Environment and Development Economics 11: 221–233 © 2006 Cambridge University Press
doi:10.1017/S1355770X05002767 Printed in the United Kingdom

Of guns and trees: impact of terrorism on forest conservation

VIVEKANANDA MUKHERJEE* and GAUTAM GUPTA
Department of Economics, Jadavpur University, Calcutta, India

ABSTRACT. Many terrorist organizations around the world seek shelter in forests and this paper tries to address the impact of this phenomenon on forest conservation. We construct a framework to measure the social loss when a terrorist lives in the forest and has full control over the forest resources. We also consider a game between the terrorists and the government when the government tries to combat them to recover the social loss. We characterize the equilibrium of the game in which the terrorist chooses the optimum rotation length of the forest and the government chooses the optimum combat-effort. We derive the impact of two popular policy measures such as strengthening the combat operations and restricting the sale of timber by the terrorist groups in the market, on forest conservation and find both to be negative.

1. Introduction

There has been a continued growth in terrorist organizations and activities around the world in the last ten years. Fully militarized and highly trained terrorist organizations have emerged in virtually all countries, with varied political, economic, and other objectives. The list of objectives includes overthrow of a particular regime, autonomy from the parent nation state, opposition to multinational business interests, opposition to religious interests, and land reforms, as well as looting, abduction, and kidnapping for profit. This growth is particularly pronounced in the less developed continents of Asia, Africa, and Latin America. There is considerable variety in the objectives, strategies, and operations of these organizations. However, while a few of these organizations operate from urban areas, the vast majority of these operate from remote rural areas, frequently using a forest as their base. The reasons for this are obvious. A dense forest provides ideal shelter for the terrorists: training operations can be carried out in relative security, hostages and booty can be held easily, and lack of proper

The paper has benefited from a discussion with Charles Perrings and his comments. We also thank two anonymous reviewers and the participants of the Conference on 'Recent Trends in Trade and Environment' held at Jadavpur University in February 2004, for helpful comments. The usual disclaimer applies.
* Corresponding author: Department of Economics, Jadavpur University, Calcutta 700032, India. Tel: +91-33-2414 6328. Fax: +91-33-2414 6008. Email: mukherjeevivek@hotmail.com

roads and communications allow evasion from government combat forces more easily. The terrorists only leave the forest hideout temporarily to carry out actions on designated targets and then retreat into the forest. They are frequently alleged to be logging trees and selling timber in the black market to finance day-to-day survival as well as to buy arms and ammunitions.[1] There are a large number of organizations that operate in this manner, e.g. Front for the Liberation of the Enclave of Cabinda (FLEC) in Angola, The Revolutionary Armed Forces (FARC) and the National Liberation Army (ELN) both operating in Colombia, Abu Sayef Group (ASG) in the Philippines, the Free Aceh Movement (GAM) in Indonesia, the Maoist rebels in the Himalayan State of Nepal.[2]

In India, several terrorist organizations, mostly demanding autonomy from India, operate in the North Eastern States. Mention can be made of the Tripura National Volunteers in Tripura and the National Socialist Council of Nagaland in Nagaland, which are both based in forests of the respective states. The Peoples War Group (PWG) and Maoist Communist Centre (MCC) have virtually taken over the Betla-Daltongunj forests, so much so that the decadal tiger census had to be called off in December 2003 due to attacks on the census personnel by the terrorists.[3]

In this paper, we try to model the interaction between the government and the terrorists over the ownership of forest resources. However, as the terrorist organizations pursue intermingled multiplicity of objectives as described above, it is extremely difficult to provide a definition of a 'terrorist' which serves the purpose of our model. Therefore, before embarking on a description of the model that seeks to capture a situation where a terrorist takes shelter (and therefore takes control of the resources) in a forest and the forest conservation gets affected as a result of that action, it is necessary to attempt a definition of the 'terrorist' whose behavior is sought to be captured here. Given forest conservation is the focus of the paper and to keep the analytical framework tractable, we will simply define a terrorist as a person operating beyond the law, with the following three features: (i) must be entrenched in a forest which he uses as his base and shelter, thereby exercising full control over forest resources such that all other users are excluded; (ii) resorts to illegal felling of trees to finance day-to-day activities; (iii) is the target of combat operation by government forces and is therefore required to use the forest as cover. Given these criteria, a wide range of activities may be defined as terrorist activities. For instance an

