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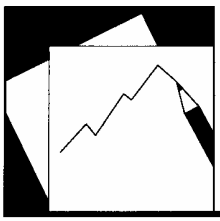

IMF Working Paper

Forestry Taxation in Africa: The Case of Liberia

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Forestry Taxation in Africa: The Case of Liberia

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Abstract

Countries generally tax the forestry sector to achieve the twin objectives of revenue maximization and sustainability of logging levels. In an ideal world of perfect markets and information, auctions would be the best instrument to determine the price of extraction rights. However, a number of factors—including a lack of information on the forest resources under consideration, uncertainties as to the stability of property rights over time, and a lack of access to credit—have limited the use of auctions so far, particularly in low-income countries. To establish transparency of the forestry sector's financial flows, this paper discusses a radical simplification of Liberia's current timber tax structure, including a proposal to reduce the sector's current tax system to two instruments, an area tax and an export tax.

JEL Classification Numbers: H20, Q23, O55

Keywords: forestry, taxation, Africa, Liberia

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I. INTRODUCTION

Liberia is well-endowed with valuable forest resources, and the sector has made an important contribution to GDP over the past few decades. However, the diversion of revenue from the sector to fund Liberia's civil war through 2003 led the UN Security Council to impose a ban on timber exports since mid-2003. Taking into account the sector's revenue potential, but also concerns about sustainable logging, the Security Council has imposed a number of preconditions for the lifting of its sanctions. One important condition is the establishment of a transparent system of revenue collection.

To establish transparency of the sector's financial flows, Liberia is taking a number of actions with external assistance. To this end, this paper discusses a radical simplification of Liberia's current timber tax structure. The paper proceeds as follows: After a description of the evolution of Liberia's timber sector and of its tax structure, it provides an overview of the theory of timber taxation. Based on a theoretical model, a range of taxes and fees applied to forestry activities is being evaluated in light of the objectives of maximizing revenue collections, achieving sustainable logging levels, and promoting transparency through the use of levies that are easy to administer. Based on the need to establish simple and transparent collection mechanisms, the concluding section presents a proposal to reduce the sector's current tax system to two instruments, an area tax and an export tax. Over the medium term, and if the sector's tax administration capacity is improved, the export tax should be replaced by a tax on production.

II. LIBERIA'S TIMBER SECTOR

A. Evolution of Liberia's Timber Sector

Liberia's forest resources are significant. About half of the country's area is covered by high forests, compared with less than 10 percent of arable land. Liberia's forests are equivalent to about 45 percent of the remaining Upper Guinea Forest, which spans 10 West African countries from Guinea to Cameroon. They contain a number of valuable species—such as African mahogany—that are in high demand on world markets.

Timber activity began in the late 1960s, driven by low stumpage fees and the establishment of basic road infrastructure that opened access to forest areas. Through the mid-1970s, the timber sector was the fastest-growing sector of the economy, increasing its contribution to GDP from less than 5 percent to about 20 percent. Logging activity was carried out largely by foreign concessionaries. During the second half of the 1970s, the world demand for timber products dropped in response to global recessions, and the number of concessions declined from 49 in 1974 to fewer than 30 by 1980, also owing to the depletion of easily accessible logging areas.

During the first half of the 1980s, the timber sector remained stagnant because of the weak global demand in key markets but also because of political instability in Liberia. The sector had recovered somewhat by the late 1980s, but the outbreak of civil strife interrupted the sector's formal activities until peace was restored in 1997. Thereafter, logging activity recovered very rapidly, driven also by the demand for charcoal and firewood, reflecting the breakdown of the country's regular electricity supply.

The surge in logging activity soon raised concerns about its sustainability. In addition, international nongovernmental organizations began to point to possible links between Liberia's timber sector and its support for the civil war in Sierra Leone. A comparison between export data reported by the Liberian authorities and those from importing countries indicates that an important share of exports may have taken place at the margin of official channels.

Liberia: Timber Exports, 1997-2002
(In thousands of U.S. Dollars, f.o.b. basis)

	1997	1998	1999	2000	2001	2002
Official exports [1/]	7,526	12,288	23,419	67,505	79,884	146,473
Exports registered by importing countries	8,541	25,194	31,573	93,987	88,389	183,163
Difference	1,015	12,906	8,154	26,482	8,505	36,690
Memorandum item:						
Main importing countries						
France	6,535	16,013	15,754	29,189	23,728	25,635
Italy	134	3,558	7,308	13,295	15,008	42,057
Turkey	851	1,825	3,507	3,847	4,975	45,409
Portugal	861	402	1,856	2,826	1,239	323
Spain	...	1,222	1,227	2,548	3,375	3,623
Germany	58	1,209	1,162	1,850	4,541	3,002
Greece	...	966	556	4,086	4,648	6,478
Netherlands	...	...	192	1,307	1,594	807
Tunisia	...	...	...	528	454	149
United States	...	...	11	...	...	...
China	...	...	...	31,401	25,614	49,462
Indonesia	...	...	...	1,841	1,404	4,021
India	102	...	...	209	...	698
Senegal	...	...	...	1,061	1,809	1,499

Source: United Nations COMTRADE database (commodity 4403, rough/squared wood).

1/ U.N. Secretary General's report to the Security Council (S/2003/793, August 5, 2003).

Reflecting these developments, the UN Security Council began to pay increasing attention to the possible link between Liberia's timber activities and the civil war in Sierra Leone and the reemergence of internal hostilities in Liberia. Following the imposition of sanctions on Liberia related to its diamond trade and the civil war in Sierra Leone in 2001, the Security Council's panel of experts highlighted the existence of extrabudgetary transactions associated with timber activities and the involvement of timber companies in violating UN sanctions.[2]

To address these issues, the UN Security Council requested in 2002 that the government take steps, including the establishment of a transparent audit regime, to ensure that revenue from timber and other activities would be used for legitimate social, humanitarian, and development purposes. Independent audits sponsored by the European Union (EU) were expected to provide the necessary assurances, but the external auditor hired by the EU withdrew from the audit in late 2002, and the government of Liberia hired a local auditor. However, the UN Security Council determined in May 2003 that the local auditor did not provide the required assurances and, in light of the intensifying internal conflict, decided to impose a ban on exports of all timber products, which went into effect in July 2003.

