-4966.00	-4618.00	-4280.00	18054.9
$\Pi_t FE_t$	4.02600	4.02700	4.02600	12.5509
$\Pi_t GR_t$	-28.6430	-28.6410	-28.6480	12.4706
$\Pi_t L_t$	43.3080	43.3430	43.4530	125.6718
$GR_t FE_t$	237.317	237.3070	237.283	49.92682
$GR_t L_t$	873.994	874.7850	876.955	2308.263
$GR_t R_t$	9.5340	9.4800	9.4230	19.1485

Note. The values in this table were calculated based on the average values assumed (see text) as a result of the linearization of the nonlinear constraints, using first order Taylor-series expansion.

The average values for log and sawnwood export quantities, prices, and charges were calculated directly from the data set, while the average values assumed for sawnwood price on the local market and the log and sawnwood production costs were based on information from Côte d'Ivoire Ministry of Forestry and Gray (1983).

Table 4 below shows that the coefficients on the squared terms of the objective function are all negative, while the coefficients on the linear terms are positive for all arguments except for labor and foreign exchange earnings. The second-order conditions are satisfied indicating that the estimated objective function was indeed maximized. The estimates across the alternative discount rates are quite similar particularly for the non-linear terms. For the linear terms there is quite a variation in the size of the estimates although the signs consistently remain the same.

4.5 Marginal Utilities and Utility Elasticities

To evaluate the relative importance of the arguments in the objective function marginal utilities and utility elasticities were calculated first for each year and then for two different time periods. The first period from 1967 to 1975 corresponds roughly to the early years of forest industrial development. The second time period, 1976-1990, is assumed to correspond to the later years of forest industrial development in the Côte d'Ivoire. If we write the objective function as $W_t = k_t'Z_t + Z_t'KZ_t$, then for any argument z_t, the marginal utility and the utility elasticity are denoted $(\partial W_t/\partial z_t)$ and $(\partial W_t/\partial z_t)(z_t/W_t)$, respectively. For example, the marginal utility of profit at time t is $(\partial W_t/\partial \pi_t)$, and the utility elasticity with respect to profit is $(\partial W_t/\partial \pi_t)(\pi_t/W_t)$. Each of these derivatives were computed assuming total independence. This means that in calculating, for example, $\partial W_t/\partial \pi_t$, no account was taken of the effects that π_t might have on all the other arguments in the objective function. In other words, the derivative with respect to an argument measures only the intrinsic or direct marginal benefit of a change in that argument. If at time t, argument z_1 has a positive marginal utility while another argument z_2 has a negative marginal utility, the interpretation is that z_1 is preferred to z_2; and that forestry policy makers are willing to trade off z_2 for higher levels of z_1. Note, however, that arguments with marginal utilities identical in sign cannot be compared with each other unless their individual utility elasticities are known. For example, if z_1 and z_2 are two arguments with positive marginal utilities; and if furthermore, the utility elasticity with respect to z_1 is greater than that of z_2, then, z_1 is said to be valued more than z_2. If two arguments have negative marginal utilities, then they are means of negociating higher levels of other arguments. If furthermore, the utility elasticities of these two arguments are known, then, it can be concluded that the argument which has the greatest elasticity in absolute value is used more heavily than the other in the negociation process.

The results of the marginal utility and utility elasticity computations are presented in Tables 5, 6, and 7 below. Tables 5 and 6 show the evolution of the marginal utilities and utility elasticities through time, while Table 7 presents average marginal utility and utility elasticity for each argument for the two time periods specified above.

Table 5. Evolution of the Marginal Utilities of the PPF Arguments, 1967-1990.

Year	$\frac{\partial W_t}{\partial \pi_t}$	$\frac{\partial W_t}{\partial FE_t}$	$\frac{\partial W_t}{\partial GR_t}$	$\frac{\partial W_t}{\partial L_t}$	$\frac{\partial W_t}{\partial R_t}$
1967	7.9E+06	-5.7E+07	1.2E+08	-1.4E+08	6.2E+08
1968	7.2E+06	-5.4E+07	1.2E+08	-1.3E+08	6.1E+08
1969	5.4E+06	-5.0E+07	1.2E+08	-1.1E+08	6.1E+08
1970	6.4E+06	-5.5E+07	1.2E+08	-1.3E+08	6.1E+08
1971	6.5E+06	-5.3E+07	1.2E+08	-1.2E+08	6.0E+08
1972	5.8E+06	-5.0E+07	1.2E+08	-1.1E+08	6.0E+08
1973	1.7E+06	-4.3E+07	1.1E+08	-7.4E+07	6.0E+08
1974	0.4E+06	-4.6E+07	1.2E+08	-7.7E+07	6.0E+08
1975	1.4E+06	-5.0E+07	1.2E+08	-9.5E+07	6.0E+08
1976	-1.5E+03	-4.3E+07	1.2E+08	-6.3E+07	6.0E+08
1977	-2.5E+06	-2.7E+07	1.1E+08	-0.3E+07	5.9E+08
1978	-3.3E+06	-4.4E+07	1.1E+08	-6.5E+07	6.0E+08
1979	-4.1E+06	-4.2E+07	1.1E+08	-5.1E+07	5.9E+08
1980	-9.2E+06	-3.6E+07	0.9E+08	-3.0E+07	6.0E+08
1981	-7.3E+06	-4.7E+07	1.2E+08	-5.2E+07	6.0E+08
1982	-4.7E+06	-4.6E+07	1.1E+08	-6.2E+07	6.0E+08
1983	-3.7E+06	-4.4E+07	1.1E+08	-6.6E+07	6.0E+08
1984	-2.0E+06	-4.6E+07	1.1E+08	-7.4E+07	6.0E+08
1985	-0.6E+05	-4.9E+07	1.1E+08	-9.4E+07	6.0E+08
1986	-4.1E+06	-5.0E+07	1.0E+08	-1.0E+08	6.0E+08
1987	-8.3E+06	-5.3E+07	0.9E+08	-1.1E+08	6.0E+08
1988	-8.9E+06	-5.5E+07	1.0E+08	-1.0E+08	6.0E+08
1989	-9.1E+06	-5.5E+07	1.0E+08	-1.0E+08	6.0E+08
1990	-9.3E+06	-5.5E+07	1.0E+08	-1.0E+08	6.0E+08

Note. The values in this Table were computed on the basis of a 6% discount rate and the average values assumed in estimating the parameters of the policy preference function.

Table 6. Evolution of the Utility Elasticities of the PPF Arguments, 1967-1990.

Year	$(\frac{\partial W}{\partial \pi})(\frac{\pi}{W})$	$(\frac{\partial W}{\partial FE})(\frac{FE}{W})$	$(\frac{\partial W}{\partial GR})(\frac{GR}{W})$	$(\frac{\partial W}{\partial L})(\frac{L}{W})$	$(\frac{\partial W}{\partial R})(\frac{R}{W})$
1967	1.382	-2.133	2.443	-1.135	0.343
1968	0.526	-0.943	1.405	-0.396	0.379
1969	0.255	-0.535	1.144	-0.174	0.279
1970	0.478	-0.858	1.176	-0.384	0.509
1971	0.415	-0.873	1.463	-0.435	0.41
1972	0.280	-0.556	1.280	-0.307	0.353
1973	0.082	-0.316	1.083	-0.139	0.213
1974	0.025	-0.506	1.210	-0.182	0.283
1975	0.132	-0.723	1.367	-0.330	0.368
1976	-0.001	-0.462	1.301	-0.152	0.231
1977	-0.083	-0.162	1.061	-0.005	0.156
1978	-0.296	-0.466	1.210	-0.175	0.286
1979	-0.327	-0.528	1.263	-0.097	0.277
1980	-0.848	-0.291	1.079	-0.044	0.241
1981	-1.162	-1.210	1.904	-0.139	0.428
1982	-0.519	-0.757	1.387	-0.124	0.326
1983	-0.318	-0.486	1.119	-0.114	0.276
1984	-0.158	-0.505	1.106	-0.124	0.278
1985	-0.052	-0.467	0.939	-0.175	0.320
1986	-0.581	-0.344	0.696	-0.229	0.383
1987	-3.440	-0.911	0.942	-0.523	0.853
1988	-9.647	-3.882	2.717	-1.239	2.130
1989	-14.152	-5.432	3.441	-1.689	2.943
1990	-10.950	-3.958	2.816	-1.298	2.276

Note. The values in this Table were computed on the basis of a 6% discount rate and the average values assumed as a result of the Taylor-series expansions in estimating the objective function parameters.

Table 7. Average Marginal Utilities and Utility Elasticities in the 1970s and 1980s . *

Arguments Z	Average Marginal Utility $\Sigma_{t=t_0}^{T}(\partial W_t/\partial Z_t)/T_o$	Average Utility Elasticities $\Sigma_{t=t_0}^{T}\{(\partial W_t/\partial Z_t)(Z_t/W_t)\}/T_o$
π_{1970s}	4.7E+06	0.397
π_{1980s}	-5.1E+06	-2.835
FE_{1970s}	-5.1E+07	-0.831
FE_{1980s}	-4.6E+07	-1.324
GR_{1970s}	1.2E+08	1.396
GR_{1980s}	1.1E+08	1.532
L_{1970s}	-1.1E+08	-0.387
L_{1980s}	-0.72E+08	-0.408
R_{1970s}	6.1E+08	0.355
R_{1980s}	6.0E+08	0.760

Note. The values in this table were computed on the basis of a 6% discount rate and the average values assumed in estimating the weights in the quadratic objective function.

*For the time period called 1970s, $t_0 = 1967$, $T = 1975$, and the length of the period is $T_o = T - t_0 + 1 = 9$. For period denoted by 1980s, $t_0 = 1976$, $T = 1990$, and the length of the period is $T_o = T - t_0 + 1 = 15$.

These average utilities are obtained by summing up the utilities in each time period and dividing the sum by the length of the period. For example, the average marginal utility of profit in the period labelled 1970s (i.e., 4.7E+06) was obtained by adding up the individual marginal utilities of the profit argument over the nine years (1967-1975) and dividing the sum by nine. The average utility elasticity of profit for the same period was also calculated in the same manner, by adding up the individual elasticities of profit over the nine year period and dividing the resulting sum by the length of the period (i.e., nine years). The same procedure was used to calculate average marginal utilities and utility elasticities for all arguments in the objective function.

