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Forest Taxes, Government Revenues and the Sustainable Exploitation of Tropical Forests

Luca Barbone and Juan Zalduendo

January 2000

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The paper also argues that models of concession rotation are not applicable to tropical forests when there are doubts as to the quality of the property rights generated by forest concessions. Rather, the model proposed links deforestation to the firm's choice of size and number of harvested trees in each hectare, thus allowing a richer examination of the challenges faced by the firm and their link to the incentive framework within which firms and government operate. Taxes and fees are viewed as essential components of this incentive framework, and their role is assessed in light of the weak institutional capacity that characterizes the public sector administrations of developing countries, particularly those in Central Africa.

Finally, the model distinguishes between the implications of taxes and fees on decisions related to the exploitation of marginal land (extensive margin) and on those related to the firm's choice of number and size of harvested trees in each hectare (intensive margin)
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* The authors, both at the World Bank, wish to thank Roger Rodriguez for discussions held during the preparation of this paper. Ayo Heinegg contributed to the literature review section and Luis-Alvaro Sanchez provided comments to an earlier draft. Additional changes were introduced based on comments received from Richard Bird, Vicente Ferrer and Giuseppe Topa. The views expressed in the paper are those of the authors and do not represent in any way the views of the World Bank.
Introduction

This paper presents a model of forester and government behavior applicable to the Central African context. The aim of the model is to gain insights on the role of different fiscal instruments at the disposal of governments in achieving the twin objectives of environmental sustainability and revenue maximization. The paper recognizes that there are limits to the role fiscal instruments may play for sustainability, but argues that these should still be given attention to ensure that, at least, sustainability is not compromised.

The model also departs from the existing literature in many respects, one of which is that it proposes a different way of modeling firm behavior in tropical forests. Specifically, we argue that the traditional models of concession rotation are not fully applicable to the tropical forests of countries such as those in Central Africa. As opposed to a man-made forest which have a uniform distribution of trees of similar size and usually of the same species, some hectares being younger than others, a tropical forest presents a diverse combination of species and tree ages in any one hectare. This confronts the firm in tropical forests with a wider array of choices. Differences of behavior in man-made forests vis-à-vis tropical forests have been argued to disappear with transferability and perpetuity of concessions. These differences may still remain, however, if for whatever reason there are doubts about the quality of the property rights generated by concessions. Bio-diversity characteristics of tropical forests may also maintain forever these differences of behavior.

The model also allows to distinguish between extensive (the firm's decision to exploit or not a marginal hectare) and intensive (the firm's decision on how to operate within any one hectare) margin implications of taxes and fees. It models the behavior of firms and government, thus enabling to trace both the revenue generating as well as the sustainability aspects of exploitation. Combinations of taxes and fees are found to exist which make these two aspects mutually consistent. As mentioned above, the paper recognizes that a tax-based forest management system has limitations, in part because of the weak institutional capacity of public sector administrations in Central Africa. However, we argue equally forcefully that the wrong combination of fiscal instruments may conduce to an abusive forest exploitation.

Finally, the model qualifies some of the findings of the literature in favor of area fees. This literature suggests that area fees induce a more efficient use of land, affecting both the decision on exploiting or not an hectare as well as the volume of timber extracted per hectare. The paper notes that the decision on exploiting or not a marginal hectare as area fees are increased depends on which of two factors dominates. Hectares can be incorporated into production as a result of increases in the opportunity cost of maintaining them idle; but they can also be driven out of production as a result of reductions in profit margins. The model does not support the suggestion that area fees affect the intensity of exploitation.
The paper proceeds as follows. The first section reviews the literature on forestry exploitation and related government revenue sources, examining in particular the key tax and fee revenue instruments prevailing in countries of the Congo basin. The following section describes a model of firm behavior, where alternative taxes are introduced into the maximization problem of a firm and where the firm's choice variables are indicators of the size and number of harvested trees. The model is closed in Section 3 by a government objective function, which includes taxes and fees as choice variables and represents the goal of maximizing government revenues from the forestry sector. An environmental constraint is added to the government model to ensure that sustainability affects decision making process. Section 4 discusses the results of the model and the final section presents some final remarks.

1. Literature Review

Forest fees (or taxes) are levies paid by the concessionaire to the owner of the forest (i.e., the country) for the right to harvest a plot of land during a prescribed period of time. In economic terms, fees and taxes serve two distinct functions. First, they enable the government to capture a share of the economic rents associated with natural forests. Second, they affect harvesters’ behavior and, as a result, may play a role in the sustainability of forest exploitation. Thus, forest taxes (or fees) may act as Pigouvian taxes by internalizing the long-term, non-wood, and off-site values of the tropical forests under exploitation.

The original aim that led to the establishment of forest taxes may well have been the result of the first of these two functions. This role has increased in importance since the early 1980s by the revenue needs of African countries confronting serious imbalances in fiscal accounts. Forest conservation objectives have been expected to be reached through government regulations. This is in fact one of the main roles still played by the State in Central Africa, one that is only deficiently performed given the weak governance and poor institutional capabilities that characterize governments in most of Africa’s timber producing countries. Examples of these regulations are the obligation to prepare and carry out forest management plans and the decision by governments to administratively set timber production quotas, the latter based on limits to total or per hectare production.