Although the National Transitional Government of Liberia (NTGL) took office in October 2003, the Security Council decided against lifting the sanctions, citing the NTGL's lack of control over the logging areas, the continued lack of transparency of the revenue flow, and the need to establish effective oversight of the sector's activities.[3] Sanctions were again extended for 12 months at end-2004.

B. Liberia's Timber Revenue System

Over time, the number of taxes, charges, and fees on forestry activity has proliferated, driven particularly by the introduction of new taxes for specific purposes during the 1980s (see Appendix I for all current taxes, fees, and changes in timber activity). Four different charges are levied on the volume of trees (not specified by species) at the felling stage: two schedules of export taxes, differentiated by 28 species and also, for processed wood, by three stages of processing. In addition, eight administrative fees are levied on forestry activity and six on port services. Finally, there is an area tax. In sum, a tree can easily be subject to about 20 taxes, fees, and charges, based, to varying degrees, on volume, species, degree of processing, and administrative actions required.

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[2] See UN Security Council resolutions and reports S/RES/1343 (2001), S/2001/1015, S/2002/470, S/RES/1408 (2002), S/2002/1183, S/2002/1115, S/2003/466, S/2003/498, S/RES/1478 (2003).

[3] S/RES/1521 (2003).

Timber companies are also financially committed under concessions to the construction of schools, clinics, or roads. Furthermore, it became common practice for timber companies to undertake certain tasks that were originally the responsibility of the government, such as road construction, and were granted tax credits for those activities.

It is doubtful that the existing revenue system has any clear objective. Also, the presumed earmarking of certain revenue for specific purposes has been ineffective, given a revenue-sharing agreement between the Forestry Development Authority (FDA) and the Ministry of Finance, which does not recognize such earmarking and the absence of a sign that the FDA has directed collected revenue to the intended purposes. However, the existence of multiple processes to assess these different charges has created a lack of transparency and significant opportunities for misappropriations of revenue.

These concerns are compounded by the FDA's weakening over time. Founded in 1976 to oversee the timber sector and collect revenue, the FDA's functions were severely curtailed when a law was passed in 2000 to transfer the administration of contracts of so-called strategic commodities (including timber) to Liberia's president and when the FDA's Board of Directors was suspended for administrative reasons. Furthermore, with the hostilities in 2003 completely destroying its facilities, car park, and files, the FDA will require substantial technical and financial support to rebuild its structure before it can resume any role in the oversight of the forestry sector. A decision on the institutional arrangements for collecting revenue and granting concessions will also need to be made—the FDA's role in supervising the sector conflicts with its function as tax collector and administrator of concessions.

III. Why Are Forestry Taxes Different from other Taxes?

The taxation of the forestry sector is different from that of other sectors. First, the government, the sovereign tax authority and, in many cases, the natural resource owner, play a dual fiscal role. As the sovereign tax power, the government is responsible for ensuring that the natural resource sector makes its due contribution to public revenues. As the resource owner, the government must determine when to exploit its natural resources as well as ensure that it obtains an appropriate price for its resources, with related considerations of distributing the benefits of resource exploitation so as to promote sustainable economic growth and intergenerational equity. At one level, there is a fundamental conflict between resource companies and the government over the division of the risk and reward of resource development. Both parties want to maximize rewards and shift as much risk as possible to the other party. At another level, resource agreements and the associated fiscal rules create mutually shared interest between the resource company and the government. The magnitude of revenues to be divided is maximized through fiscal arrangements that encourage a stable fiscal environment and efficient resource development.

Second, taxation of forestry sector represents the price for the right to extract a scarce resource, whereas traditional taxes are concerned with raising a given amount of revenue while minimizing efficiency, equity, and administration costs. Third, forests

provide multiple services to society, not merely the market value of the wood harvested. These services include watershed protection, rangeland, recreation opportunities, and aesthetic values. Since many of these services are nonmarketable, private owners will make harvest decisions that may not coincide with maximizing the social benefits from woodland exploitation. However, the form in which these taxes are imposed influences the owner's decision on when to cut and hence the size of the social benefits obtainable from forestry. Forestry taxes can thus help reduce negative externalities and create positive externalities. Also, property rights, which define the rights to natural resources and the associated fiscal arrangements, are often not stable. The design of natural resource tax arrangements plays a role in determining the stability of natural resource property rights and thus influences the efficiency with which natural resources are exploited and their potential fiscal return.

In pursuing its objectives, the government needs to assess how efficient the various types of tax instruments would be in achieving them, their effect on the incentives and behavior of taxed companies, and their simplicity in terms of administrative costs. Based on a theoretical model presented in Appendix II, the following section compares alternative tax instruments being used in the forestry sector, with regard to their impact on efficiency, incentives, and administrative simplicity.

IV. Assessment of Fiscal Instruments Used in Forestry Sector[4]

The potential use of auctions as a policy tool for allocating public resources is increasingly being recognized in the economic literature.[5] Not only can well-designed auctions raise revenue for the government, but they also promote efficient allocation of resources. The government can also design the rules of the auction to address various policy goals, such as avoiding a monopoly or directing licenses to local firms. However, in many countries, auctions do not work because of poor design, political preference, market failures, and the absence of natural resource property rights. In the forestry sector, the costs to potential bidders in obtaining information on the forest, the timber, the contract requirements, and the costs of fulfilling the requirements can be a significant problem in auctioning forest contracts. In the presence of imperfect credit markets, the costs, along with the risk and uncertainty of inadequate information, can discourage bidders and result in lower bids on forest use contracts (Gillis, 1992).