The literature on forest-based industrial development in developing countries increasingly stresses the assertion that forestry policies are consistently tailored toward private profit maximization with very little or no benefit to the public sector. This implies, in terms of the model of this study, that profit is the only argument with intrinsic value in the policy preference function.

The point estimates in Tables 5, 6, and 7 above tell us quite a different story. Marginal utility figures in period called 1970s are positive for profit, government revenue, and reforestation, indicating that these arguments are intrinsically important to policy makers in the early years of forest industrial development. The elasticity estimates in this period show that government revenues are relatively more important than profit and reforestation, which are roughly equally valued.

Employment and foreign exchange earnings/savings did not appear to be directly valued. The interpretation is that policy makers compromise on employment and foreign exchange in order to achieve their revenue, profit, and environmental objectives. Table 5, 6, and 7 also show negative values for the profit argument in the 1980s. This indicates that the profit objective is no longer valued in the second period of forest industrial development; only government revenues and reforestation continue to be intrinsically important to policy makers. Referring particularly to Table 7, one observes that government revenue has always been valued the most in any time period (its average elasticities being higher than that of any other arguments); and that the reforestation objective is gaining momentum as its utility elasticity doubles from the first period to the second. This emphasis on reforestation in the 1980s may be attributed to the combination of two factors: the government commitment to stop the runaway deforestation phenomenon so pronounced in the Côte d'Ivoire[6], and the increasing pressure[7] and support[8] from the World community and financial institutions.

[6]The Côte d'Ivoire currently has the highest rate of deforestation in the World (Bertrand,1983; Ehui and Hertel,1989).

[7]Recent environmentalists' threats to boycott tropical timber (see Vincent, 1990) resulted in low demand for tropical hardwoods (African Timber Organisation, 1991). Governments in developing countries can no longer ignore the environmental effects of forest industrial development.

[8]In recent years SODEFOR activities have been largely financed by the World Bank and French AID Funds. More recently in 1992 a multi-million dollar World Bank financial support was given to the Côte d'Ivoire for reforestation purposes (personal communication with Narendra Sharma, Principal Economist, World Bank. May 1992).

The use of average values (Table 7) to describe the preference structure of forestry policy makers should not be understood as an indication of little or no variation in the marginal utilities and utility elasticities. The main purpose of Tables 5 and 6 is to show that there exits indeed a significant variability in the preferences of forestry policy makers over time.

The numbers in Table 7 are also graphically presented below in Figs. 4.1 to 4.3 in order to provide an illustrative comparison of the utility elasticities of the different arguments. Fig.4.1 compares the elasticities with respect to each of the five arguments together. The first line corresponds to the evolution of the elasticities with respect to government revenue; the second line corresponds to the evolution of the elasticities with respect to reforestation; while the third and fourth line refer respectively to profit and foreign exchange earnings. It is important to note that at each point in time, the higher the elasticity line the more valuable the corresponding argument becomes. Thus, it can be seem, as previously stated, government revenue is the most valued forestry development objective in the Côte d'Ivoire, followed by reforestation, and profit in that order. Figs. 4.2 and 4.3 are clearer versions of Fig.4.1 as they show fewer lines than Fig.4.1. Fig.4.2 compares government revenue and reforestation with each other and with forestry employment and foreign exchange earnings. Fig.4.3 is a comparative illustration of government revenue, reforestation, and profit. Because these last two figures show few lines at a time, they are better visual presentation of the information contained in fig.4.1.

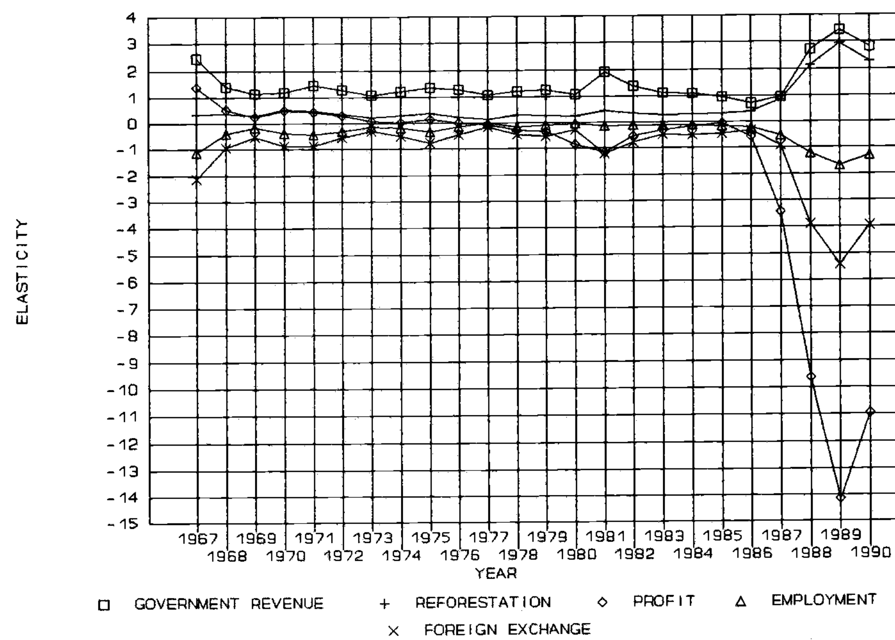

Fig.4.1 Comparative Evolution of Utility Elasticities for Government Revenue, Reforestation, Profit, Employment, and Foreign Exchange Earnings.

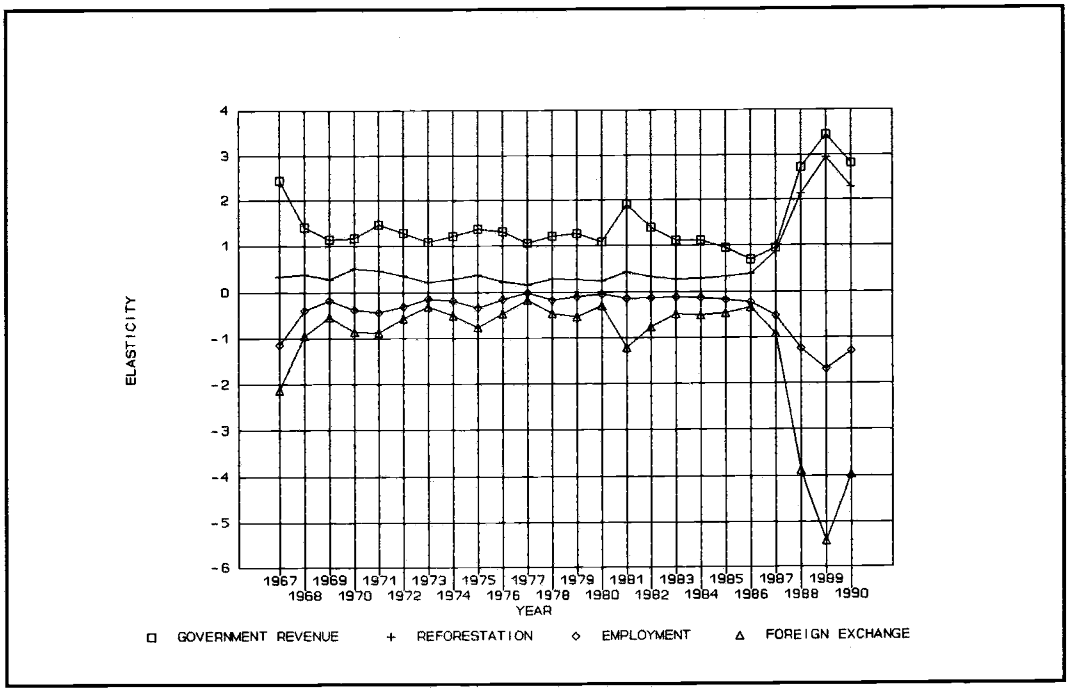

Fig.4.2 Comparative Evolution of Utility Elasticities for Government Revenue, Reforestation, Employment, and Foreign Exchange Earnings/savings.

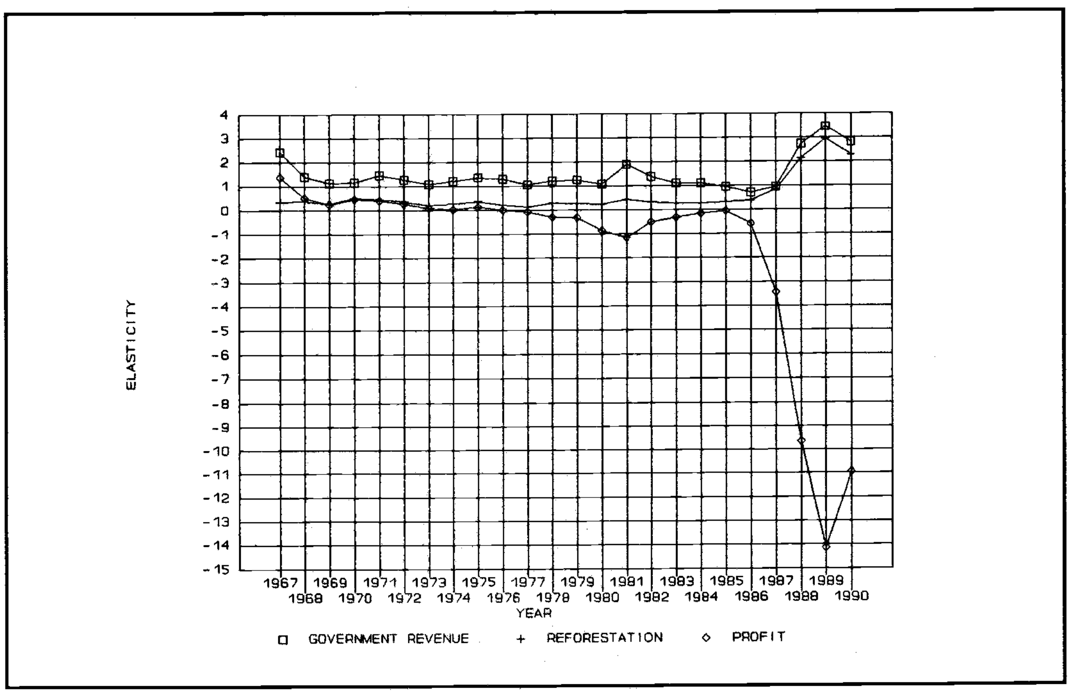

Fig.4.3 Comparative Evolution of Utility Elasticities for Government Revenue, Reforestation, and Private Profit.