During the 1980s and early 1990s greater 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 bureaucracies, particularly in countries with governance deficiencies. Market-based incentives could help control deforestation by

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1 Much like land has a rent value, natural resources have a resource value equal to the excess profits of forest exploitation (i.e., what remains after accounting for costs and for “normal” profits).

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internalizing negative externalities. More specifically, deforestation was seen to be encouraged by under-pricing of timber through outdated forest fees and taxes. In turn, this 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 were recommended by Gray (1983, 1997), and Grut et. al. (1990). Stumpage fees were recommended by Gray (1983, 1997), and profit taxes by Gillis (1992).

The “raise taxes” prescription, namely 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 (1998) stress that simply raising forest fees may not lead to sustainable management of forests since fiscal instruments “on output (the number of logs or total timber production in cubic meters) do not necessarily provide incentives to improve forest management, limit waste and logging damage.” It is also noted that some taxes are difficult to collect and do not take into account the long-term social costs of forest exploitation.

Karsenty (1998) also claims that because of the great heterogeneity of loggers, high taxes (redistribution from loggers to the State) will have no predictable influence on loggers as a whole. He also suggests that the goals of capturing government revenue and protecting environmental degradation might be contradictory. 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 in this new wave 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 (1998), stressed the importance of “eco-certification.” Topa and Pendleton (1998) noted the importance of a more integral, structural, and participatory framework, and Meijerink (1997) stressed the importance of sector policy harmonization (e.g. with agricultural activities), mainly to prevent negative and/or contradictory signals.

As to the different types of forest fees, these are summarized in, among other, Day (1998) and Karsenty (1998), along with their features, advantages and disadvantages. Four
main revenue instruments exist in Central African countries and are the focus of this paper: export taxes, waste fees, profit taxes, and concession/area fees. Their main characteristics and relative importance in countries of the Congo Basin are partly summarized in Table 1.

Table 1: The Forestry Sector in Central African Countries

<table>
<thead>
<tr>
<th></th>
<th>Cameroon</th>
<th>Congo DRC</th>
<th>Equatorial Guinea</th>
<th>Gabon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Production in Cubic Meters (thousands)</td>
<td>3500.0</td>
<td>669.4</td>
<td>? / 2298.0</td>
<td></td>
</tr>
<tr>
<td>Total Exports in Cubic Meters (thousands)</td>
<td>1790.0</td>
<td>137.0</td>
<td>620.5</td>
<td>1366.0 / 2219.0</td>
</tr>
<tr>
<td>Log Exports</td>
<td>1557.0</td>
<td>95.0</td>
<td>567.5</td>
<td>1334.0 / 1553.0</td>
</tr>
<tr>
<td>Processed Exports</td>
<td>233.0</td>
<td>42.0</td>
<td>35.0</td>
<td>32.0 / 666.0</td>
</tr>
<tr>
<td>Total Exports (in million US$)</td>
<td>262.8</td>
<td>50.0</td>
<td>75.4</td>
<td>340.0 / 345.0</td>
</tr>
<tr>
<td>Total Government Revenues from the Forestry Sector (in million US$)</td>
<td>45.7</td>
<td>12.9</td>
<td>39.6</td>
<td></td>
</tr>
<tr>
<td>Export Taxes</td>
<td>34.1</td>
<td></td>
<td>11.3</td>
<td></td>
</tr>
<tr>
<td>Concession Fees / Area Taxes</td>
<td></td>
<td></td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Government Revenues from Timber as a Share of their Export Value</td>
<td>17.0</td>
<td>17.1</td>
<td>11.5</td>
<td></td>
</tr>
<tr>
<td>Government Revenues from Timber as a Share of Total Revenues</td>
<td>3.0</td>
<td>15.8</td>
<td>4.0</td>
<td></td>
</tr>
</tbody>
</table>

The export tax, also referred by Klemperer (1976) as a yield tax for those countries where logs are not exported but processed locally, is levied as a fixed percentage of the value of the resource harvested and exported. Transfer pricing or corruption in port and custom administrations have been a frequent problem in Central African countries for the accurate collection of this tax, though the emergence of firms specialized in trade securitization activities has helped to reduce the significance of these problems. The waste fee is only remotely similar to the stumpage fee. Our waste fee is applied “per tree” harvested irrespective of tree volume, while stumpage fees have usually remained tied to the volume of harvested trees. It is worth highlighting that stumpage fees have also been applied in different ways, degenerating at times simply into an additional export tax. For example, in Equatorial Guinea it is calculated as a percentage of the value of harvested volume but, since it is in
effect assessed at the port of exit and based only on timber exports, it is akin to an additional export tax. The waste fee could also vary across timber qualities and species.

The profit tax and the area tax are in a different category. Profit taxes in our model are levied on the companies’ total returns (after other taxes); the area tax, referred by Klemperer as a productivity tax, is 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 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 which have a short-term exploitation mentality, “hopping” from one forest to the next, a behavior that can only be combated through well-established and long-term property rights, including mechanisms to distinguish between investors.