In light of these difficulties, a variety of second-best fiscal instruments are used in the forestry sector. (See Figure 1 for an overview of the taxes and fees that apply to the forestry sector.) The most common fees that apply to forest sector activities are *stumpage fees*, or royalties, based on the amount of timber harvested. This type of fee can be based on the

[4] See Appendix II for a formal derivation of the results presented in this section.

[5] See Appendix III for a brief overview of the literature.

volume of timber harvested (per cubic meter), the number of trees harvested, or the value of the trees harvested, with each type having its own advantages. However, fees based solely on the quantity of timber extracted may lead to "high grading"—the practice of selectively extracting only the most valuable tree species, leaving harvestable timber in the forest. This practice is economically inefficient in the long run because it creates disincentives for forestry practices that would maximize the net present value of log production under sustained production—that is, the entire value of areas set aside for logging is not captured. It can also increase waste because trees are often damaged or destroyed in the process of getting to the high-value trees scattered in large forest segments.

In general, stumpage fees and royalties, if they are differentiated enough across species and updated frequently to reflect market conditions, have the potential to yield a high proportion of revenues. Their key disadvantage is that they can be quite complex to determine and can thus burden understaffed and poorly funded forestry agencies that are in charge of measuring and classifying timber harvest. Fees can also be applied to timber after it has been extracted and processed into other wood products, such as sawn wood, veneer, and plywood. Fees on processed products are classified as postharvest fees, as opposed to the harvest-based fees discussed above. One of the main advantages of postharvest fees is that they can be applied to logs that are illegally harvested. In countries where a large proportion of timber is processed for export, and illegally harvested timber makes up a large portion of processed wood products, postharvest fees can raise significant revenues. They are also easier to apply because it is relatively simple to measure the quantity of products manufactured or exported. Postharvest fees are quite common, with many governments applying them (or even imposing outright export restrictions) on unprocessed logs to encourage domestic processing of timber. However, because post-harvest fees are often estimated based on the amount of timber that would be required to produce a given amount of processed wood, these fees can penalize more efficient processing firms.

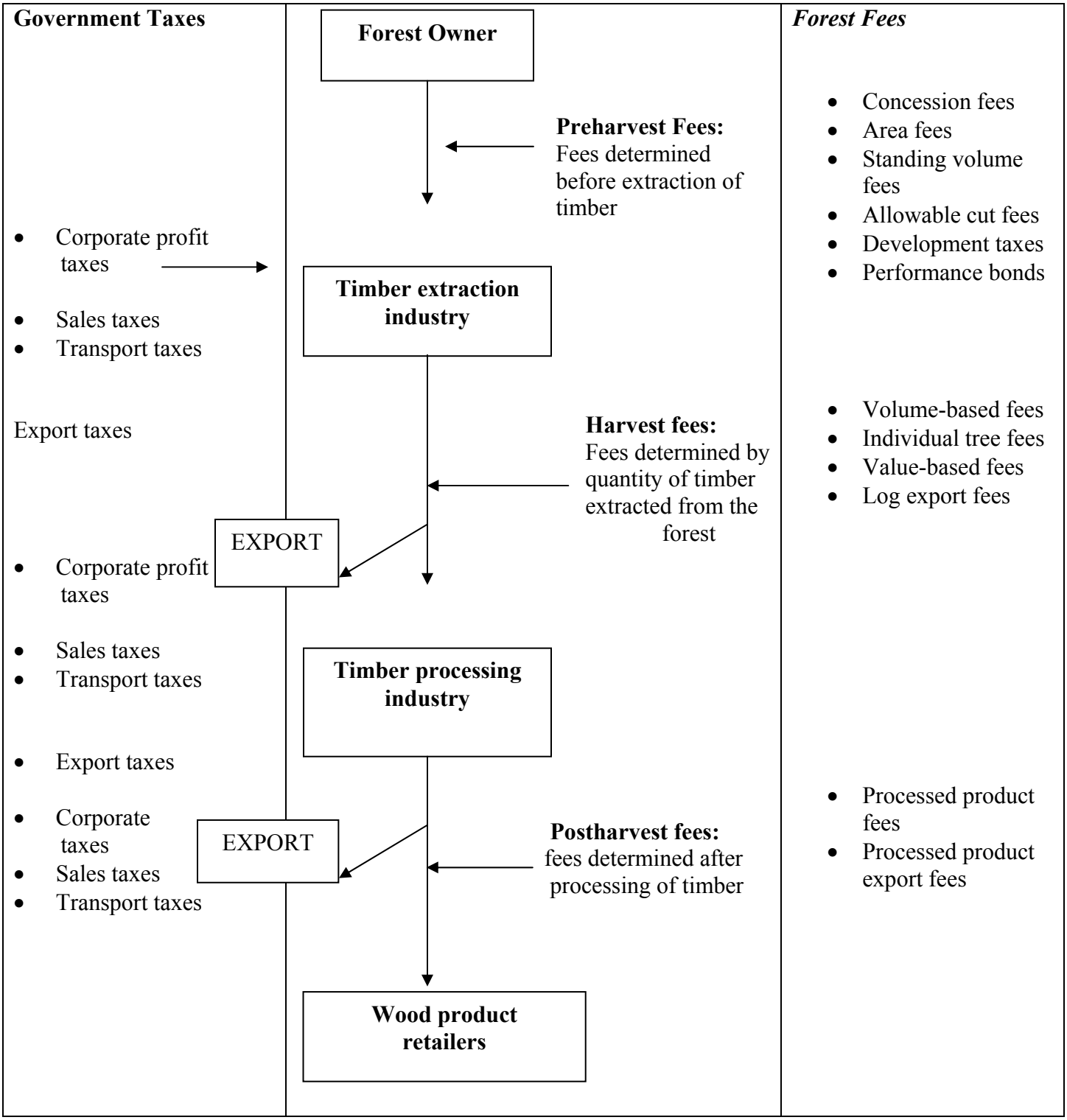
The *profit tax* and the *area tax* are in a different category. The *profit tax* is levied on a company's total returns (after other taxes); the *area tax* is as a productivity tax, charged on an equal and annual basis on each hectare under concession. These taxes represent a powerful instrument with which to collect revenues. Unfortunately, they are, to differing degrees, difficult to monitor or are arbitrarily applied, particularly in countries with weak tax administrations. For the profit tax, in particular, transfer pricing practices and the global characteristics of most timber-producing companies pose significant administrative challenges. In fact, many tropical forests are exploited by firms that have a short-term exploitation mentality and "hop" from one forest to the next—a behavior that can be changed only after property rights, including mechanisms to distinguish between investors, are well established and have been in place for a long time.