CHAPTER V

HYPOTHESIS TESTING, MODEL VALIDATION AND USE

In this chapter two hypotheses tests about the objective function parameters are performed after standard errors of estimated PPF weights are obtained. Then, the estimated model is validated using one of the existing validation procedures. Finally, the model is used for policy evaluation.

5.1. Hypothesis Testing

The hypothesis that all the coefficients in the objective function are equal to zero is tested statistically. This is important to assess whether the model as a whole is of some value in explaining the behavior of forestry policy makers in the Côte d'Ivoire. This will also provide an additional (although crude) basis for using the model in policy analysis. A second equally important test to be performed concerns the hypothesis that profit is the only significant argument in the policy preference function. This will serve as an additional evaluation of the marginal utility of the arguments in the objective function.

To perform the hypothesis tests mentioned above, it is necessary to compute standard errors for the estimated PPF weights. This is done using a first-order Taylor series expansion to approximate the large-sample variance of the vector of the objective function parameters (Kmenta, 1986 p.486; Fulton and Karp, 1989). The procedure can be described as follows: First, let K^* be the column vector of the estimates of the objective function parameters, K and k_t. Also, let Y be the column vector of the estimates of the parameters in the equations of motion and the optimal feedback rule. Conceptually, one can think of K^* as a nonlinear function of Y. Then, by letting $J = (\partial K^*/\partial Y)$ represent the matrix of first derivatives, and Ω denote the variance-covariance matrix of Y, the variance of K^* can be written, using a first-order Taylor series expansion, as (see Kmenta, 1986 p.486; Fulton and Karp, 1989)

$$Var(K^*) = \Sigma = J\Omega J'$$

The variance-covariance matrix (Ω) is derived from the least square regressions associated with Eqs.(20) and (21). The matrix J of first derivatives is obtained by taking numerical derivatives. This involves varying each element of Y by a small increment, and rerunning the model as many times as there are elements in Y. In carrying out the procedure, a discount rate of 6% was used. The results are presented in Table 4, where the square root of the diagonal elements of Σ are used to approximate the large-sample standard errors of the parameter estimates of the objective function.

Using these standard errors in t tests reveal that only three out of sixteen estimates are statistically significant. This means that the individual coefficients are not estimated with much accuracy, except for the parameters associated with the terms FE_t^2, $\pi_t GR_t$, and $GR_t FE_t$, which are all significant statistically at the 5% level (two-tailed test). This, however, does not mean that the estimates are altogether useless (see the result of the first hypothesis test below).

Table 8. Selected Hypothesis Tests for the Objective Function Parameters

Null hypotheses	Test Statistic (χ) *	ν
(1) $H_0: k_1 = k_2 = \ldots = k_{16} = 0$	1.68E+08	16
(2) $H_0: K_2 = \ldots = K_5 = k_7 = \ldots = k_{16} = 0$	1.27E+08	14

* For the first hypothesis, $H_0: RK^* = 0$, and if K^* is assumed to be distributed $N(0, \Sigma)$ for the large-sample case, then under the null hypothesis, $\chi = (RK^*)'(R\Sigma R')^{-1}(RK^*)$ is distributed χ^2 with degrees of freedom ν, where ν is equal to the number of rows in the prior information design matrix R.

Having obtained standard errors of estimated PPF weights, the two hypothesis tests selected above have been performed using a Chi-square test. The results, presented in Table 8 above, shows that the hypothesis that all the estimates of the objective function parameters equal zero is rejected statistically at the 1% level. This implies that although the individual estimates do not seem to be measured accurately, they do, when taken together, suggest that the elements specified in this model are informative enough to be used in explaining the behavior of forest policy makers in the country under study.

A claim commonly made in the literature is that forest-based industrial development in developing countries benefits only the private sector. The second hypothesis test in Table 8 above rejects this claim at a 1% significant level, suggesting that forestry policies in the Côte d'Ivoire have other objectives besides creating profitability for private investments.

5.2. Model Validation

To be useful in policy analysis, the policy preference function has to be validated. This can be done by constructing confidence intervals around the PPF weights and judging the validity of the model by the width of the intervals. However, in this study, a validity test that focuses on the predictive ability of the model was used. Predicted policy outcomes were compared with observed policy levels. Predicted policy outcomes were obtained through simulation by maximizing the estimated PPF under the constraints of the estimated equations of motion while the exogenous variables were set at observed levels. Root mean squared error (RMSE) was computed to evaluate the closeness of the predicted policy levels to the policy levels actually observed. This is achieved by comparing the magnitude of RMSE with the average size of the variable in question (Pindyck and Rubinfeld, 1981). For each variable, the average size value is computed by summing up all the data points and dividing the result by the length of the simulation period. If the magnitude of RMSE for a variable is less than the average size of that variable, then the model used for the prediction is valid. The results of the validity test are presented in Table 9 below. In addition, actual and predicted policy outcomes are plotted in Figs. 5.1 to 5.4. From Table 9 and the related figures, it can be concluded that the model is quite valid for policy evaluation. For example, the magnitude of RMSE for log production is 695.2416 which compared with an average size of 3949.3809 for logging output passes the validity test. For the domestic processing variable, RMSE is 227.7796 which compared with the average size of 1769.333 also passes the validity test. For the remaining two variables also RMSE is less than average size of variable, the estimated model is validated.

The graphical illustration of the predictive ability of the model also provides additional evidence for the validity of the model. This is seen through how closely the simulated curves approximate the actual plot of the data. It must be noted, however, that the model was not able to capture drastic variations in the data (see for example Fig.5.3, where the high level of log export tax in 1977 was not captured by the simulation).

Table 9. Results of the Predictive Ability Test

	Test Period: 1970-1990	
Policy variable	RMSE	Average Size of Variable
Log production	695.2416	3949.3809
Local processing	227.7796	1769.3330
Log export tax	7.9343	32.0220
Sawnwood export tax	1.5212	13.0490

Note. The root-mean-square simulation error (RMSE) for a variable X_t is defined as $RMSE = \sqrt{\frac{1}{T}\sum_{t=1}^{T}(X_t^s - X_t^a)^2}$