[1] Note, there is an important distinction between the terrorists, as we define them, and the poachers, who poach timber from the forest. The poachers need not use the forest as shelter, while the terrorists need to. The poachers, provided they evade capture, can survive on the money they generate from poaching, and do not otherwise need the forest. However, this is not the case for the terrorist groups, who use the forest cover as their shelter.

[2] Source: Patterns of Global Terrorism, 2000 – a report periodically published by Office of the Coordinator on Counterterrorism, US State Department and newspaper reports/websites on terrorism.

[3] 'Tiger Census halted on track', *The Statesman*, Kolkata Edition, 2nd January, 2004, p. 7.

organization using terror for achieving political objectives will belong to this set even if they sometimes resort to abduction and kidnapping for profit. In the same way an organization waging war against the government will belong to the set even if they sell timber or animal products for purchase of arms. Finally a pure bandit who hides in the forest but loots and plunders the non-forest population will be seen as a special case of terrorism where the objective is pure financial gain. In order to retain our focus on forest conservation issues, we refrain from including the political, financial, or other objectives of the terrorist as well as the non-profit objectives of the government such as improved peace and order in society in combating the terrorist.[4] A possible consequence of these omissions is that gains from successful combat operations by the government against the terrorist will be underestimated. Possible gains by the terrorist are not considered, as the terrorist is not considered part of the society. In this framework, if the terrorist captures the forest, the government as the representative of society loses *de facto* control of the forest and its resources to the terrorists. Therefore the flow of all timber and some of the non-timber benefits from the forest to society ceases. The government is left with mounting combat operations from time to time to flush out and capture the terrorists. The terrorist organizations on the other hand use the forest as shelter and cover from government combat forces as well as to extract timber from the forest for money. The purpose of this paper is to derive a measure of the social loss to society from terrorists' control of the forest. It also tries to examine the effect of the combat operation on the forest management strategy of the terrorists and to measure the resulting change in the social benefit.

The literature on forest conservation and natural resource management is notably silent on the subject. Brown (2000) in a recent survey looks at the various issues related to management of renewable resources including the forest, but does not mention the problem of terrorism. Similarly, Conteras-Hermosilla (2000), in a paper which looks at the different causes of degradation of forest resources, does not mention terrorist activities as one of the probable causes of forest decline. Ostrom (1999) deals with common property resource management of forest resources, but does not discuss the problem of terrorists. So, to the best of our knowledge, this is the first paper which tries to construct a framework in which the problems of terrorism and forest conservation are discussed.

The paper organizes itself in the following way. In the next section it constructs a model following the standard literature on the choice of optimum rotation length and optimum forest management.[5] It describes the choice of rotation by society and the terrorist when either of them has full control over the forest resources. The problem of the terrorists is reinterpreted in such a way that their concern for forest cover as their hiding place is reflected in their choice of rotation length. We compare

[4] For such type of models see Grossman (1991), Tornell (1998) which focus on the political objective of the organization.

[5] See Conrad (1999), Hartman (1976).

these choices to show that it is not certain that the terrorist chooses shorter rotation length than the government. However, if the society has no control over the timber benefit from the forest, its objective function itself changes and any choice of rotation length by the terrorist appears sub-optimum from its perspective. We calculate the social loss. Then, the paper builds a game theoretic model in which the government conducts a combat operation to free the forest from terrorist occupation and tries to recover the social loss as well as to gain some political advantage. The terrorist reacts by choosing the optimum rotation length. We find the Nash equilibrium and perform some comparative static exercises regarding some popular government policies on behalf of society *vis-à-vis* the terrorist group. We check what happens if the government strengthens its combat forces and if it is able to ban the sale of timber by the terrorist in the market. We find that the impacts of both the policies are negative on forest conservation and on society. This is a surprising and unexpected result.[6] The last section concludes.