Governments have increasingly adopted preharvest fees such as concession fees and area fees. From a revenue perspective, preharvest fees have certain advantages. They are independent of the amount of timber harvested and encourage intensive use of the forest,

with high recovery rates of timber from all valuable tree species, therefore effectively precluding "idle" concession areas.[6] They also tend to be simpler to collect because they are defined in the concession agreement and do not require measuring and classifying the harvested timber. However, such fees could result in inefficient harvesting of low-value timber and the unnecessary destruction of forest biodiversity. Determining the appropriate fees may require a considerable amount of information on the quantity and quality of timber at specific sites unless the government auctions concessions.

[6] Taxes to enforce the commercial use of concessions and land titles are also used in other sectors, such as taxes on unused land or area fees to encourage exploration of oil fields.

Figure 1. Flow of Timber Through the Forest Sector and Application of Taxes



Auctioning concessions may require less information, since governments can establish a minimum price for the concessions and the burden of evaluating the full value of such a concession falls on bidding companies. Under competitive conditions, auctions can be a mechanism to extract a high proportion of the rents available. However, the auctioning process is not free from political maneuvering problems.

In addition to fees specific to the forestry sector discussed above, other types of government taxes and charges may apply to activities in this sector. Just like other types of economic activities, the forestry sector may be subject to sales, export, and corporate profit taxes. While the primary motive for such taxes is to raise revenues, they do capture some amount of rent if forest-specific fees are below efficient levels. These taxes can sometimes be easier to collect, since they rely on institutions and procedures that are a part of the normal tax raising functions of a government. But because such taxes are not specifically designed to capture resource rents, they are usually inefficient mechanisms for this purpose, and have little or no incentive impact on the logging and wood processing industry. A summary of the advantages and disadvantages of forest taxes is given in Table 1.

Table 1. Advantages and Disadvantages of Forest Taxes and Fees

Forest Taxes	Advantages	Disadvantages
Uniform--based on the volume cut	• Easy to implement	• Encourages underreporting of volumes cut • High incentive for "creaming" and logging only accessible stands
Based on volume cut, but also differentiated by species and location	• Limits incentive to cream and take the most accessible stands • Takes into account the relative scarcity of the various species • Tries to base the royalty level on economic and not just physical values	• Requires sustained, accurate field monitoring by forestry administration
Per tree tax	• Simple principle limits opportunities for cheating: can be verified expost by a stump count • Wide potential variety of rates in terms of location and species • Discourages cutting young trees (minimum trunk diameter can be enforced more easily) • Encourages minimizing damage to residual stand and maximizing use of trees (if royalty applies to broken trees too)	• Requires a sound inspection system that can only come from the forestry administration • Encourages cutting of large trees, which may denude the canopy and cause changes in species makeup of the stand
Based on total market value of harvest	• Yield significant revenues if rate is high enough • Limits temptation to cream	• Less simple than the per tree system • No particular incentive to limit damage to the residual stand
Based on the stumpage value (SV) harvested	• Tax burden varies with market conditions and efficiency of processing (recovery rate) • Can be adjusted for each species and to reflect transport costs and market conditions • Limits temptation to cream • Compensates, at least partially, for cost differentials related to distance from point of sale	• Requires a sound information system on wood prices and recovery rates and a tax administration that can react quickly (regular stumpage value reviews) • Can become complicated if applied to composite products incorporating several species • No particular incentive to limit damage to residual stands
Area-based tax	• Simple to administer; based on the area approved for cutting • Generates revenue prior to logging Ensures commercial use of concessions	• May not reflect the true value of the timber • Supervision is required to ensure that logging is within the designated area • Profit risk is fully transferred to the concessionaire
Export taxes on logs or processed products	• Easy to collect	• Creates distortions between export and domestic activities

V. AN INTERIM PROPOSAL FOR TIMBER TAXATION

A country's forestry sector offers significant opportunities for its resource-constrained government to raise domestic revenues. Currently, the private sector captures a large proportion of forestry rents. Rent collection would result in social redistribution of rent between the state and the private sector, thereby freeing up resources for social and environmental investments. Economic theory suggests that the links between rent capture in the forestry sector could lead to a more efficient use of forest resources, which may, indirectly, reduce deforestation. However, the theoretical results on the links between rent capture in the forestry sector and resource efficiency are not definitive. Definitions of rent vary, and different taxes and competitive mechanisms penalize certain conservation practices and encourage others. Further, the economic and institutional context of individual countries determines whether and to what extent resource taxation enhances resource use and harvesting efficiency. Low rent capture in developing countries is closely tied to illegal harvesting and to implicit and explicit contractual agreements that benefit a few interest groups.

The inability of Liberia's revenue collection agencies and the FDA to oversee timber activities requires that the tax and fee system be radically simplified. The collection activities should concentrate on stages of the process that do not require a high level of expertise and that are easy to monitor. While simplicity and transparency of the collection process need to take priority under these circumstances, sustainability should also be considered so as to avoid a return to unsustainable logging levels when UN sanctions are removed. As mentioned before, some tax instruments do a better job of gearing activity toward sustainability, which is imperative given that effective oversight of forestry activity does not exist.