where X_t^s = simulated value of X_t

X_t^a = actual (observed) value of X_t

T = length of simulation period

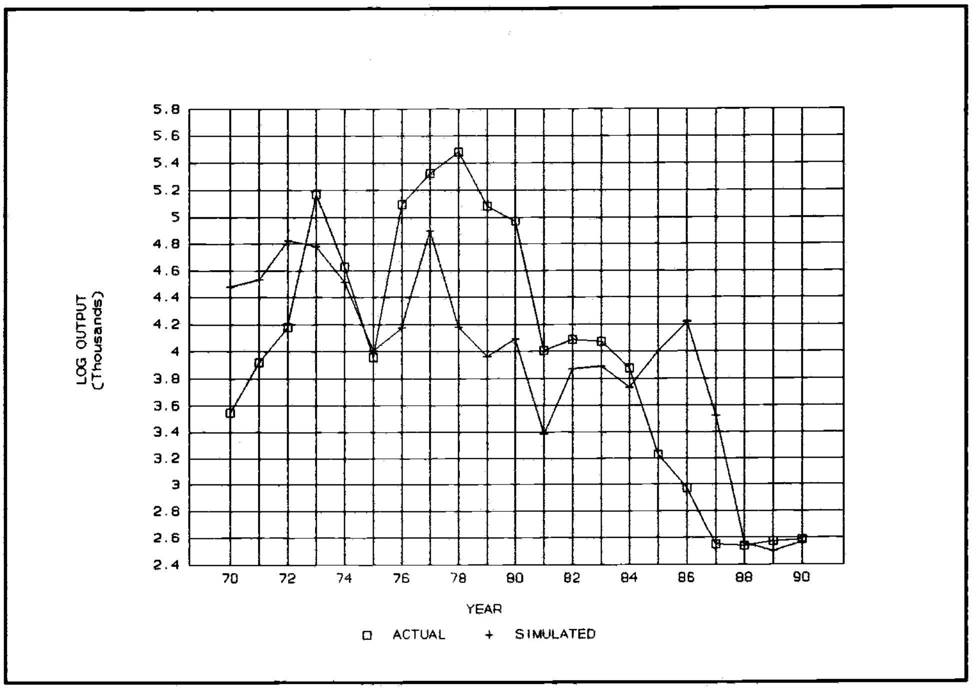

Fig.5.1 Historical Simulation of Log Production

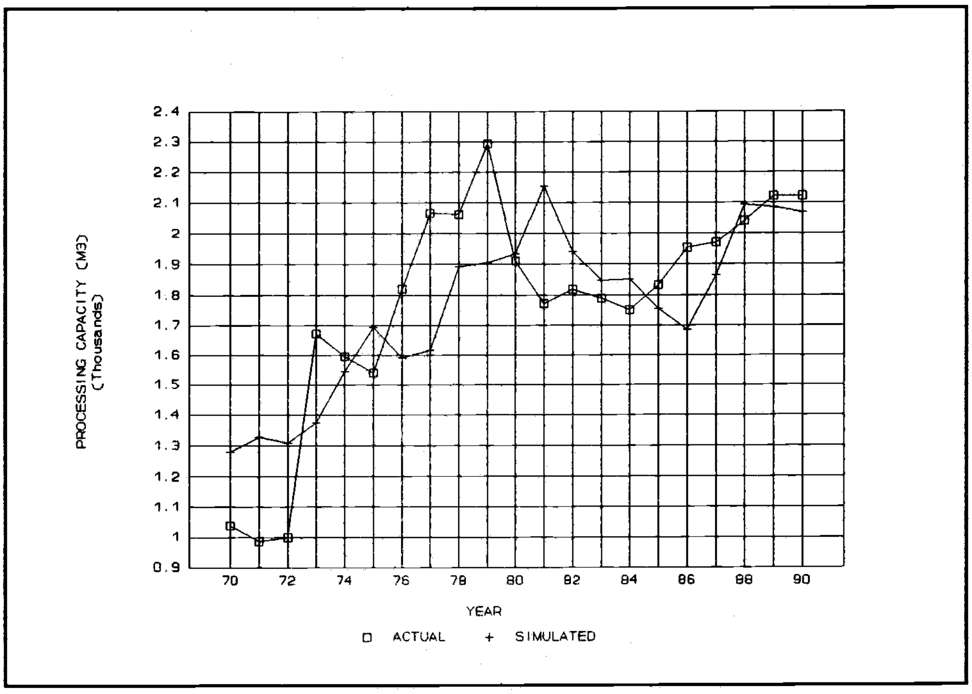

Fig.5.2 Historical Simulation of Domestic Processing Capacity

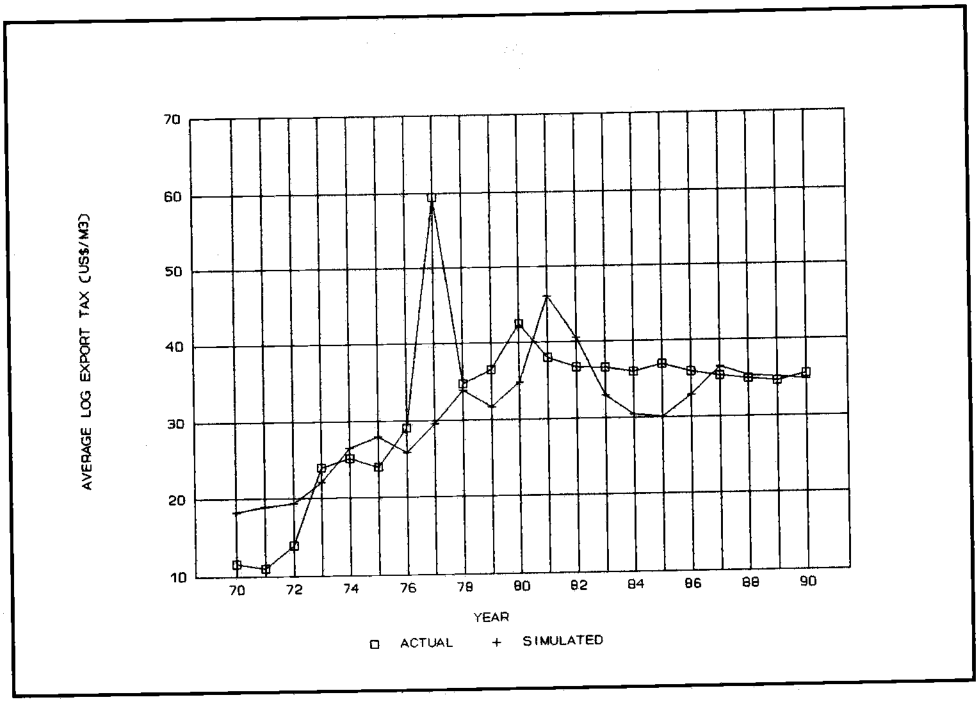

Fig.5.3 Historical Simulation of Average Log Export Tax

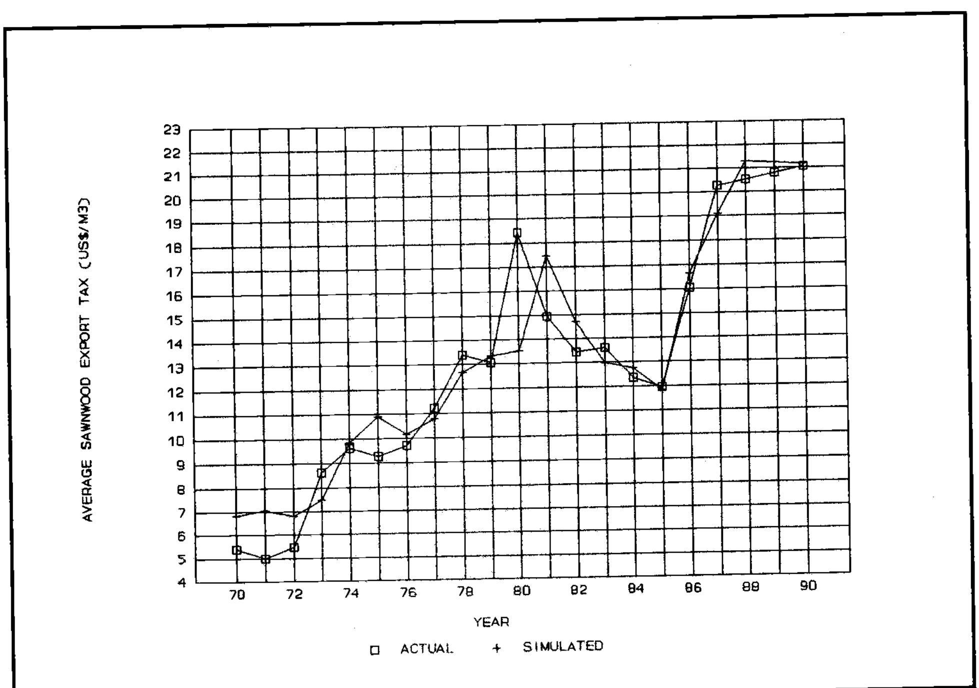

Fig.5.4 Historical Simulation of Average Sawnwood Export Tax

5.3. Using the Model in Policy Evaluation

Using the validated PPF, alternative policy scenarios can be analyzed. This analysis has to be performed over a short planning horizon during which the PPF weights can be assumed fixed (Love et al., 1990). Even then, it is important to keep in mind that these weights depend upon the values of the state variables; and are likely to vary over time with changes in the state variables.

The following four simulation scenarios were examined using the estimated model.

Scenario #1. This scenario is designed to serve as a benchmark. With no changes in the equations of motion, the model was simply simulated seven years into the future. The results from other scenarios will be compared with this benchmark scenario in order to assess possible paths in the behavior of forestry policy makers in the Côte d'Ivoire under alternative policy scenarios.

Scenario #2. In this second experiment, a 20% reduction in logging activities was postulated as a possible policy measure that could result from international pressures to boycott tropical timber. The objective in this experiment is to forecast the effects of such a change on forestry related employment, reforestation activity, government revenue collection, foreign exchange earnings and savings, and private profit. This will provide an alternative avenue to evaluate the relative importance of the performance measures in the PPF.

Scenario #3. Reform in forest pricing and revenue systems has been a major concern of the recent literature on forest-based industrial development in the Third World. Pricing and revenue policies have been increasingly characterized as a major source of mismanagement of the world tropical forests. Policy reform recommendations include pricing and taxation re-adjustments, so that forest charges more closely approximate the stumpage value of the standing trees. To evaluate this policy option, Scenario #3 considered the effects of a 20% increase in log export charges together with a 10% increase in sawnwood export charges, on each of the arguments in the objective function.

Scenario #4. In this last scenario, a 10% increase in domestic processing capacity was considered. The objective is to analyze the impacts and the possible trade-offs that may result if such policy option were to become a reality.

The results of all these experiments are presented graphically in Figs. 5.5 to 5.9 below. The results are quite revealing.

Looking at the results of Scenario #2 in relation to base forecast reveals two interesting outcomes: (1) a 20% reduction in logging will reduce both private and public concerns; but (2) the public sector will be hurt more than the private sector because forestry policy makers will not allow private profit to fall beyond a certain threshold. Instead they would rather allow employment, reforestation, government revenue, and foreign exchange earnings to drop substantially in order to minimize the effect on profits. This is illustrated graphically by a larger drop in all arguments but profit. Since government revenues and reforestation are equally important to policy makers, it is doubtful whether a policy option that tends to reduce logging drastically would ever be politically acceptable.

Comparing scenario #3 to the baseline case indicates that the combined increase in log and sawnwood export charges results in (a) a slight increase in the employment level; (b) a substantial increase in reforestation activities, government revenues, and private profit; and (c) a deep reduction in foreign exchange earnings and savings. The implication is that foreign exchange earnings and savings would be given up in order to obtain greater levels of these other performance measures, especially profit.

Comparing Scenario #4 with Scenario #1 (benchmark scenario) reveals that a 20% increase in domestic processing capacity is likely to (1) improve significantly the employment level (see Fig.5.5); (2) reduce reforestation activities a little (see Fig.5.6); (3) reduce government revenues substantially (see Fig.5.7); (4) improve foreign exchange earnings in 1991, then worsen the country's foreign exchange position in the following years (see Fig.5.8); (5) reduce very drastically private profit (see Fig.5.9). Because of this drastic reduction in profit, it is questionable whether a policy proposal to increase the current level of domestic processing by 20% would ever be implemented.