2. Concessionaire Behavior

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 foregone from unearned profits). This time dimension and the role played by the underlying tax and fee structure have been examined in the literature, though much of this work has been, to our knowledge, couched in heuristic terms. Moreover, the goal of the firm can be achieved either by choosing an optimal “rotation period” or, as in this paper, by choosing an optimal combination of number and size of harvested trees. This latter choice set is in our view more adequate to the tropical forests of Central Africa and has the additional advantage of allowing to assess the impact of different types of taxes and fees.

General Features

2 The paper could be viewed as an analysis of concessionaire behavior in any one hectare where the concessionaire represents the firm.

3 Biological tree growth is usually said to follow a logistic growth behavior (Wilen, 1985). Thus, trees grow rapidly when young but, once a certain maturity is reached, growth decelerates. For simplicity, however, this paper assumes that the forest in any one hectare grows at a constant rate $g$.

4 This paper, unless otherwise specified, uses interchangeably the terms taxes and fees for referring to the alternative revenue instruments applied in the forestry sector of Central African countries.
Some features of tropical forests and their relevance for the model in this paper are worth noting before proceeding. First, most forest lands in Central Africa are owned by the State which allocates concession rights using a variety of mechanisms, though unfortunately this allocation rarely follows pre-defined and objective criteria. This lack of transparency in the allocation of concessions in turn weakens the quality of the property rights it generates.

Second, forest resources in tropical areas regenerate to a large extent by themselves, at least as long as exploitation is sensible. This is facilitated if a forest management plan exists, thus defining the do's and don'ts by which concessionaires must abide. But exploitation could still be abusive, as is frequently observed in Central Africa. While the strict enforcement and the quality of forest management plans is of utmost importance, the argument we wish to highlight is that sustainability also depends on the incentive structure in place, of which forest taxes and fees are a key, though obviously not the sole, component.

Third, we pose the concessionaire's problem as one requiring to decide on number and size of harvested trees. This is in our view a more accurate representation of the decision making process of firms operating in Central Africa, as several studies have suggested that special attention is given by firms in these countries to the choice of tree species and sizes. It also allows a richer analysis of the policy implications of taxes and fees for sustainability, an analysis which cannot be undertaken in the models of concession rotation.

Finally, the model proposed also brings out an important feature of forest exploitation by distinguishing between the impact of taxes and fees on "marginal land" (i.e. the total land under exploitation or extensive margin, which may be viewed as the Ricardian component of forest exploitation) and on intensity of hectare exploitation (the intensive margin). Both decisions are key in determining whether a forest is sustainably exploited and both have an impact on government revenues. This feature serves to put into perspective the reviewed literature, as it allows to model both the "raise taxes" literature as well as the literature that stresses the role of taxes and fees on determining forest management practices.

The Model

We assume that world prices of timber are given, as is the in Central Africa. Firms maximize the present value of an infinite stream of profits given, in any hectare i, by

\[
\text{Max} \sum_{t=0}^{\infty} \beta^t \left[ \text{Revenues} - \text{Costs} - \text{Taxes}\right] (1 - t_p) , \quad 0 < \beta < 1 ,
\]

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where the choice variables are indicators of the size $a$ and number $n$ of harvested trees. More precisely, $a$ is the ratio of harvested cubic meters of timber to total cubic meters of timber in the forest/hectare, and $n$ is the ratio of number of harvested trees to total number of trees in the same forest/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 profits after all other taxes, and $\beta$ is the private sector’s discount factor. The higher is $\beta$, the greater is the value put by firms on future profits and vice-versa.\footnote{If the discount factor is defined by $\beta = 1/(1+\phi)$ and $\phi$ is the annual interest rate, then the discount factor $\beta$ is close to one for low $\phi$ and becomes smaller as this interest rate increases.} The firm’s revenue function is given by

\begin{equation}
\text{Revenues} = M_t \ d = M_t \ f(a, n),
\end{equation}

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

The deforestation rate 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. Since both $a$ and $n$ are restricted to the interval $[0,1]$, this is also the case for deforestation rate.\footnote{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 $d$, though this happens at a decelerating rate as it is increasingly difficult to find large size trees.} 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. Similarly, assuming a certain number of cubic meters may be obtained cutting several small size 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 as this enables smaller ones to develop further.

We assume that costs are given by

\begin{equation}
\text{Costs} = h(a, n) \ d \ M_t,
\end{equation}

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

\begin{equation}
\text{Taxes} = t_x M_t \ d + t_w N_t + t_a,
\end{equation}

where $t_x$ is the export tax which applies as an ad-valorem tax on the value of exports. Thus, export taxes have the limitation of not penalizing 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 waste tax $t_w$ is modeled as a specific tax and is applied as a fixed amount per tree harvested. It is different to a stumpage fee in that the latter has usually been modeled as linked to the value of the volume of trees harvested. If all production is exported, then this reduces traditional stumpage fees into an additional export tax. This result, together with the fact that export taxes by themselves cannot ensure sustainability of forest exploitation, serve to explain the past failure of tax-based forest management policies. In sum, the waste fee attempts to increase the opportunity cost of irresponsible logging. For simplicity, we assume that all production is exported. The area tax $t_a$ is applied as a fixed amount per hectare and is measured in cubic meters.