2. The model

In developing the model, we first discuss the government's problem when it has full control over the forest and next discuss the terrorist's problem when he has full control over the forest. We compare the welfare of the society in these two different equilibria. Thereafter we describe the game between the terrorist and the government if the latter tries to combat terrorism through different policies and we discuss the implications of these policies in terms of forest conservation.

2.1. The government's problem if it controls the forest

Suppose the government, on behalf of society, owns the forest and can assert its full control over it. It obtains both the timber and non-timber benefit from it. The non-timber benefit typically includes bio-diversity preservation, reduction of environmental pollution, use of forest for tourism, and so on. Let, $pf(T)$ measure the timber benefit from trees kept for T years, where $f(T)$ represents the volume function of the timber and p represents its stumpage price.[7] The non-timber benefit is given by $A(T) = \int_0^T a(T)e^{\delta(T-t)}\,dt$, where $a(t)$ is the benefit accrued in the tth year and δ is the social discount rate (usually considered to be equal to the market rate of interest). If it is a multiple rotation commercial forest, the present value of the net benefit that society derives from it is given by the following expression

$$\pi(T) = \frac{pf(T) + A(T) - c}{e^{\delta T} - 1} \tag{1}$$

[6] In its spirit, the result is comparable to the result of Neher (1978), which discusses the problem of muggery and calls for restriction in security actions against organized mugging, if it cannot weed it out, since society is benefited if mugging is restricted.

[7] The stumpage price of the timber is defined as its market price minus the harvest cost.

where c is the opportunity cost of the land.[8] The government, on behalf of society, maximizes (1) by choosing T, i.e. the duration of investment and an optimum forest management strategy is adopted to maintain the steady flow of $\pi(T)$ over the years. The first-order condition of the above exercise is $\pi'(T) = 0$, which implies

$$pf'(T) + a(T) = \delta[pf(T) - c] + \delta\pi. \tag{2}$$

Suppose equation (2) solves for T^*. We assume $\pi''(T) < 0$ to ensure that the second-order condition for maximization is satisfied at T^*. At T^*, the marginal benefit of keeping the tree (left-hand side of equation (2)), which equals the growth of timber and non-timber benefit obtainable from the tree as the tree remains for one more period, is equal to the marginal cost of keeping the tree (right-hand side of equation (2)), which equals the loss of nominal interest on the profit that could be generated by the sale of the timber in the current period and suspension of the profit stream for all future rotations. This defines the social optimum where the forest cover is maintained at a constant level at which the net benefit from the forest is at its maximum. We want to compare this equilibrium with a different equilibrium where the terrorist has full control over the forest.

2.2. The terrorist's problem if it controls the forest

The terrorist group is a breakaway fraction of society and uses the forest as its shelter. Since terrorism is an illegal activity, it is assumed that the welfare accruing to the terrorist is not included in the welfare calculation of society as a whole. Suppose the terrorist has full control over the forest instead of the government. The terrorist is concerned with the timber value of the forest, as is the government, but they are not interested in the full menu of non-timber benefits in which the government has its interest. However, they derive an important non-timber benefit from the forest: it provides them with their shelter and allows them to evade capture when the government launches combat operations. This motivates them to keep the trees in the forest for more years, but also deprives them of the timber benefit they could earn from cutting the trees. Therefore, the most appropriate way to describe the terrorist's problem appears to be the choice of the optimum density of the forest by equating its marginal benefit and its marginal cost. However, in order to provide more rigor to the analysis, in this paper we take an indirect route to capture the terrorist's concern. Note that the density of the forest has a positive relation with the number of years the trees are allowed to grow in the forest and therefore with the volume of timber. In our model, the terrorist, instead of choosing the density of the forest, chooses the optimal time for timber harvesting to maximize the sum of the timber and non-timber benefits (where the latter comes only from provision of shelter). Suppose the non-timber benefit they derive from the forest is represented by $b(t)$. Clearly, $b(t) < a(t)\ \forall t \in [0, T]$, the non-timber benefit derived by