One solution would be to reduce the current tax system to two instruments: taxes on timber exports that should be differentiated by species and an increased area tax. While an export tax should be strictly temporary, its ease of collection and the presence of an external collecting agency (Bureau Veritas) with a mandate to assess the value of exports, including timber, are important arguments for such a shift. Differentiation of the export tax by species will address the sustainability of forests because it will deter people from logging the higher-value species of trees. At the same time, the tax should be based on the number of logs filled to encourage the logging of larger trees, thus protecting the younger ones.

The higher area tax is proposed in light of the on-going review of concessions. As noted above, an area tax will not alter production decisions when the area has already been determined (like a change in the property tax for property already purchased); however, if concessionaires are permitted to determine the size of their concessions, the area tax is expected to influence those decisions. An early announcement of a change of area taxes could therefore induce concessionaries to request smaller areas, thus reducing logging and also helping to address the issue of overlapping concessions. On the collection side, area taxes are easy to administer once the area has been determined.

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Liberia: Fees and Charges on Forestry Activities

Fees/Charges	Amount	Use of Revenues
Volume-based charges		
Severance charge	US$1.50/cubic meter	
Reforestation charge	US$5.00/cubic meter	To be used solely for funding reforestation (artificial plantation) projects and programs.
Conservation charge		
Class A	US$4.00/cubic meter	To implement conservation activities
Class B	US$2.50/cubic meter	.
Forest research charge	US$1.00/cubic meter	Research and development activities.
Area-based charges		
Land rental fee	US$0.50/acre/year	

Source: FAO, 2004.

Liberia: Fees and Charges by Tree species

Species	Industrialization Incentive Fee	Forest Product Fee per m^3		
		STT 1/	SEU 2/	SED 2/
	(In U.S. dollars per cubic meter)			
Sipo/Utile	58.56	30.6	9.0	1.2
Makore	24.96	13.8	6.0	1.2
Sapele	21.84	12.2	6.0	1.2
Kosipo	15.72	7.5	4.0	0.8
Tiama/Edinam	15.72	7.5	4.0	0.8
Acajou/Khaja	15.72	7.5	4.0	0.8
Dibetou/Lovoa	15.72	7.5	4.0	0.8
Niangon	15.72	7.5	4.0	0.8
Bosse/Guarea	7.68	3.4	2.0	0.4
Iroko	7.68	3.4	2.0	0.4
Bete/Mansonia	7.68	3.4	2.0	0.4
Amazakoue	6.72	3.1	2.0	0.4
Wawa/Obeche	6.72	3.1	2.0	0.4
Framire	6.72	3.1	2.0	0.4
Amingre	6.72	3.1	2.0	0.4
Frake	2.76			
Tali	2.76			
Danta/Kotibe	2.76			
Naga	2.16			
Illomba	2.16			
Doussie	2.16			
Sikon	2.16	0.0	0.0	0.0
Movingue	2.16			
Koto	2.16			
Kusta/Builinga	2.16			
Aiele	1.44			
Azobe/Ekki	1.44			
All other species	1.44			

Source: FAO, 2004.

Note: The charges by species were affected by the 10 percent Special Trade Depression Allowance and later increases in charges. The IFF is still applied.

1/ STT = sawn through and through.

2/ SEU = squared edged four sides (undressed in the rough).

3/ SED = squared edged dressed four sides.

Liberia - Fees and Charges on Forestry Activities
(In U.S. dollars, unless otherwise specified)

Type of fee	Amount	Comment
Administrative Fees		
Annual registration fee	500.00	Per year
Survey permit fee	2,000.00	Per permit
Hammer fee	600.00	As and when required
Forest map fee	300.00	As and when required
Waybill (local and export) fee	150.00	As when required
Annual coupe/block-cutting fee	25	Per coupe as and when required
Performance bond 1/	150,000.00	Per agreement
Forest resource utilization contract fee	5,000.00	Per contract
Port charges		
Usine port equipment (delivered products at port yard)	10.00	Per m3
Delivery to ship hook	10.00	Per m3
Use pf shippers' equipment	5.00	Per m3
Custom inspection fee (in percent of f.o.b. value)	7.50	f.o.b.
Storage fee (per export parvel)	6.00	Per cubic meter
Marking and grading fees 2/(in percent of f.o.b. value)	1.25	f.o.b.

Source: FAO, 2004.

1/ The performance bond is paid prior to operation by the concessionaire and is refundable upon satisfactory performance. The amount of the performance bond was established in the act creating the FDA on December 20, 1976.
2/ The marking and grading fees are charged for the inspection and grading of exports and are collected by Bureau Veritas, a subsidiary of a foreign inspection company.

A SIMPLE THEORETICAL MODEL

Forest resources in tropical areas regenerate to a large extent by themselves, at least as long as exploitation is sensible. Most forest lands in West Africa are owned by the state, which allocates concession rights using a variety of mechanisms, though, unfortunately rarely according to predefined and objective criteria. This lack of transparency in the allocation of concessions, in turn, weakens the quality of the property rights it generates. This is facilitated if a forest management plan exists that concessionaires must abide by. But exploitation could still be abusive, as it frequently is in West Africa. While the quality of forest management plans and their strict enforcement are of utmost importance, sustainability also depends on the existing incentive structure, of which forest taxes and fees are a key, though obviously not the sole, component. The concessionaire's problem is to decide on the number and size of trees it will harvest. Several studies have suggested that firms in West African countries pay special attention to the choice of tree species and sizes. We follow the approach of Barbone (2000), wherein government is modeled to achieve the twin objectives of revenue maximization and environmental sustainability.