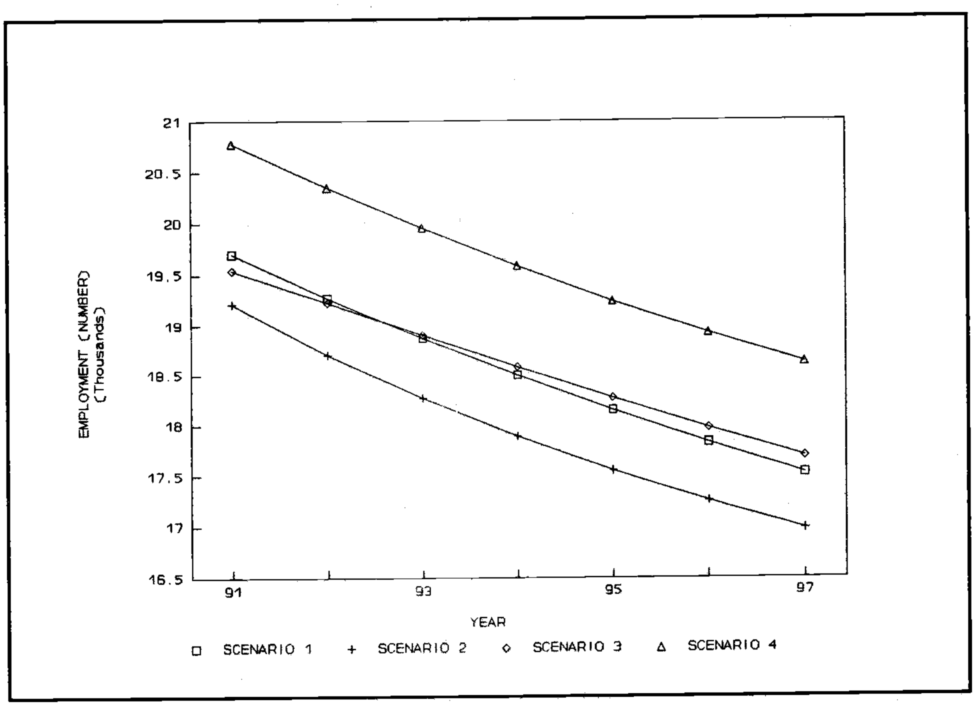

Fig.5.5 Comparison of Employment by Alternative Policy Scenarios, 1991-97

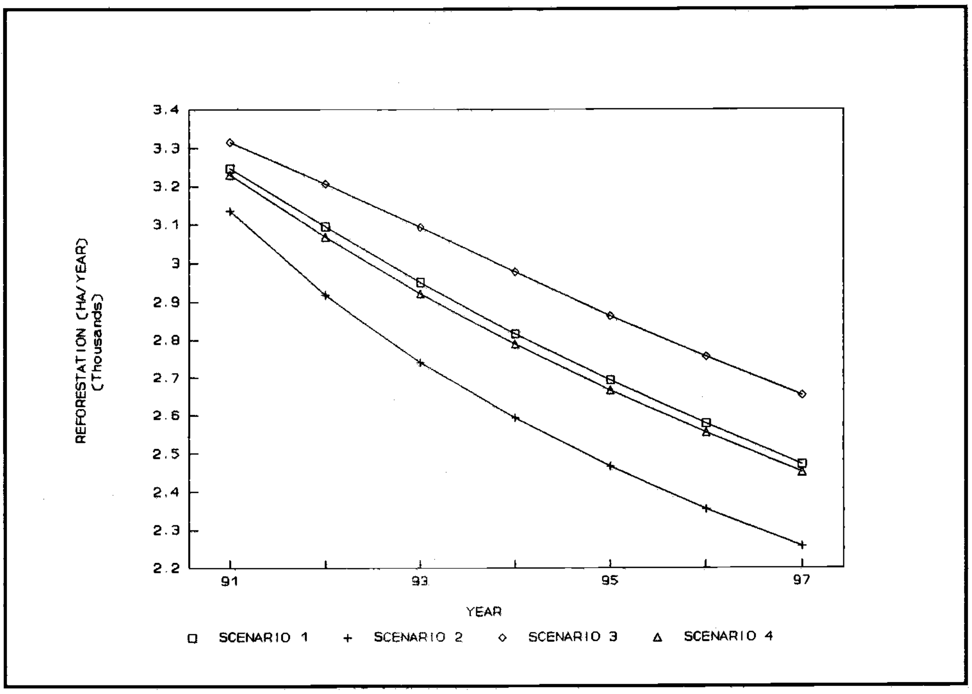

Fig.5.6 Comparison of Reforestation by Alternative Policy Scenarios, 1991-97

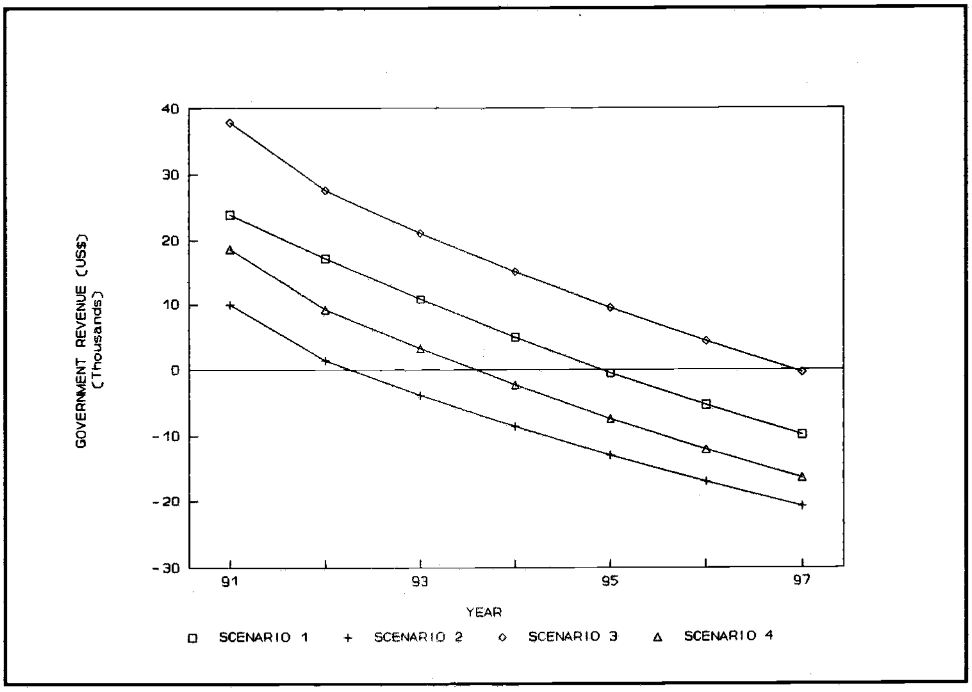

Fig.5.7 Comparison of Government Revenue by Policy Scenarios, 1991-1997

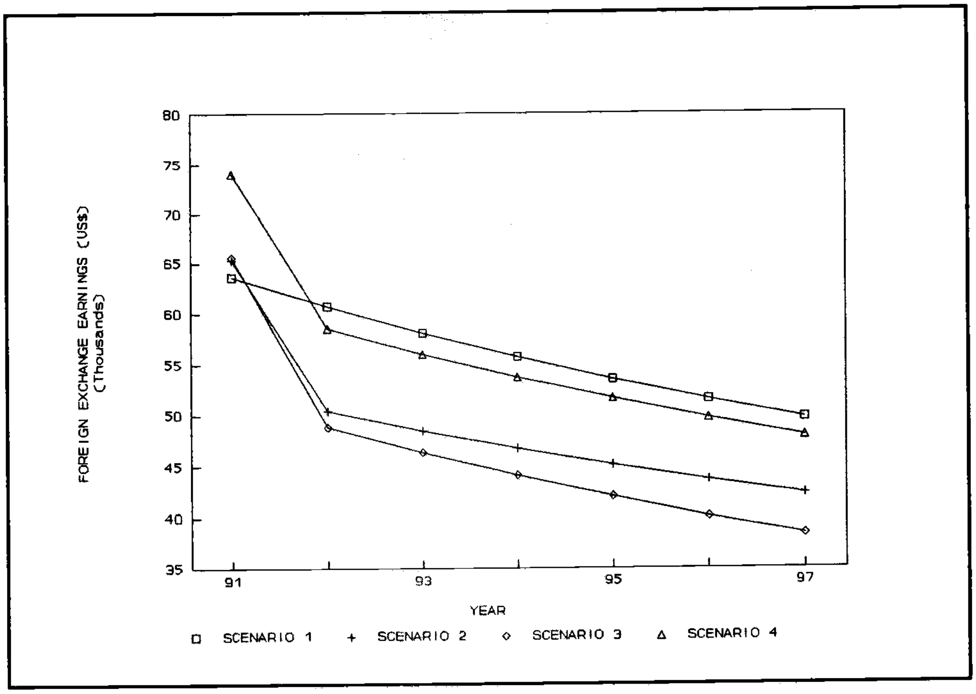

Fig.5.8 Comparison of Foreign Exchange Earnings by policy Scenarios, 1991-97

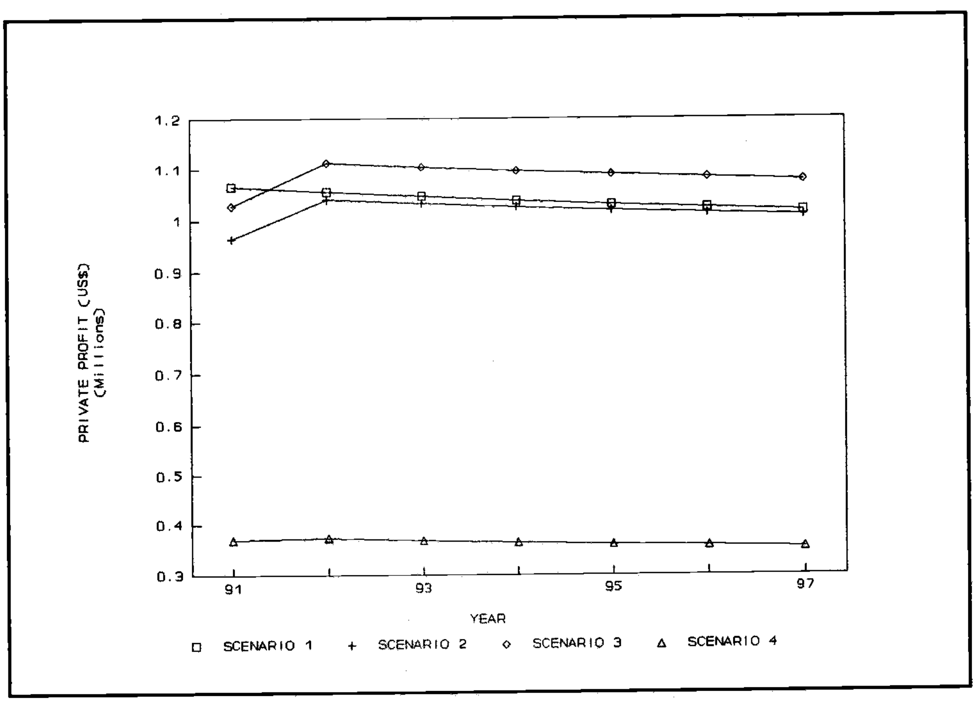

Fig.5.9 Comparison of Profit by Alternative Policy Scenarios, 1991-1997

CHAPTER VI

SUMMARY AND CONCLUSIONS

This study begins with the premise that traditional forestry policy evaluations are incomplete because they consider only economic efficiency; and that the integration of both economic and political forces is essential in understanding the behavior of public policy makers and to achieve meaningful forestry policy reforms in developing countries. The analysis, therefore, was formulated in a dynamic policy preference function framework whereby policy weights for alternative policy options could be estimated.