[8] The technique to arrive at this expression is fairly standard in the literature. See Conrad (1999) and Hartman (1976) for details.

https://doi.org/10.1017/S1355770X05002767 Published online by Cambridge University Press

the government. So, the amount of profit they derive from the forest is given by

$$\overline{\pi}(T) = \alpha \frac{\overline{p} f(T) + B(T) - \overline{c}}{e^{\overline{\delta}T} - 1} \tag{3}$$

where $B(T) = \int_0^T b(T)e^{\overline{\delta}(T-t)}dt$ and $(1-\alpha)$ is the probability of capture. Equation (3) is similar to equation (1) with a few differences as follows: (i) the stumpage price $\overline{p} < p$; this is because, given the same market price of the timber, the harvesting cost is much higher for the terrorist than for the government since illegal logging is costly. For example, he cannot use capital-intensive methods, or, even if he does, the cost of capital is much higher for him;[9] (ii) the opportunity cost of the land is almost zero for the terrorist since he cannot use the land for any other purposes, therefore $\overline{c} < c$; (iii) $\overline{\delta}$ is close to zero for the terrorist since his perception of return on the assets is much lower than the market rate of interest. The realization of profit is also uncertain for the terrorist as he faces the threat of combat from the government. With probability $(1-\alpha)$ he is captured, in which case his profit becomes zero. So, $\overline{\pi}(T)$ represents the expected profit of the risk-neutral terrorist.[10] He maximizes $\overline{\pi}(T)$ by choosing an appropriate value of $T \geq T_0$. He puts a lower limit T_0 on the size of the timber since he prefers to keep trees of a reasonable size in the forest, which helps him to hide. The first-order condition implies

$$pf'(T) + b(T) = \overline{\delta}[\overline{p} f(T) - \overline{c}] + \overline{\delta}\frac{\overline{\pi}}{\alpha} \tag{4}$$

which solves for $\overline{T} \geq T_0$. We assume $\overline{\pi}$ is concave in T so that the second-order condition for maximization is satisfied. Now, we want to compare T^* obtained from (2) with $\overline{T}$ obtained from (4) to see whether the terrorist or the government chooses longer rotation lengths.

2.3. Comparison of the equilibria

In the previous subsections we have solved the government's problem and the terrorist's problem, where both of them choose the optimum rotation length of the trees by equating their marginal benefit from waiting with their marginal cost of waiting. Observe, since the terrorist does not take into account any of the non-timber benefits accruing to society from the forest, and as the stumpage price is lower for him (see subsection 2.2), it is surely the case that the marginal benefit (MB_T) is lower for him than for the government, (MB_S) for all values of T. However, it is difficult to compare the values of their marginal costs. The stumpage price and the opportunity cost of land are both lower for the terrorist. They also suffer from the uncertainty of capture due to government combat operations. But, as the terrorist attaches less weight to the future, i.e. $\overline{\delta} \to 0$, then it must be the case that the marginal cost to the terrorist, MC_T, is near to zero and lower than the marginal cost to society, MC_S (see subsection 2.2). The determination of

[9] See footnote 7 for the definition of stumpage price.
[10] We assume the terrorist is risk neutral for analytical convenience.