A. THE FIRM'S OBJECTIVE

The firm's goal is to harvest a plot of land so as to maximize a discounted stream of profits. This can be interpreted as the trade-off between the benefits of further tree growth (i.e., increased future value from postponing the harvest) and the implicit cost of harvest delays (i.e., interest forgone from unearned profits). The firm has to weigh in the time dimension and the underlying tax and fee structure. Moreover, the firm can achieve its goal by choosing either an optimal "rotation period" or an optimal combination of number and size of harvested trees. The growth profile of a stand of trees of the same age is usually supposed to have the logistic shape indicated in Figure 2. Let *f(t)* be the yield (volume per hectare) of a *t*-year-old forest on a particular site. The net value of the crop will be denoted *R(f(t))*--that is, the value of the logs minus the costs (c), of cutting and transporting the logs. Normally the value of the wood per cubic meter increases with the size of the logs because more valuable products can be manufactured from them (large-dimension boards, veneer). Moreover, logging costs per cubic meter fall because fewer pieces need to be handled for the same volume of wood. Thus, average revenue per cubic meter--that is, *R(f(t))/f(t)*--should increase with the age of the trees.

Figure 2. Typical Volume-Age Curve for Timber

For simplicity, assume the private owner begins with bare land on which it costs *c* to establish a crop of trees. Letting *r* denote his discount rate, the present value of this operation is

$$PV(t) = \frac{[R(f(t)) - c](1+r)^{-t}}{1-(1+r)^{-t}} - c\,. \qquad (1)$$

A wealth-maximizing owner would then choose his rotation period *t* to maximize this present value. Equation (1) says then that the optimal cutting date is when the growth rate of the value of his investment in trees and forest land is just equal to the rate of return on liquid capital (Faustmann rule). Thus, it is the opportunity return to using the forest land in the highest alternative use to its use for growing the current stock of trees. The trees should be cut when this marginal user cost is just equal to the marginal return to continuing to grow the current stock of trees. However, this result requires that capital, timber, and input markets be perfect, there be no uncertainty, the harvesting cost function be linear, and forest owners have no nontimber preferences. In the ideal world of perfect markets and information, auctions would be the best instrument to determine the price for extraction rights. (See, for example, Gilles, 1990.) However, a number of factors—including a lack of information about the forest resources under consideration, uncertainties as to the stability of property rights over time, and a lack of access to credit—have limited the use of auctions so far, particularly in low-income countries. These countries therefore generally rely on a number of tax instruments at the preharvest, harvest, and postharvest stages. Each of these instruments has its own advantages and disadvantages vis-à-vis the objectives of revenue maximization, administrative ease, and sustainability.

Specifically, we assume that world prices of timber are given. Firms maximize the present value of an infinite stream of profits given, in any hectare *i*, by

$$\underset{\{a,n\}}{\text{Max}} \sum_{t=0}^{\infty} \beta^t \left[\text{Revenues - Costs - Taxes}\right] (1-t_p)\,, \qquad 0<\beta<1\,, \qquad (2)$$

where the choice variables are *a (*size of tree) and *n* (number of harvested trees). We can define *a* as the ratio of harvested cubic meters of timber to total cubic meters of timber in the forest or hectare, and *n* is the ratio of the number of harvested trees to the total number of trees in the same forest or hectare. The size of harvested trees belongs to the interval [0, 1], and the same is the case for the ratio indicator *n.* The profit tax t_p is levied on after tax profits, and β is the private sector's discount factor. The higher is β, the greater is the value firms put on future profits and vice versa.[7]

[7] If the discount factor is defined by $\beta = 1/(1+\phi)$, and ϕ is the annual interest rate, then the discount factor β is close to one for low ϕ and becomes smaller as this interest rate increases.

The deforestation rate (d) is a function of both a and n and can be interpreted as the rate at which a concession is consumed per unit of time. Given that both a and n are restricted between 0 and 1, this is also the case for the deforestation rate.[8] Or

$$d = f(a, n), \text{ where } a + n \in [0, 1].$$

The firm's revenue function is given by

$$\text{Revenues} = M_t \,.\, d = M_t f(a, n), \qquad (3)$$

where M_t is the stock of trees in the concession at time t and d is the deforestation rate.

We assume that cost is a function of size and number of trees and is given by

$$\text{Costs} = h(a, n) \,.\, d \,.\, M_t, \qquad (4)$$

which is a multiplicative function of the size of the harvest, where the function h has positive first derivatives. Taxes and fees are assumed given so that

$$\text{Taxes} = t_x \; M_t \; d + t_n \; N_t + t_a, \qquad (5)$$

where t_x is the export tax which applies as an advalorem tax on the value of exports. Thus, export taxes are limited in that they do not penalize irresponsible logging (i.e., taxation is independent of tree selection). The number of trees harvested N_t is determined as a function $j(n)$ of the total number of cubic meters harvested. The per tree tax t_w is modeled as a specific tax and is applied as a fixed amount to each tree harvested.[9] The tree tax attempts to increase the opportunity cost of irresponsible logging. For simplicity, we assume that all

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[8] It is assumed that the first derivatives of the function $f(a, n)$ are positive and that $f_{nn} > 0$ and $f_{aa} < 0$. The last derivative assumption implies that increases in a will also increase the deforestation rate d, this happens at a decelerating rate as the difficulty of finding large trees increases. The function f links d to the firm's two choice variables and serves to reflect environmental concerns. For example, if all trees are harvested, then no "standing" cubic meters remain, thus implying that the forest disappears, and d equals one.