The review of governmental forestry policies in the Côte d'Ivoire revealed that private profit enhancement, government revenues, foreign exchange earnings and savings, reforestation, and employment expansions were appropriate attributes measuring the objectives pursued by policy makers in the forest sector. It was recognized that first-best solutions would be difficult, if not impossible, to achieve. The full achievement of one objective can be accomplished only at the expense of another. For example, the government desire to expand employment may not be fully realized if the profit maximizing producer insists on using more skillful foreign nationals rather than unskillful local labor. Trade-offs among these development objectives are, therefore, inevitable.

A quadratic policy preference function (PPF) was postulated with the above attributes as arguments. Using time series from the Côte d'Ivoire the expected value of the PPF was maximized subject to a set of stochastic economic constraints. The solution process was the Revealed-Preference-Inverse-Control estimation technique (RPIC). The implementation of RPIC required the linearization of any nonlinear constraints in order to express the problem as a linear-quadratic stochastic control problem. The solution of the problem took the form of a linear feedback control equation, where the optimal levels of the policy instruments were expressed as linear functions of lagged values of appropriate state variables.

Using a 2SLS technique proposed by Chow (1983) the coefficients of the arguments in the PPF were estimated. Next, marginal utilities and utility elasticities were calculated for the arguments in the objective function. The results revealed that forestry policy makers in the Côte d'Ivoire have attached higher weights to profit, government revenue expansion, and reforestation in the beginning of forest-based industrial development. But by 1990, the importance of private profit was reduced. The 1990 utility elasticities indicate that government revenue was the most valued objective, followed by private profit and reforestation. Employment and foreign exchange earnings and savings do not appear to be valued directly. They are given up by public policy makers in order to obtain greater levels of profit, government revenue, and reforestation activities. Only three estimates (those associated with FE_t^2, $\pi_t GR_t$, and $GR_t FE_t$) out of the sixteen estimates of the PPF parameters were found to be statistically significant, suggesting that most of the objective function parameters are not estimated accurately. This, however, did not mean that the estimates of the objective function were uninformative. A formal hypothesis test, using the Chi-square distribution, rejected the hypothesis that all the estimated PPF weights were equal to zero, implying that the arguments specified in the PPF were of some importance in explaining the behavior of forestry policy makers in the Cote d'Ivoire. The hypothesis that private profit was the only important argument in the policy preference function was also tested. The result showed clear statistical evidence against that hypothesis.

The predictive ability of the model was tested successfully using the Root Mean Square Error (RMSE) criterion. The validated model was then used in policy evaluation. Four economic scenarios were simulated. The simulation results revealed three interesting conclusions: (1) a 20% reduction in logging activities in the Cote d'Ivoire would be detrimental to both private and public interests, with a heavier burden on the public sector. This is because forestry policy makers would react by allowing the country's foreign exchange position, and government revenue to decline to protect private sector, and thereby maintain private capital in the forest sector; (2) a simultaneous increase in log and sawnwood export taxes by 20 and 10 percent respectively, would result in a substantial increase in government revenue, reforestation, and profit. Foreign exchange earnings and savings would have to be sacrificed significantly. Employment would deteriorate only slightly; (3) a 10 percent increase in domestic processing capacity would improve employment, but worsen all other arguments; profits would be reduced to almost nothing.

The implication of the information provided by the simulations is that forestry policy reform proposals should not be implemented too quickly. Care should be exercised as to the intensity and direction of the effects of the proposed measures. For example, tropical timber boycotts are often advocated as a means to reduce deforestation in the tropics (see Vincent, 1990). However a boycott, leading to a reduction of logging in the range of 20%, is likely to face strong political resistance since such reduction would worsen all forestry development objectives. Increase in forest product export taxation, on the other hand, seems to be a good idea since it would improve all forestry development objectives except foreign exchange and labor. Since these last two objectives are important to policy makers only to the extent that they provide higher levels of the other objectives, there are no major obstacles for forestry taxation policy reform in the Cote d'Ivoire.

The results of this study are instructive on their own. However, the data series used are still crude and because time series were not available for some variables (e.g; log export tax, sawnwood export tax), many assumptions have been made concerning key factors in the model. This may have been responsible for the lack of accuracy in the imdividual estimates of the PPF parameters. These weaknesses may be remedied with additional data and testing. But for now, the paper and its results may be viewed not so much as a recommendation for policy but rather as a description of a promising methodology for forest sector analysis in developing countries.

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APPENDICES

APPENDIX A

DATA DESCRIPTION AND SOURCES

To econometrically estimate the model specified in this study, time series were collected on a number of variables concerning the forest sector in the Côte d'Ivoire. This appendix describes the data formation and sources.

1. **Logging Output** (q_t).

This is the total quantity of industrial roundwood produced each year. It is measured in thousand cubic meter, and is taken directly from various issues of FAO Yearbook of Forest Products. It appears in Table 13 below as (q_t).

2. **Domestic Processing Capacity** (q_{1t}^d).

In this study, the capacity of wood-processing plants is measured in terms of the total quantity of raw logs allocated to local mills for processing. Domestic processing capacity is expressed in thousand cubic meter of industrial roundwood, and is computed by subtracting log export quantity from total logging output in a given year, as tabulated in FAO Yearbook of Forest Products. The series is presented in Table 13 below as (q_{1t}^d).

Sawnwood is the major processed wood product exported from the Côte d'Ivoire. Furthermore, prior to June 1, 1990, sawnwood has been the only processed wood product whose exports were subject to taxation (Ministère de l'industrie, 1990). Thus, in this study, "processed products" means sawnwood.

3. **Average Log Export Price** (P_{1t}^{e}).

This is the average unit value of yearly raw log exports. It is computed by dividing the dollar value of total industrial roundwood exports (expressed in $1000 and available from FAO Yearbook of Forest Products) by the total quantity of raw log exports (expressed in 1000 cubic meters, and also available from FAO Yearbook of Forest Products). Thus, log export price is measured in $\$/m^3$. Both price and export values were expressed in current dollars. The resulting time series is presented in Table 13 below as (P_{1t}^{e}).

4. **Average Sawnwood Export Price** (P_{2t}^{e}).

Like average log export price, sawnwood export price is measured as the average unit value of yearly sawnwood exports (expressed in $\$/m^3$). This is obtained by dividing the total dollar value of sawnwood exports (measured in $1000) by the total quantity of sawnwood exports (expressed in 1000 cubic meters) as tabulated in FAO Yearbook of Forest Products (see Table 11).

5. **Average Log Export Tax** (T_{1t}).

Log export tax in the Côte d'Ivoire accounts for about 90% of total government log export revenues. It is by far the major fiscal instrument existing in the forest sector. Timber royalty, license fee and area fee (taxe de superficie) also are applied in the forest sector, but their rates are so low (see Table 10 below) that it was assumed in this study that they can be neglected without loss of generality. Although the statistics for earlier years are not available, it is very likely that forest royalty rates in the 1960s were much lower than the 1984 rates shown in Table 10.

Table 10. Côte d'Ivoire Royalty Schedule, 1984 ($US\$/m^3$)

Type of Log	Exported	Locally Used
High-valued species	1.50	0.75
Middle-valued species	1.00	0.50
Low-valued species	0.50	0.25

Source: Gray 1983.

Gray also reported representative export taxes on logs in the Côte d'Ivoire (see Table 11).

Table 11. Côte d'Ivoire: Representative Log Export Taxes(1980)

Species of Logs	Tax rate (%)	Taxes (US$/m3)
Sipo	44.6	111.50
Aboudikrou	44.6	94.10
Acajou (Mahogany)	44.6	60.20
Iroko	36.6	65.90
Samba	36.6	49.40
Llomba	24.6	16.00

Source: Gray 1983; Repetto and Gillis 1988.

As in many other developing countries, log export tax in the Côte d'Ivoire is "ad valorem" and is based on the posted price (valeur mercuriale) of log exports. These posted prices are in general slightly lower than f.o.b prices.

The tax rates shown in Tables 10 and 11 above have apparently remained unchanged throughout the 1980s (Gray,1983). Thus, time series for log export charges are identical numbers with no variation in them. In this study, the variability problem was overcome by exploiting the variations in both posted prices and the quality composition of log exports from one year to another. For example, in the 1960s and early 1970s, log export quantities compositions were intensive in high-valued species; while in the 1980s and 1990s, as high-valued species become rare, log exports consisted of more middle and low-valued species.

Also, in the early years of forestry development in the Côte d'Ivoire, as in most developing countries, the need for capital investment was so great and the government desire to attract foreign investors so real, that it is likely that log export taxes were much lower than those shown on Table 11 above. Thus, the tax rate structure shown in Table 12 below was assumed for log exports:

Furthermore, for each year, a specie composition of aggregate log export quantity is derived based on sparse information available from various sources. For example, in 1966 it was postulated that 65.8% of total log export was in high-valued species, while 32.9% and 1.3% were respectively in medium and low-valued species. Multiplying these percentages by the log export tax rates specified in Table 12, an average log export tax rate is obtained for 1966, which in turn is multiplied by the corresponding posted price (measured by log export unit value) to determine finally the log export Tax T_{1t} presented in Table 13 below.

Table 12. Log export Tax Rates Structure Asumed in the Derivation of Time Series for Average Log Export Tax (% of Posted Prices).

Log Quality Specification	Period 1966-1975. (1)	Period 1976-1990. (2)
High-valued Species	35	44.6
Medium-valued Species	30	36.6
Low-valued Species	5	24.6

(1) the values assumed for this period are based on information in Marchés Tropicaux et Mediterranéens. But their relative sizes are purely speculative, based only on the author's own perception.
(2) the values for this period are taken from Gray, 1983.

6. **Average Sawnwood Export Tax** (T_{2t}).

The procedure used to derive the sawnwood export tax series is similar to that used for log export tax. The resulting time series for average sawnwood export tax, T_{2t}, is presented in Table 13 below.

7. **Total Employment in the Forest Sector** (L_t).

This is the total number of people employed in the forest industrial sector each year. The data for this variable are collected from various sources including Minitère de l'Industrie, 1990; and Gillis, 1988. The resulting series is in Table 13 below as (L_t).