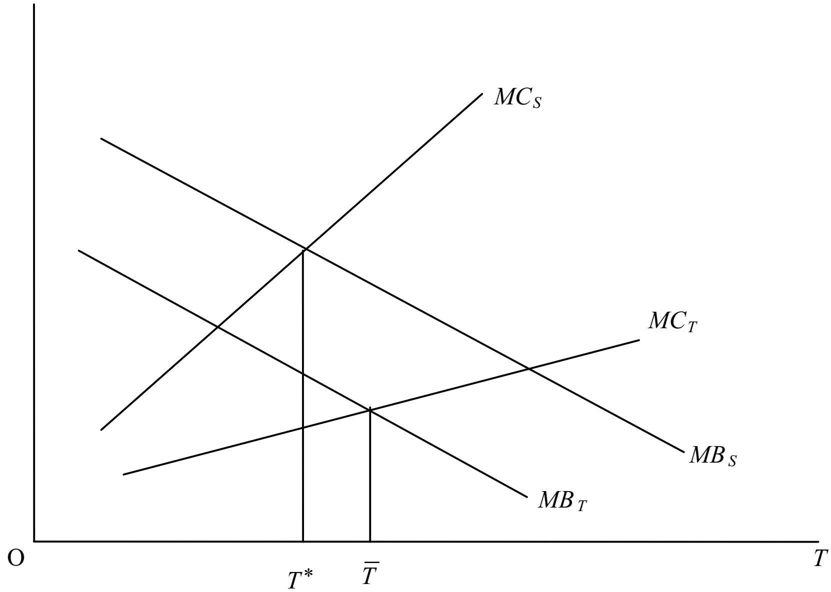

Figure 1. *Comparison of the equilibria*

$\overline{T}$ and T^* is illustrated in figure 1. The comparative magnitude of $\overline{T}$ and T^* is ambiguous. It depends on the relative positions of the marginal benefit and marginal cost curves. However, if $T_0 \geq T^*$, it can be concluded that $\overline{T} > T^*$. The above discussion leads us to state the first observation of our model:

Observation 1: When the terrorist has *de facto* ownership of the forest, he may choose rotation lengths longer or shorter than the socially optimal rotation length, depending on his calculation of his marginal benefit and marginal cost. However, if the terrorist cares too much about the forest cover, he chooses a longer rotation time than the government.

Now we try to measure the social loss as the terrorist establishes full control over the forest. Note that the social profit function described in equation (1) is no longer valid if the terrorist occupies the forest. In this case, society does not get the timber benefit[11] and some of the non-timber benefits such as tourism, etc. from the forest. However, as long as the forest is there, they enjoy the positive impact of the forest on the environment, as

[11] By 'timber benefit' we mean the revenue benefit generated from the sale of timber. It can be argued that even if the terrorist owns the forest, society, as consumers of timber, does not lose all of the timber benefits they used to get when the forest was owned by the government. This happens because ultimately the terrorist sells the timber in the market, the consumption of which benefits the consumers. But, observe that this benefit is independent of regime change and, for a given rotation length, it gets netted out of overall welfare comparison under alternative regimes.

https://doi.org/10.1017/S1355770X05002767 Published online by Cambridge University Press

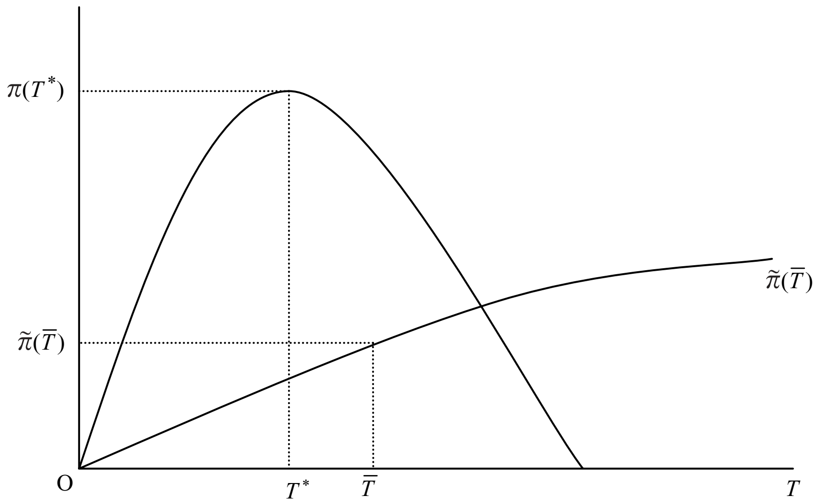

Figure 2. *Profit functions of the society with and without control over the forest*