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

$$M_t = M_{t-1} \left(1 + g - d\right)$$

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

$$\text{Max} \left(1-t_p\right) M_0 \left[1 - \beta \left(1 + g - f(a, n)\right) \cdot \left(f(a, n) - h(a, n) - t_w \cdot j(n) \cdot f(a, n) - t_a\right)\right],$$

where $M_0$ is the forest stock in cubic meters that exists when exploitation begins.

**Main Results from the Model**

Differentiating (6) with respect to $a$ and $n$ yields a system of two equations; the first order conditions (FOCs) 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,

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7 The risk of cherry picking (i.e., choosing the most valuable trees and species) can be reduced by using differential “waste” fees, though this obviously has burdening administrative implications.

8 This is a strong assumption as logs commercialized and harvested tend to differ. The model could be modified to distinguish between these differences, however, in effect requiring to apply the waste fee on all harvested trees (i.e. irrespective of if they are or are not commercialized).

9 The revenue and cost functions, as well as the export tax term, are expressed in currency terms. They may be re-written by normalizing for the price of a cubic meter of timber.
and, as a derivative function, the deforestation rate per hectare is given by

$$d = d (t_x, t_w; \beta, \cdot)$$

Closed form solutions for $a$ and $n$ do not exist but, as discussed in the appendix, 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 (7) and (8).

The numerical simulations carried out produce a series of results, three of which are worth highlighting. The first relates to the fact that both $a$ and $n$ (and consequently $d$) are independent of area fees and profit taxes. This is a strong but not counterintuitive result as 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 rather heavy-handed purpose of driving concessions in and out of business (extensive margin).

The second result worth noting is that increases in the waste fee lead to a decline in the number of harvested trees while the size of harvested trees increases (Figure 1). 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, as they modify the behavior of the concessionaire in any one hectare (intensive margin), but as will be shown individually they might not ensure sustainability. In this regard, Table 2 displays the $d$ rate of an hectare for different combinations of export and waste taxes, and shows that sustainable exploitation (i.e., a deforestation rate $d$ lower than or equal to the forest’s natural growth rate) can be ensured only once these taxes are sufficiently high (non-shadowed area). This table also shows that a high tax burden leads to negative profits. This is represented in the table by combinations of taxes (boxed area) resulting in $d$ rates equal to zero (i.e., firms exit production and government revenues disappear).

The final result is that the deforestation rate $d$ in any hectare is sensitive to the discount rate $\beta$ (Figure 2). Specifically, high discount rates (i.e., a greater uncertainty about the future, resulting in turn in a smaller $\beta$) lead to fast forest exploitation for the same combination of export and waste taxes. Thus, uncertainty plays against sustainability, an
expected result which suggests that well-defined, long-term property rights will serve to reduce uncertainty (at least to the extent that these reflect in the discount rate) vis-à-vis other timber producing countries, and contribute to a lower rate of forest exploitation per hectare.

**Figure 1: Optimal Choices of Size and Number of Harvested Trees for Different Export Taxes and Waste Fees**

![Optimal Choices of Size and Number of Harvested Trees for Different Export Taxes and Waste Fees](image)

**Table 2: Deforestation Rate per Hectare for different \( t_x \) and \( t_w \) (assuming \( g = 0.075 \))**

<table>
<thead>
<tr>
<th>( t_x )</th>
<th>0.1</th>
<th>0.3</th>
<th>0.5</th>
<th>0.7</th>
<th>0.9</th>
<th>1.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>0.137</td>
<td>0.114</td>
<td>0.104</td>
<td>0.098</td>
<td>0.094</td>
<td>0.091</td>
</tr>
<tr>
<td>0.3</td>
<td>0.120</td>
<td>0.100</td>
<td>0.092</td>
<td>0.086</td>
<td>0.083</td>
<td>0.080</td>
</tr>
<tr>
<td>0.5</td>
<td>0.102</td>
<td>0.084</td>
<td>0.077</td>
<td>0.072</td>
<td>0.069</td>
<td>0.067</td>
</tr>
<tr>
<td>0.7</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>0.9</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Note: Shadowed area represents unsustainable combinations of export taxes and waste fees; that is, deforestation rates larger than the natural growth rate \( g \). The boxed area reflects tax combinations too high to ensure positive excess profits and, as a result, government revenues decline to zero (i.e., exploitation also drops to zero).

**Figure 2: Deforestation Rate per Hectare for Different Private Sector Discount Rates**

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3. **Government Behavior**

The firm model just discussed allows to highlight two important policy dilemmas. First, we note that high export and waste taxes may eliminate excess profits and, therefore, drive concessions out of business (i.e. government revenues decrease to zero). In fact, this may be achieved through any of the government’s revenue instruments examined in this paper, including high profit taxes or area fees.\(^\text{10}\) Thus, a high tax burden drives hectares out of production, an obvious result which is consistent with the main recommendation of the “raise taxes” literature. Total timber production may or may not vary, however, depending on how firms respond to hectares being driven out of production. Second, the intensity of exploitation and the impact on firm behavior of each revenue instrument may vary

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\(^{10}\) This paper presents an infinite horizon model; i.e. 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.
significantly. More specifically, different types of taxes have different impacts 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 played by different taxes and fees in forest management is not uniform.