8. Total Reforestation (R_t).

The reforestation variable is the total area of forest artificially regenerated each year (measured in hectare). The corresponding time series was collected partly from FAO, 1981, and partly from Ministère de l'Industrie, 1990. Adjustments by extrapolation were made by the author whenever there is discrepancy in the data between the two sources, and for years where the data are not available. The final form of the series is presented in Table 13 below as (R_t)

Table 13. Selected Statistics for the Côte d'Ivoire's Forest Sector, 1966-1990

Year	q_t	q_{1t}^d	L_t	R_t	P_{1t}^e	P_{2t}^e	T_{1t}^e	T_{2t}^e
1966	2572	750	8750	237	32.90	69.71	10.92	4.30
1967	2992	820	8983	614	33.33	69.89	11.13	4.35
1968	3470	890	8997	1820	33.10	72.12	11.15	4.50
1969	4276	950	9531	2699	35.00	86.90	11.88	5.47
1970	3548	1037	10475	2943	33.74	86.83	11.55	5.39
1971	3920	987	14374	3045	31.82	78.27	10.98	4.98
1972	4178	1000	16100	3279	40.12	85.71	13.96	5.47
1973	5169	1672	17341	3266	68.53	132.94	24.04	8.61
1974	4629	1596	18375	3691	71.34	148.01	25.23	9.62
1975	3959	1540	18787	3313	67.30	140.50	23.98	9.27
1976	5095	1820	21700	3427	80.94	146.41	29.07	9.69
1977	5321	2067	23500	4427	87.14	166.91	31.54	11.22
1978	4580	2061	21400	3826	95.28	196.42	34.76	13.39
1979	5079	2292	17100	4207	99.37	188.96	36.53	13.07
1980	4968	1912	15100	4106	160.45	262.60	59.43	18.43
1981	4005	1772	15050	4000	128.58	209.93	47.98	14.95
1982	4086	1819	14033	3810	97.67	186.17	36.72	13.44
1983	4075	1789	14062	3750	88.97	185.90	33.70	13.60
1984	3878	1751	13305	3679	83.79	166.21	31.97	12.33
1985	3227	1833	12545	3598	93.77	158.75	36.04	11.94
1986	2973	1953	12250	3510	121.33	210.67	46.98	16.05
1987	2547	1971	11997	3450	131.39	265.26	50.98	20.26
1988	2541	2040	11576	3398	131.39	265.26	51.87	20.53
1989	2574	2122	10957	3309	131.39	265.26	52.61	20.79
1990	2585	2122	11456	3410	131.39	265.26	54.13	21.06

Note: See text for data sources and formation

APPENDIX B

OBJECTIVE FUNCTION PARAMETERS ESTIMATION

I. Linearization of the Nonlinear Constraints

The adoption of the revealed-preference-inverse-control method as estimation technique requires that the problem at hand be written as a linear-quadratic optimal control problem. However, the government revenue constraint, the profit constraint, and the foreign exchange earnings/savings constraint, as expressed in Eqs.(3-8), (3-9) and (3.10), respectively, are not linear[9], and thus cannot be utilized in a linear-quadratic optimal control problem. This obstacle could, however, be overcome by linearizing the nonlinear constraints equations using a first-order Taylor-series expansion.

1.1 Linearization of the Government Revenue Equation

The government revenue constraint equation is:

(3-8) $$GR_t = \rho H_t + T^e_{1t} q^e_{1t} + T^d_{1t} q^d_{1t} + T^e_{2t}\, q^e_{2t}$$

---

[9]The government revenue constraint [Eq.(3-8)] is not linear in log and sawnwood export taxes and quantities; while both the profit constraint (Eq.[3-9]) and the foreign exchange earnings and savings constraint (Eq.[3-10]) are nonlinear in prices and quantities.

Evidence in the literature (Gray, 1983; Grut et al., 1991) suggest that the only taxes of any significance are those levied on log exports and exports of processed products (sawnwood in this study). Consequently, both the area tax rate and the tax rate on logs locally processed are set equal to zero (i.e., $\rho \approx 0$; $T^{d}_{1t} \approx 0$). Equation (3-8) thus becomes

(B-1) $$GR_t = T^{e}_{1t} q^{e}_{1t} + T^{e}_{2t} q^{e}_{2t}$$

Applying a first-order Taylor-series expansion to (B-1) and recognizing that $q^{e}_{1t} = q_t - q^{d}_{1t}$ yield the following expression for government revenue constraint:

(B-2) $$GR_t \approx -[\overline{T^{e}_1 q^{e}_1} - \overline{T^{e}_2 q^{e}_2}] + \overline{T^{e}_1} q_t - \overline{T^{e}_1} q^{d}_{1t} + \overline{q^{e}_1} T^{e}_{1t} + \overline{q^{e}_2} T^{e}_{2t} + \overline{T^{e}_2} q^{e}_{2t} + h.o.t$$

where h.o.t stands for the higher-order terms in the Taylor-series expansion.

Next, substitute the sawnwood export price expectation equation (Eq.[3-5]) into the sawnwood export equation and write Eq.(3-6) as

(B-3) $$q^{e}_{2t} = \mu_0 \delta_1 + (\mu_1 \delta_1) p^{e}_{2t-1} + \delta_2 T^{e}_{2t} + \delta_1 \varepsilon_{4t} + \varepsilon_{5t}$$

Finally, substituting (B-3) into (B-2) results in the following approximated equation for the government revenue constraint:

$$\text{(B-4)}\qquad GR_t \approx -[\overline{T_1^e q_1^e} + \overline{T_2^e q_2^e} - (\delta_1\mu_0)\overline{T_2^e}] + \overline{T_1^e} q_t - \overline{T_1^e} q_{1t}^d + \overline{q_{1t}^e} T_{1t}^e + (\overline{q_2^e} + \delta_2 \overline{T_2^e}) T_{2t}^e + (\overline{T_2^e} \delta_1 \mu_1) p_{2t-1}^e + \varepsilon_{7t}$$

where $\varepsilon_{7t} = \delta_1 \varepsilon_{4t} + \varepsilon_{5t} + h.o.t.$

Note now that in this approximated form, the government revenue constraint is linear in taxes, quantities, and price. Thus it can be appropriately used in a linear-quadratic optimal control problem.

1.2 Linearization of the Profit Equation

The profit constraint (Eq.[3-9]) is recalled here for convenience

$$\text{(3-9)}\qquad \pi_t = (p_{1t}^e - T_{1t}^e) q_{1t}^e + p_{1t}^d q_{1t}^d + (p_{2t}^e - T_{2t}^e) q_{2t}^e + p_{2t}^d q_{2t}^d - m_1 q_t - m_2 (q_{2t}^e + q_{2t}^d)$$

Letting $p_{1t}^d = \overline{p}_1^d$ (i.e., fixed since more or less controlled by the government), (3-9) becomes Eq.(B-5) below

$$\text{(B-5)}\qquad \pi_t = [p_{1t}^e q_{1t}^e - T_{1t}^e q_{1t}^e + p_{2t}^e q_{2t}^e - T_{2t}^e q_{2t}^e] + [\overline{p}_1^d q_{1t}^d - m_1 q_t - m_2 q_{2t}^e + (\overline{p}_2^d - m_2) q_{2t}^d]$$

The expression in the first bracket is nonlinear in prices, quantities and taxes. This makes the profit equation unsuitable for use in a linear-quadratic optimal control problem. Applying a first-order Taylor-series expansion to (B-5), however, yields the following linear approximated equation for the profit constraint:

$$(B\text{-}6)\quad \pi_t \approx (\overline{T_1^e q_1^e} - \overline{p_1^e q_1^e} + \overline{T_2^e q_2^e} - \overline{p_2^e q_2^e}) + \overline{q_1^e} p_{1t}^e + (\overline{p_1^e} - \overline{T_1^e}) q_{1t}^e - m_1 q_t + \overline{p_1^d} q_{1t}^d$$
$$+ (\overline{p}_2^e - m_2 - \overline{T_2^e}) q_{2t}^e - \overline{q_1^e} T_{1t}^e + \overline{q_2^e} p_{2t}^e - \overline{q_2^e} p_{2t}^e - \overline{q_2^e} T_{2t}^e + (\overline{p}_2^d - m_2) q_{2t}^d$$

Recalling again that

$$q_{1t}^e = q_t - q_{1t}^d$$

$$q_{2t}^d = \psi_0 + \psi_1 q_{1t}^d + \varepsilon_{6t}$$

$$q_{2t}^e = \delta_1 p_{2t}^e + \delta_2 T_{2t}^e + \varepsilon_{5t}$$

$$p_{1t}^e = \gamma_0 + \gamma_1 p_{1t-1}^e + \varepsilon_{3t}$$

$$p_{2t}^e = \mu_0 + \mu_1 p_{2t-1}^e + \varepsilon_{4t}$$

and making the appropriate substitutions in (B-6) gives the following final approximated equation for the profit constraint:

$$(B\text{-}7)\quad \pi_t \approx \overline{T_1^e q_1^e} - \overline{p_1^e q_1^e} - \overline{p_2^e q_2^e} + \overline{T_2^e q_2^e} + \psi_0 (\overline{p}_2^d - m_2) + \gamma_0 \overline{q_1^e} + \mu_0 \overline{q_2^e}$$
$$+ \mu_0 \delta_1 (\overline{p_2^e} - m_2 - \overline{T_2^e}) + \gamma_1 \overline{q_1^e} p_{1t-1}^e - \overline{q_1^e} T_{1t}^e + (\overline{p_1^e} - \overline{T_1} - m_1) q_t$$
$$+ \delta_2 (\overline{p_2^e} - m_2 - \overline{T_2^e} - \overline{q_2^e}) T_{2t}^e + [\psi_0 (\overline{p}_2^d - m_2) - \overline{p_1^e} + \overline{T_1} + \overline{p}_1^d)] q_{1t}^d$$
$$+ \mu_1 (\overline{q_2^e} + \delta_1 \overline{p_2^e} - \delta_1 m_2 - T_2^e) p_{2t-1}^e + e_{\pi_t}$$

where,

$$e_{\pi_t} = \overline{q_1^e}\varepsilon_{3t} + [\overline{q_2^e} + \delta_1(\overline{p_2^e} - m_2 - \overline{T_2^e})]\varepsilon_{4t} + (\overline{p_2^e} - m_2 - \overline{T_2^e})\varepsilon_{5t} + (\overline{p_2^d} - m_2)\varepsilon_{6t} + h.o.t$$

Note that the nonlinear profit equation is now linear in all of its variables, and thus can be appropriately used in a linear-quadratic optimal control problem.