the forest helps carbon sequestration and uptake,[12] watershed maintenance, soil stabilization, regulation of local atmospheric quality, etc., but these are the only non-timber benefits they get from the existence of the forest. So the social benefit function takes the following form

$$\tilde{\pi}(T) = \beta \int_0^T a(T)e^{\delta(T-t)}dt \tag{5}$$

where $\beta \in (0, 1)$. Clearly, $\frac{\partial \tilde{\pi}(T)}{\partial T} = \beta[a(T) + \delta A(T)] > 0$. We assume $a'(T) < 0$, so that $\frac{\partial^2 \tilde{\pi}(T)}{\partial T^2} < 0$. The profit functions of the society in the two situations: (i) having full control over the forest (i.e. $\pi(T)$) and (ii) having no control over the forest (i.e. $\tilde{\pi}(T)$, are shown in figure 2. The government maximizes $\tilde{\pi}(T)$ by choosing the value of T. Since $\frac{\partial \tilde{\pi}(T)}{\partial T} > 0\ \forall T$, society would like to keep the trees in the forest for an infinite number of periods. But, since $\beta \in (0, 1)$, $\tilde{\pi}(\overline{T}) < \pi(T^*)$ for any value of $\overline{T}$ chosen by the terrorist, the value of forest under the terrorists' control is always suboptimal from the point of view of society. The social loss is $[\pi(T^*) - \tilde{\pi}(\overline{T})]$. We note this result in the first proposition of our model as:

Proposition 1: *If the terrorist occupies the forest, society loses and the amount of loss is measured by* $[\pi(T^*) - \tilde{\pi}(\overline{T})]$.

Now, consider a situation where the terrorist has complete control over the forest and the government conducts combat operations to capture the terrorist. The government has an incentive to conduct such operations, since the government stands to gain in two ways: (i) it can recover the

[12] See Van Kooten *et al*. (1999) for importance of forest in carbon uptake.

https://doi.org/10.1017/S1355770X05002767 Published online by Cambridge University Press

social loss from the forest (as mentioned in proposition 1) and (ii) it may be a politically desirable outcome. These motivate the government to increase the intensity of combat operations. But, as the intensity of combat operations increases, from the point of view of the terrorist the probability of capture increases, which in turn reduces their choice of rotation length. But, the terrorist's choice of rotation length increases the social loss from the forests and therefore the government's incentive to conduct combat operations. So, there is a strategic interdependence between the behavior of the government and the terrorist, as they impose negative externalities on each other's behavior without internalizing them. In the next subsection we look at the game between the government and the terrorist and find the Nash equilibrium of the game. Then we take up some comparative static exercises.

2.4. The game

Suppose the government wants to recover the social loss since the terrorist controls the forest. So, it conducts combat operations in the forest to free it from the control of the terrorist by employing its combat forces. We have calculated the gain from the forest in proposition 1 as $[\pi(T^*) - \tilde{\pi}(\overline{T})]$. We want to check the effect of these operations on forest conservation. We assume, if the government conducts the operations, it can free the forest with $(1-\alpha)$ probability and with α probability the mission fails. But for conducting the operations, it has to put in effort e. In particular, we assume $e = (1-\alpha)$ so that, if $e \to 1$, $(1-\alpha) \to 1$, i.e. almost certainly the terrorist is captured. But the effort has a cost which is given by $\phi(e, \theta)$ with $\frac{\partial \phi}{\partial e} > 0$ and $\frac{\partial^2 \phi}{\partial e^2} > 0$ ∀e ∈ [0, 1]. The parameter θ represents the efficiency of the combat forces such that $\frac{\partial}{\partial \theta}(\frac{\partial \phi}{\partial e}) < 0$. Assuming that the government is risk neutral its expected payoff from conducting the combat operation is as follows