[9] The risk of selective logging or high grading can be reduced by using differential "tree taxes," though this obviously has administrative implications. Similarly, assuming a certain number of cubic meters of timber may be obtained from several small trees or, alternatively, fewer but larger trees, then d will be larger in the first of these two cases. The reason is simple. For the same ratio a, the ratio n is larger when young trees are harvested. In turn, this also suggests that there are benefits to be derived from harvesting large trees--a practice that allows smaller ones to develop further.

production is exported. The area tax t_a is applied as a fixed amount per hectare and is measured in cubic meters. [10]

The forest in any one hectare is assumed to grow at a constant rate g and is harvested at a rate d; thus,

$$M_t = M_{t-1} \ (1 + g - d). \qquad (6)$$

The firm's maximization problem in any hectare i may, therefore, be rewritten as

$$\underset{\{a,n\}}{\text{Max}} \ \frac{(1 - t_p) \ M_o}{1 - \beta} \left[(1 - t_x) \, f(a,n) - h(a,n) \, f(a,n) - t_n \, j(n) \, f(a,n) - t_a \right], \qquad (7)$$

where M_o is the forest stock in cubic meters that exists when exploitation begins.

Differentiating (7) with respect to a and n yields a system of two equations; the first-order conditions of the firm model, which depend on two of the four revenue instruments included in our model, and some of the other parameters. More precisely,

$$a = a \, (t_x, t_n ; \beta , \cdot), \qquad (8)$$

$$n = n \, (t_x, t_n ; \beta , \cdot), \qquad (9)$$

and, as a derivate function, the deforestation rate per hectare is given by

$$d = d \, (t_x, t_n ; \beta , \cdot). \qquad (10)$$

Closed form solutions for a and n do not exist, but plausible specifications for the functions of the model may be chosen and numerical simulations can be carried out to derive the comparative statics of equations (8) and (9).

Some of the results are worth highlighting. The first is that both a and n (and consequently d) are independent of area fees and profit taxes. This is a strong but not counterintuitive result because they are akin to sunk costs. If a concession is in operation, then these taxes will have to be paid irrespective of the rate at which trees are being cut or, as in the profit tax, at a constant and proportional rate on profits after all other taxes. However, these taxes affect total timber production to the extent that they drive concessions in and out of exploitation. Hence, these taxes will not have an impact on the marginal decision of the firm in any one hectare (*intensive* margin) and cannot be used for environmental purposes, except for the

[10] The revenue and cost functions, as well as the export tax term, are expressed in currency terms. They may be rewritten by normalizing for the price of a cubic meter of timber.

rather heavy-handed purpose of driving concessions in and out of business (*extensive* margin).

The second result worth noting is that increases in the per tree tax leads to a decline in the number of harvested trees while the size of harvested trees increases. This should be expected and, in principle, leads to greater efficiency in production (i.e., less waste and better tree selection). Similarly, increases in export taxes lead to a decline in both the size and number of harvested trees, thus implying a decline in the deforestation rate of any one particular hectare. More generally, export and waste taxes appear to have strong environmental effects in that they modify the behavior of the concessionaire in any one hectare (*intensive* margin), but do not necessarily ensure sustainability.

The final result is that the deforestation rate d in any hectare is sensitive to the discount rate β. Specifically, high discount rates (i.e., a greater uncertainty about the future, resulting, in turn, in a smaller β) lead to fast forest exploitation for the same combination of export and waste taxes. Thus, uncertainty plays against sustainability, an expected result that suggests that well-defined, long-term property rights will reduce uncertainty (at least to the extent that the property rights are reflected in the discount rate) vis-à-vis other timber-producing countries and contribute to a lower rate of forest exploitation per hectare.

The firm model just discussed allows us to highlight two important policy dilemmas. First, we note that high export and tree taxes may eliminate excess profits and, therefore, drive concessions out of business (i.e. government revenues decrease to zero). In fact, this result may be achieved through any of the government's revenue instruments examined in this paper, including high profit taxes or area fees.[11] Thus, a high tax burden drives hectares out of production, an obvious result that is consistent with the main recommendation of the literature to raise taxes. Total timber production may or may not vary, however, depending on how firms react to hectares being driven out of production. Second, the intensity of exploitation and the impact on firm behavior of each revenue instrument may vary significantly. More specifically, different types of taxes have different effects on the intensity of exploitation, with some taxes and fees (e.g., area fees and profit taxes) having, in fact, no direct impact. This is consistent with the literature which notes that the role of different taxes and fees in forest management is not uniform.

[11] In an infinite-horizon model, production takes place only if the discounted stream of profits is greater than, or equal to that of, alternative investment opportunities, thus implying that government revenues exist only if the concession is under exploitation.

THE GOVERNMENT'S OBJECTIVE

The government is assumed to maximize a discounted stream of revenues subject to an environmental constraint and the firm's optimal behavior.[12] In effect, this allows for the co-existence of goals aimed at maximizing government revenues while exploiting the forest in a sustainable manner. To this end, the government can choose a combination of environmental taxes and fees (such as a per tree tax) and pure revenue-generating taxes and fees (such as area and profit taxes).[13]

Specifically, the government's maximization problem is given by

$$\underset{\{t_x, t_w, t_a, t_p\}}{\text{Max}} \; R\left(a^*(t_x, t_n), n^*(t_x, t_n), t_a, t_p\right), \tag{11}$$

subject to

$$g = f^*\left(a^*(t_x, t_n), n^*(t_x, t_n)\right), \tag{12}$$

where the * indicates that these are the firm's optimal choices of *a* and *n* and that R is the government revenue function. Equation (11) represents the environmental constraint and results from equating the function f*(*a**, *n**) to the forest's natural growth rate *g*. If a forest is exploited in a sustainable manner, then *d* matches the forest's natural growth rate *g*. Intuitively, since an increase in export or waste taxes reduces production, an increase in any of these two taxes must be offset by a decline in the other.

Thus, assuming for simplicity that profit taxes do not exist, the government's objective function for *m* hectares or firms may be written as

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[12] Following the two-stage maximization methodology proposed by Lucas and Stokey (1983) on optimal tax policies; the first stage must solve for the firm's optimal behavior, and the second stage must incorporate the resulting optimal firm choices as constraints in the government's model. An equilibrium is defined as a set of pure environmental taxes and pure revenue-generating taxes which solves both the firm as well as the government model.