In this context, the government’s behavior is modeled by assuming that its goal is to maximize a discounted stream of revenues subject to an environmental constraint and the firm’s optimal behavior.\textsuperscript{11} In effect, this allows for the co-existence of goals aimed at capturing State revenues while sustainably exploiting the forest. To this end, the government can choose a combination of “purely environmental” taxes and fees (export and waste taxes in our model) and “purely revenue-generating” taxes and fees (area and profit taxes).\textsuperscript{12} Specifically, the government’s maximization problem (assuming one hectare) is given by

\[
\text{Max}_{\{tx, tw, t_a, t_p\}} R(a^*(tx, tw), n^*(tx, tw), t_a, t_p)
\]

subject to

\[
0.075 = f^*(a^*(tx, tw), n^*(tx, tw))
\]

where the \( ^* \) indicates that these are the firm’s optimal choices of \( a \) and \( n \) and \( R \) is the government revenue function. Equation (10) represents the environmental constraint and results from equating the function \( f^*(a^*, n^*) \) to the forest’s natural growth rate \( g \), arbitrarily set equal to 0.075. If a forest is sustainably exploited, 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/firms may be written as

\textsuperscript{11} This reflects the Lucas and Stokey (1983) methodology on optimal tax policies; namely a two-stage maximization problem where the first stage requires to solve for the firm’s optimal behavior, and the second stage requires to incorporate the resulting optimal firm choices as constraints of the government’s model. An equilibrium is defined as a set of purely environmental taxes and purely revenue-generating taxes which solves both the firm as well as the government model.

\textsuperscript{12} Export and waste 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. In turn, this impact depends on the environmental constraint being faced. Their main role, however, is to generate revenues for the State. The classification of revenue instruments into purely environmental taxes or purely revenue-generating taxes attempts to highlight the key features of each revenue instrument.
where $i$ is an index that represents the hectare/firm. Using the transition equation of forest growth, this maximization problem may be written as

\[
\text{(11)} \quad \text{Max} \left\{ \sum_{i=1}^{m} \sum_{t=0}^{\infty} \delta^t \left[ t_x f_i M_{i,t} + t_w j_i M_{i,t} + t_a \right] \right\},
\]

subject to the optimal choices for $a$ and $n$ of each firm and an environmental constraint. The parameter $\delta$ 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.

(f) **Analysis of Purely Environmental Taxes (Export Taxes and Waste Fees)**

In order to investigate the choices faced by the government, 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 (12) 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 which maintain production at the level defined by the environmental constraint used while also determining choices of $a$ and $n$ which maximize the firm's profits. Each given level of export tax allows to calculate a new set of optimal choices of $a$ and $n$ and a new equilibrium waste fee. 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.\(^{13}\)

These results are reflected in Figure 3 for various combinations of waste and export taxes, for a given set of area and profit taxes, while complying with the environmental constraint. This figure also shows that government revenues are maximized for high export and low waste taxes (i.e., the peak of the curve in Figure 3). There is a limit to export tax increases as a means to increase government revenues, however, as can be observed from the sudden decline to zero in these revenues (i.e., profits will eventually disappear or, more

\[\text{(12)} \quad \text{Max} \left\{ \sum_{i=1}^{m} \left[ \frac{f_i M_0 \left( t_x + t_w j_i \right)}{1 - g \cdot f_i} + \frac{t_a}{1 - g} \right] \right\} \]

\(^{13}\) 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).
precisely, become too low vis-à-vis other investment opportunities). In sum, the forester will go out of business and government revenues will fall to zero.  

Figure 3: Implications of Export Taxes and Waste Fees for Government Revenues in a Representative Firm Model

- Govt. Revenues per Firm = 0.69
- Optimal a = 0.42
- Optimal n = 0.29
- Equilibrium Export Tax = 0.63
- Equilibrium Waste Fee = 0.22

Some additional insights can be derived from viewing this figure in the two-dimensional space $t_r-t_w$ (see Figure 4, which represents Figure 3 as seen from above). First, there is a concave inverse relationship between export taxes and waste fees when $d$ is kept constant. The explanation for this result is simple. Each combination of $t_r$ and $t_w$ defines a deforestation rate $d$. According to the results reflected in Figure 2, an increase in any of these

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14 Certain tax combinations push the model to levels of $a$ or $n$ above the interval $[0,1]$ (i.e., the firm experiences a corner solution, thus requiring both $a$ and $n$ to be fixed at the maximum allowed level).
revenue instruments will then result in the decline of the deforestation rate. Thus, the other revenue instrument must decrease at an increasing rate if the deforestation rate is to remain constant. In sum, it can be shown that $d$ is greater than $g$ to the left of the locus for which $d=g$ (i.e., low taxes lead to excessive exploitation), and the opposite is the case for tax combinations to the right of that $d$ locus (i.e., high taxes reduce exploitation).