1.3 Linearization of the Foreign Exchange Earnings and Savings Equation

The foreign exchange earnings and savings equation is:

(3-10) $$FE_t = \theta_1(p_{1t}^e q_{1t}^e + p_{2t}^e q_{2t}^e) + \theta_2(p_{2t}^d q_{2t}^d)$$

where p_{2t}^d, the average price of sawnwood on the domestic market could be assumed constant and set equal to $\overline{p}_2^d$; since it is more or less controlled by the government. Thus, the foreign exchange earnings and savings equation is nonlinear only in export prices and quantities. Applying a first-order Taylor-series expansion to it yields the following approximation:

(B-8) $$FE_t \approx -\theta_1(\overline{p_1^e q_1^e} + \overline{p_2^e q_2^e}) + \theta_1\overline{q_1^e}p_{1t}^e + \theta_1\overline{p_1^e}q_{1t}^e + \theta_1\overline{q_2^e}p_{2t}^e + \theta_1\overline{p}_2^e q_{2t}^e + \theta_2\overline{p}_2^d q_{2t}^d + h.o.t.$$

But $$q_{1t}^e = q_t - q_{1t}^d\,,$$

$$p^e_{1t} = \gamma_0 + \gamma_1 p^e_{1t-1} + \varepsilon_{3t} ,$$

and

$$p^e_{2t} = \mu_0 + \mu_1 p^e_{2t-1} + \varepsilon_{4t} ;$$

thus, (B-8) becomes

$$\text{(B-9)} \quad FE_t \approx \theta_1(-\overline{p^e_1 q^e_1} - \overline{p^e_2 q^e_2} + \gamma_0 \overline{q^e_1} + \mu_0 \overline{q^e_2}) + \theta_1 \overline{p^e_1} q_t - (\overline{p^e_1}\theta_1) q^d_{1t} + (\theta_1 \gamma_1 \overline{q^e_1}) p^e_{1t-1} + (\overline{q^e_2}\theta_1 \mu_1) p^e_{2t-1} + (\overline{p^e_2}\theta_1) q^e_{2t} + (\overline{p^d_2}\theta_2) q^d_{2t} + \theta_1(\overline{q^e_1}\varepsilon_{3t} + \overline{q^e_2}\varepsilon_{4t}) + h.o.t$$

Furthermore, recall that

$$q^e_{2t} = \delta_1 p^e_{2t} + \delta_2 T^e_{2t} + \varepsilon_{5t}$$

where

$$p^e_{2t} = \mu_0 + \mu_1 p^e_{2t-1} + \varepsilon_{4t} ;$$

and

$$q^d_{2t} = \psi_0 + \psi_1 q^d_{1t} + \varepsilon_{6t}$$

Substituting these last expressions into (B-9) results in the following final approximation for the foreign exchange earnings and savings constraint equation:

$$\text{(B-10)} \quad FE_t \approx (\theta_1 \delta_1 \mu_0 \overline{p^e_2} + \theta_2 \psi_0 \overline{p}^d_2 + \theta_1 \mu_0 \overline{q^e_2} + \theta_1 \gamma_0 \overline{q^e_1} - \theta_1 \overline{p^e_2 q^e_2} - \theta_1 \overline{p^e_1 q^e_1}) + \theta_1 \overline{p^e_1} q_t + \theta_1 \overline{q^e_1} \gamma_1 p^e_{1t-1} + (\psi_1 \theta_2 - \theta_1 \overline{p^e_1}) q^d_{1t} + \theta_1 \delta_2 \overline{p^e_2} T^e_{2t} + (\theta_1 \mu_1 \overline{q^e_2} + \theta_1 \mu_1 \delta_1 \overline{p^e_2}) p^e_{2t-1} + e_{FE_t}$$

where $e_{FE_t} = \theta_1 \overline{p}^e_2(\delta_1 \varepsilon_{4t} + \varepsilon_{5t}) + (\theta_2 \overline{p}^d_2)\varepsilon_{6t} + h.o.t$

Note here also that in its approximated form, the foreign exchange earnings and savings constraint is linear in its variables; thus it can be used in a linear-quadratic optimal control problem.

Now that all the constraint equations are linear, the maximization problem facing forestry policy makers in the Côte d'Ivoire is written in matrix notation as the following linear-quadratic stochastic programming problem:

(19) $$Max_{X_t}. \quad W = E\{\sum_{t=1}^{\infty} \lambda^t (k_t' Z_t + Z_t' K Z_t)\}$$

subject to

(20) $$Z_t = AZ_{t-1} + CX_t + b_t + \epsilon_t$$

where Z_t and X_t are respectively, the vector of state variables and the vector of control variables. More specifically,

$$Z_t' = [\pi_t \; FE_t \; GR_t \; L_t \; R_t \; q_t \; q_{1t}^d \; p_{1t}^e \; p_{2t}^e]$$

$$X_t' = [q_t \; q_{1t} \; \mathrm{T}_{1t} \; \mathrm{T}_{2t}]$$

ϵ_t is a vector of serially uncorrelated error terms; and k_t, K, A, C, and b_t are matrices of fixed values. K, A, and C are assumed to be time invariant, but b_t may depend on time.

The solution of the problem presented by Eqs. [19] and [20] takes the form of a linear feedback control equation where the vector of policy instruments, X_t, becomes a linear function of the vector of past values of the state variables, Z_{t-1}

(Chow, 1983; Fulton and Karp, 1989); i.e.,

(21) $$X_t^* = G Z_{t-1} + g_t$$

Because K, A, and C are assumed constant over time, the feedback rule matrix G is also time invariant. The vector g_t may vary over time, because of changes in the economic environment (i.e., changes in b_t) and/or variations in the linear portion of the objective function (k_t).

Knowing K, A, C, k_t and b_t, matrices G and g_t can be computed using the following equations iteratively,

(22) $$G = -(C'HC)^{-1}C'HA$$

(23) $$H = K + \lambda (A+CG)'H(A+CG)$$

(24) $$g_t = -(C'HC)^{-1}C'(Hb_t - h_t)$$

(25) $$h_t = [I - \lambda (A+CG)']^{-1}[-k_t/2 + (A+CG)'Hb_t].$$

The solution method is that of a dynamic programming where the above equations are solved iteratively and backward in time until they reach a steady state.

In the first iteration, H is set equal to K and Eq.(22) is solved for G. In the second iteration, H is calculated using Eq.(23). This iterative process is continued until the absolute values of the roots of (A+CG) are less than unity, assuring that G and H converge. Next, Eq.(25) is used to compute the vector h_t. Finally, Eq.(24) is used to obtain the intercept of the feedback rule, g_t (Chow, 1983; Fulton and Karp, 1989).

2. Objective Function Parameter Estimation: Chow's 2SLS Method.

The method suggested by Chow (1983) for the estimation of models such as this one consists of applying ordinary least squares (OLS) technique twice.

(1) In the first stage the equations of motion and the optimal feedback rule are estimated by OLS. This leads to consistent estimates of A, C, G, b_t and g_t.

(2) The idea in the second stage is to use the results of the first stage together with Eqs.(22)-(25) to recover the parameters in the quadratic objective function. The procedure can be operationalized as follows[10]:

(i). Write Eqs.(22) and (23) above as

$$(R' @ C')h = 0$$

$$(I - \lambda R' @ R')h = k$$

where R=A+CG; h=vec(H) and k=vec(K); and @ is the Kronecker product operator.

(ii). Next, collect the non-zero rows of the second equation above corresponding

[10]The estimation procedure described here is based on Fulton and Karp (1989).

to the non-zero elements of matrix K or vector k and write them as,

$$(I-\lambda R' @ R')_0 h = 0$$

(iii). Now using the first equation in step (i) together with the equation in step (ii), the following linearly homogeneous equation in h can be written,

$$Bh = 0$$

where $$B = \begin{pmatrix} R' @ C' \\ (I-\lambda R' @ R')_0 \end{pmatrix}$$

Because no unique (non-trivial) solution exits for homogeneous-equations systems, a solution may be to discard extra equations and make the remaining homogeneous equations nonhomogeneous by a normalization process. Such a solution may be consistent, but involves discarding useful information. Chow suggests the following:

(iv). Select only the $n(n+1)/2$ unique elements of the n-dimensional symmetric matrix H to form a column vector M so that the above homogeneous system be written as

$$QM = 0,$$

where Q is a subset of the matrix B in which all the columns of B such that $h_{ij} = h_{ji}$ are added together (the determination of Q becomes less confusing once the matrix Bh is written out in its extensive form). Next, normalize by setting one $h_{ii} = 1$, and partition Q and M' as $(Q_1 Q_2)$ and $(M_1' \ -1)$. This transformation allows the above homogeneous system to be written as the following nonhomogeneous-equations system

$$Q_1 M_1' - Q_2 = 0$$

which leads to the following ordinary least squares estimator

$$M_1 = (Q_1' Q_1)^{-1} Q_1' Q_2$$

(v). Once M_1 is estimated, the symmetric matrix H is known, and the non-zero elements of vec(K) can be estimated using the non-zero rows of $(I - \lambda R' @ R')$

(vi). Having estimated H and K, the vector k_t of the parameters of the linear portion of the quadratic objective function can be derived by first solving the following equation for a_t

$$C' [I - \lambda R'] K a_t = C' H C g_t + C' [I - \lambda (I - \lambda R')^{-1} R'] H b_t$$

and then estimating k_t by $k_t = -2 K a_t$ (Chow, 1983 p.383).

Note that for an exactly identified model as the one in this paper, the vector k_t will be uniquely identified if the number of elements in a_t is equal to the number of policy instruments in the problem.

(vii). Obviously, for the above estimation procedure to be implemented, it is necessary to assume a value for the scalar discount factor λ. In this paper various values of λ ranging from 6, 6.5, and 7% have been assumed in order to assess the sensitivity of the objective function parameter estimates to changes in the social discount rate.