[13] Export taxes generate revenues for the state, but their main feature is that they have implications for intensity and, thus, for forest sustainability in each hectare. Similarly, area and profit taxes may also drive firms out of production and, thus, have an impact on sustainability. This impact depends, in turn, on the environmental constraint being faced. Their main role, however, is to generate revenues for the State. The classification of revenue instruments into pure environmental taxes or pure revenue-generating taxes attempts to highlight the key features of each revenue instrument.

$$\underset{\{t_a, t_x, t_n\}}{\text{Max}} \sum_{i=1}^{m} \sum_{t=0}^{\infty} \partial^t \left[t_x \; f_i \; M_{i,t} + t_n \; j_i \; f_i \; M_{i,t} + t_a \right], \qquad (13)$$

where i is an index that represents the hectare or firm. Using the transition equation of forest growth, this maximization problem may be written as

$$\underset{\{t_a, t_x, t_n\}}{\text{Max}} \sum_{i=1}^{m} \left[\frac{f_i \; M_o \; (t_x + t_n \; j_i)}{1 - \partial (1 + g - f_i)} + \frac{t_a}{1 - \partial} \right], \qquad (14)$$

subject to the optimal choices for *a* and *n* of each firm and an environmental constraint. The parameter ∂ represents the government's discount factor. Each hectare is assumed to have a profitability level given by location and by firm characteristics. Production takes place only if profits are greater than or equal to *k*, which is the return of other investment opportunities.

Export taxes and Per tree taxes

To investigate the choices the government faces, we first look at the revenue results obtained by the model in the case in which there is only one firm of one hectare (i.e., m = 1). The government's maximization problem is reduced to the terms inside the square brackets of equation (13) subject to the environmental constraint and the firm's optimal choices. Although closed-form solutions do not exist, the model can be solved numerically. These calculations search for tax combinations that maintain production at the level defined by the environmental constraint used while also determining the choices of *a* and *n* that will maximize the firm's profits. Each given level of export tax allows us to calculate a new set of optimal choices of *a* and *n* and a new equilibrium tree tax. Thus, a series of government revenue results can be calculated, one for each tax combination, the solution to the model being the tax combination that maximizes government revenues.[14]

Area fees

Area fees are perceived as an instrument that will make the exploitation of forest land more efficient by affecting both the firm's decision to exploit or not a marginal hectare and the volume of timber it will extract from each hectare under exploitation. While area fees may drive hectares in and out of production (*extensive* margin), they do not affect the intensity of exploitation in individual hectares (*intensive* margin) because they are, in effect, fixed costs.

[14] Since the firm's FOCs are not a function of the area and profit tax, changes in these taxes have an impact only to the extent that hectares are driven out of production (i.e., excess profits disappear).

In this regard, the evidence noted to support the existence of implications from area fees on production per hectare needs to be correctly accounted for in terms of its cause-effect characteristics. For example, area fees have also been a mechanism through which the government introduces institutional changes. These changes improve the quality of the property rights generated by forest concessions, which, in turn, have an impact on how any one hectare is exploited.

REVIEW OF LITERATURE

During the 1980s and early 1990s rising attention was paid to the economics of the environment (e.g., Binswanger, 1987; Gillis, 1980, 1988, and 1992; Gray, 1983; Repetto, 1988; and Grut et. al., 1990). Many authors argued that deforestation could be better controlled through market forces rather than through regulation, particularly in countries with governance deficiencies. Market-based incentives could help control deforestation by internalizing negative externalities. More specifically, deforestation was seen to be encouraged by under-pricing of timber through outdated forest fees and taxes, which provided false signals regarding the value of forests, leading to severe waste in harvesting and processing. In sum, low taxes/fees distort forest management decisions and encourage inefficiencies, not to mention their negative implications for government revenues. To address these problems, many authors recommended that forest fees and taxes be increased, preferably as close as possible to the value of economic rents. Some suggested different combinations of forest fees and different methods for raising them. For example, annual concession fees, stumpage fees and profit taxes (Gray, 1997; Gillis, 1992).

The "raise taxes" prescription, mainly aimed at reducing profit margins, came under serious criticism from several authors during the 1990s (e.g., Blakeney, 1993; Topa and Pendleton, 1998; Meijerink, 1997; and Karsenty, 1998). These authors stressed that not all fees and taxation systems "promote sound forest management." Some are capable of generating significant revenue for the state without affecting the firm's behavior, while others may actually encourage unsound forest management practices. Topa and Pendleton emphasized that simply raising forest fees would not necessarily lead to sustainable management of forests, because fiscal instruments on output (the number of logs or total timber production in cubic meters) do not necessarily provide incentives to improve forest management, and limit waste and logging damage. Some taxes have been identified as difficult to collect and do not take into account the long-term social costs of forest exploitation. Karsenty also claimed that because of the great heterogeneity of loggers, high taxes (redistribution from loggers to the state) would have no predictable influence on loggers as a whole. He said, specifically, "the role of environmental taxation is precisely to take them into account, to internalize them, either by penalizing practices that should be changed (a high tax rate and a narrow base, the typical features of an environmental tax), or by imposing lower tax rates (but with a broader base, in line with normal taxation logic) on operations as a whole and using the funds collected to finance renewal works and to compensate for degradation of the environment." Authors who subscribe to this new way of thinking agree that taxes and fees should be adjusted for negative distortionary incentives. Some recommended that the area tax become the primary forest fee while others, such as Karsenty, stressed the importance of "eco-certification." Topa and Pendleton noted the importance of a more integral, structural, and participatory framework, and Meijerink stressed the importance of sector policy harmonization (e.g. with agricultural activities), mainly to prevent negative signals, contradictory signals, or both.