Figure 4: Two-Dimensional Representation of Tax Combinations for which $d = g$

Second, the fact that for some tax burdens the choices of $a$ and $n$ become corner solutions also suggests that "equilibrium" tax combinations exist, as shown in Figure 4, only within certain ranges of the export tax and the waste fee. This is also suggested by the fact that for a certain tax burden, as represented by Figure 3, firms exit the production process. In such extreme, no production takes place and $d$ ceases to be equal to $g$.

Finally, do increases in export tax rates and declines in waste fees lead to increases in government revenues, as suggested by Figure 3? Assuming area fees do not exist the total differential of equation (12) in steady state (i.e., when $f = d = g$) is given by

$$dGR = \frac{g M_0}{1 - \phi} \left[ dt_x + dt_w \frac{\partial n}{\partial t_x} + \frac{\partial n}{\partial t_w} \right]$$
Thus, changes in export tax rates (and opposite sign changes in waste fees) may lead to either an increase or a decrease in government revenues (i.e., the sign of the total differential remains undefined for changes in $t_x$ and $t_w$ and depends on the parameters and functional forms assumed). This is not that important, however, as the key is to define export taxes and waste fees within the ranges which ensure that $d = g$. Additional revenues can then be collected through other means. For example, once export taxes and waste fees are defined so that sustainability is ensured, area fees could be established through an auction system so that the government may capture a larger share of the underlying economic rents. Larger profit or area taxes in effect shift vertically up the government revenues function.

**Figure 5: Intensive and Extensive Margin Implications of Forest Taxes and Fees**

![Figure 5: Intensive and Extensive Margin Implications of Forest Taxes and Fees](image)

We now assume the existence of several different concessions where the differences arise from the costs of exploitation. Specifically, decisions on concession exploitation (i.e., both entry and exit into production as well as the firm’s choice of $a$ and $n$) are not only the result of the overall tax burden and composition, but also of the parameter values that define a hectare’s own characteristics. A total of $m$ different and uniformly distributed hectares are assumed. The forest’s natural growth rate and the initial stock of the forest in each hectare are

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15 A clarification is required at this stage. The paper treats concessions as individual hectares but can be generalized to concessions of equal number of hectares or assumed to apply to concessions of different sizes, the latter then viewed as imaginary plots of land of equal size. These issues do not affect the results which, by examining individual hectares, may be generalized to any concession size.
assumed equal. The government maximization problem is now given by equation (12) subject to the FOCs of the firm model and an environmental constraint, where $m$ is the total number of different hectares and each firm has its own optimal choice of $a$ and $n$ for a given set of taxes and fees. The general effects of increases in the tax burden are represented in Figure 5, where concessions are uniformly distributed in the interval $[0, m]$ from high to low profitability (i.e., hectares with high profitability closer to the origin). Increases in taxes lead to declines from $j$ to $j^*$ in the number of hectares under exploitation (extensive margin implications), while also reducing total profits by $GHIJ$. This decrease in profits is the result of declines in profit margins due to higher taxes and its origin may be traced to both the intensive margin as well as the extensive margin implications of tax and fee increases.\(^{16}\)

Again, the model is solved numerically as closed form solutions do not exist.\(^{17}\) These calculations target an average $d$ for the whole forest which equals the forest’s natural growth rate $g$. As before, the government chooses a combination of export and waste taxes that maximizes revenues, for a given set of area fees and profit taxes, while complying with the mentioned environmental constraint. The $m$ firms are assumed to differ in the parameter value of their cost function (or any other firm/hectare specific parameter), perhaps as a result of distance to port or differences in the difficulty of access to each concession. Although government revenues still increase for a given area and profit tax as, for example, export taxes are increased and waste fees decreased, some hectares are eventually abandoned. This occurs in a gradual manner, however, as firms do not all exit simultaneously the production process. In turn, this impacts negatively on government revenues, and may be viewed as a quasi-Laffer effect resulting from high taxation, an effect working through the firm’s decision to exit production (i.e., reduction of the tax base). The equivalent of Figure 3 would show increases in the government revenue function as the tax burden is increased. Eventually, a gradual decline in the revenue function will start to take place as the reduction of the tax base outweighs the revenue gains of a higher tax burden.

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16 If hectares are not uniformly distributed based on their cost or productivity parameters, then the government revenue function may have many local maxima or, even, multiple equilibria.

17 Note that the environmental constraint may be modeled in two slightly different ways. The first is for the average deforestation rate of the whole forest to be equal to $g$, thus implying that as hectares exit the production process those that remain are exploited more intensely. This constraint is defined as

$$\sum_{i=1}^{j} \left[ \frac{f_i}{m} \right] = 0.075 = g$$

for $i$ from 1 to $j$, with $m$ being the total number of existing hectares and $j$ the total number of hectares under exploitation. Alternatively, the constraint could apply only to those hectares that are producing timber so that their average deforestation rate equals $g$, thus implying that as hectares exit the production process the forest’s total deforestation rate will decrease. This constraint, represented by

$$\sum_{i=1}^{j} \left[ \frac{f_i}{j} \right] = 0.075 = g$$

for $i$ from 1 to $j$, implies that total timber production will eventually be below the forest’s sustainable exploitation level. For simplicity, this paper adopts the first environmental constraint. Even though the second constraint-type is more consistent with sustainability of exploitation per hectare, the thrust of the conclusions reached is not affected.
A Digression on Area/Concession Fees

Several authors (e.g., Robbins et al., 1995) have noted that the introduction of area fees in Bolivia has led to an increase in the average number of harvested cubic meters per hectare; from 2 to about 10 cubic meters per hectare. Concurrently, the average number of hectares under exploitation in any one concession has decreased, from 15,000 to 2,500 hectares per year, and total hectares under concession have declined from about 22 to 5.7 million hectares. Thus, area fees are perceived as a means to induce a more efficient exploitation of forest land, affecting both the decision on exploiting or not a marginal hectare as well as the volume of timber extracted from each hectare under exploitation.

This paper argues that 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) as area fees are in effect fixed costs. 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 to introduce institutional changes. These changes improve the quality of the property rights generated by forest concessions, in turn having an impact on how any one hectare is exploited. This is the result of the underlying institutional changes, however, and not of using area fees as a revenue instrument. In the particular case of Bolivia the noted evidence on the implications of area fees could also be the reflection of some of the other reforms introduced in parallel. For example, area fees were introduced as volume-based taxes (i.e., export taxes) were eliminated, the latter in effect leading to an increase production per hectare. More simply, increases in average cubic meters per hectare may be the aggregate outcome of marginal hectares exiting production.

As to the implications of area fees for concession hoarding, which may be viewed as the extensive margin effect, the net outcome of reductions in hoarding on the number of hectares under exploitation depends on which of two opposing factors dominates. Either hectares are driven out of production as a result of reductions in profit margins, or they are incorporated into the production process as a result of increases in the opportunity cost of maintaining hectares idle. The model supports the first of these factors under the argument that a higher tax burden leads to a reduction in profit margins. This serves to explain the reduction in total hectares under exploitation in Bolivia, which in turn may explain the aggregate increase in average timber production per hectare. The second factor seems at odds with the results of the model, however. How can hectares be incorporated into production? In our view the explanation is simple. If the concessionaire has a leisure or non-monetary component in its objective function (e.g., saving the rainforest), then an increase in area fees would increase the opportunity cost of maintaining hectares idle. Much as increases in labor income taxes drive people into leisure activities, increases in area fees have the opposite
impact on concessionaires. In sum, land may be held more as a consumption than as an investment good; e.g. Bird and Rhoads (1967) stress that “land is held idle ... to provide pleasure and prestige ... so that it is in a real sense very often a consumer good.” Similarly, the opportunity cost of land and timber speculations increases as area fees are increased.

Do auction mechanisms based on a payment above a given floor area fee, such is the case in Cameroon, have any implications on land use? Auctions serve to maximize government revenues but, administrative issues aside, similar results could in fact be reached by auctioning off concessions based on an additional rate over, say, a floor profit tax rate. More importantly, while auction of area fees may serve to maximize government revenues, our model suggests that area fees do not ensure environmental sustainability. The auction process pushes firms to evince how much they are willing to allow their excess profits to decline while still remaining interested in doing business. It says nothing, however, as to the sustainability of exploitation in the hectare for which the auction is taking place as, once again, sustainability issues are tied only to what we refer to as environmental taxes and fees. Total timber production is also not affected; if the auction attracts offers, then this also means that exploitation will follow. Only increases in the fixed component of the area fee will reduce interest in marginal hectares through reducing profit margins and, thus, having an indirect impact on sustainability by driving hectares out of production.

4. Summary of Results

We can summarize the paper's results in the following way. Once a certain environmental constraint is chosen, a key element of a sustainable forest exploitation policy resides in the mix of export and waste taxes as these are the revenue instruments which affect the deforestation rate in any one hectare (intensive margin). It is important to note that both export taxes as well as waste fees are needed, and the latter must be defined as a specific tax per tree harvested. In fact, export taxes by themselves will not ensure sustainability. Also, the level and mix of these fiscal instruments cannot be defined without consideration being given to profit and area taxes, as the overall tax burden has extensive margin implications. These results are found to be consistent with the main literature on forestry taxation. Therefore, the paper suggests that tax combinations can be found that maximize revenues and ensure sustainability. Specifically, it recommends that export taxes and waste fees be defined so as to ensure sustainability once profit taxes and “fixed” area fees have been defined, and that an additional auction-based area fee be used for the government to capture a larger share of the economic rents.

In sum, tax and fee combinations need to be given careful attention. For example, if export and waste taxes are such that \( d = g \) and excess profits are zero in any one hectare, then increases in area and profit taxes would drive production in this hectare to zero. This would
also eliminate government revenues. Similarly, the wrong mix of waste and export taxes leads to a deforestation rate which might not be sustainable, irrespective of area and profit taxes, and a tax structure solely based on area and profit taxes would imply the determination of an exploitation level based solely in profit objectives, thus without due consideration being given to environmental concerns. Timber production would then be affected only indirectly, namely by the process of driving hectares out of production. Similar is the case of taxation based only on volume taxes (i.e., export taxes or export taxes combined with stumpage fees which have been defined so that they are equivalent to volume-based taxes).

It is also confirmed that area fees serve to reduce concession hoarding, where the net outcome on the number of hectares that remain under exploitation depends on which of two factors dominates; either hectares are driven out of production as a result of reductions in profit margins, or they are incorporated into production as a result of increases in the opportunity cost of maintaining hectares idle. More importantly, area fees are shown to have only indirect implications on the intensity of exploitation in any one hectare; e.g. as a result of institutional improvements that accompany the introduction of area fees.

Finally, to the extent that discount rates reflect in part the quality of the property rights generated by a forest concession, lower values of β (i.e. greater uncertainty) result in a more abusive forest exploitation. Long-term and well-defined property rights would thus help to facilitate exploitation sustainability. The paper also argues that the quality of the property rights generated by forest concessions is weak in Central African countries, thus supporting the use of models different from those based on the rotation of forest concessions.

5. **Concluding Remarks**

The goals of capturing government revenues and protecting the environment have often been seen as contradictory. This paper shows, however, that appropriate revenue instruments may make these potentially opposing goals mutually consistent. This requires to understand the individual implications of each instrument, both for revenue generation as well as for sustainability. Specifically, the paper’s recommendation is to define export taxes and waste fees so as to ensure the sustainability of forest exploitation, the latter fiscal instrument defined as a specific tax per tree harvested, and then use auction of area fees as a means for the government to capture a larger share of the underlying economic rents.

Is this proposal weakened by the fact that Central African countries have weak tax administrations? The paper’s main recommendation in our view fares well when compared with existing alternatives on forest management. For example, an important role has been suggested for forest management plans, and this role is in no way diminished by our paper. However, even though tax administrations are weak in Central Africa, this is also the case of
those administrations in charge of monitoring forest management plans. The difficulty of developing an aggregate sector knowledge on which to ground a tax-based forest management system is not being underestimated, but such management system has the advantage of not requiring to continuously monitor each concession.

At a minimum, the paper highlights that an ill-defined tax structure could itself conduce to an abusive exploitation of tropical forests, and this independently of the quality of existing forest management plans. In part, this constitutes the main aim of the paper as we believe the literature frequently neglects the individual implications of fiscal instruments on the potentially opposing goals of capturing revenues and protecting the environment.

The paper also qualifies the role that area fees can play for a better utilization of land. These fees are shown to have extensive margin implications but no effect on the intensity of exploitation per hectare (intensive margin). In sum, by themselves area fees may lead to an abusive exploitation of the forest. It is also argued that auction-based area fees serve to elicit information from firms on the value of the resource, but they do not eliminate the usual wedge between social and private costs and benefits of forest exploitation (i.e. environmental concerns are not addressed as area fees do not have intensive margin effects).

Are there any alternatives to taxes as a means to affect the underlying incentive framework of forest exploitation, thus affecting both government revenues as well as forest sustainability? Yes, alternatives do exist. For example, performance bonds may serve to assess the behavior of individual firms, thus enabling to compensate or penalize firms based on results on the ground. This is also administratively burdening, however. Although abuse may be diminished by the risks intrinsic to the loss of the bond, it also requires operators to believe that the system will be fairly applied. The system we propose is potentially less dependent on direct monitoring of individual concessions, and emphasizes a greater aggregate understanding of the sector to determine a tax-based forest management policy. It could also be combined with other instruments contained in forest management plans, provided accountability mechanisms for these instruments can be designed and enforced.
Appendix

The first order conditions (FOCs) of the maximization problem of the firm are given by

\[(1 - \beta (1 + g)) [ (1 - t_x) f_a(a, n) - t_w j(n) f_a(a, n) ] + \beta f_a(a, n) h(a, n) f(a, n) -
( h_q(a, n) f(a, n) + h(a, n) f_a(a, n) ) (1 - \beta (1 + g - f(a, n))) = 0 \]

and

\[(1 - \beta (1 + g)) [ (1 - t_x) f_n(a, n) - t_w j(n) f_n(a, n) ] + \beta f_n(a, n) h(a, n) f(a, n) -
( h_q(a, n) f(a, n) + h(a, n) f_n(a, n) - t_w j(n) f(a, n) ) (1 - \beta (1 + g - f(a, n))) = 0 \]

These FOCs are functions of the firm's choice variables \(a\) and \(n\). Assuming the functional forms

\[f(a, n) = \sigma a^{0.5} n^{0.5}, \]
\[h(a, n) = \gamma a n, \]

and

\[j(n) = \alpha n^2, \]

the model can be solved numerically (i.e., closed form solutions do not exist). The second order conditions for a maximum can be shown to hold under usual assumptions. It can also be derived from the FOCs that

\[n = \gamma a \frac{2}{\alpha t_w}, \]

Since \(a\) has been normalized to the interval \([0,1]\), values of \(n\) can be obtained from this equation for each possible value of \(a\) (or vice-versa). The one combination of \(a\) and \(n\) that maximizes profits is also the combination which ensures that the FOCs equal zero. Alternatively, numerical optimization procedures may be used to solve for \(a\) and \(n\), and, once a government model is introduced, for the underlying optimal choices of taxes.
References