$$\hat{\pi} = e\,\pi(T^*) + (1-e)\tilde{\pi}(\overline{T}) - \phi(e, \theta)$$

which in turn implies

$$\hat{\pi} = \tilde{\pi}(\overline{T}) + e[\pi(T^*) - \tilde{\pi}(\overline{T})] - \phi(e, \theta). \tag{6}$$

The government maximizes $\hat{\pi}$ by choosing an appropriate value of e. Since, $[\pi(T^*) - \tilde{\pi}(\overline{T})] > 0$ and $\frac{\partial \phi}{\partial e} > 0$ $\forall e \in [0,1]$, the interior solution exists and the first-order condition is

$$\pi(T^*) - \tilde{\pi}(\overline{T}) = \phi\prime(e, \theta) \tag{7}$$

which solves for $e(\overline{T})$. The second-order condition is also satisfied since $\frac{\partial^2 \phi}{\partial e^2} > 0$ $\forall e \in [0, 1]$. The function $e(\overline{T})$ also represents the reaction function of the government corresponding to all possible choices of $\overline{T}$ by the terrorist. Clearly, as $\overline{T}$ goes up, all other things remaining the same, $\tilde{\pi}$ goes up and the marginal benefit from the combat operations falls. Since, the marginal cost of supplying effort is increasing in e, the effort level by the government falls. Since by definition $e = (1-\alpha)$, as e falls, α rises, and in the $\alpha - \overline{T}$ plane the reaction function becomes a positively sloped curve. On the other

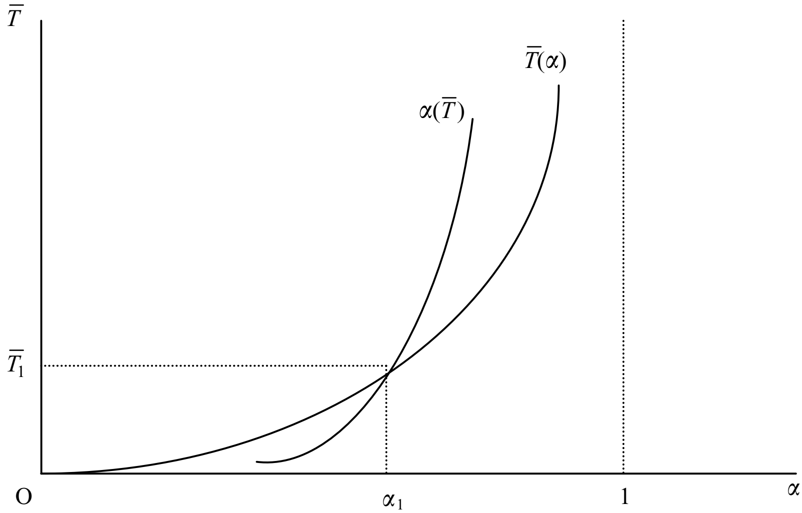

Figure 3. *Nash equilibrium*

hand, from equation (4) we can derive the reaction function for the terrorist in his choice of $\overline{T}$ for all possible effort levels chosen by the government in combat operations. As e goes up, α falls. But from equation (4), which equates marginal benefit and marginal cost to the terrorist in his choice of $\overline{T}$, as α falls, the marginal cost of keeping the trees for one more period rises, given the marginal benefit, making his marginal profit negative. Since his marginal profit is diminishing in $\overline{T}$, he chooses a lower value of $\overline{T}$. Therefore the slope of the terrorist's reaction function $\overline{T}(\alpha)$ in the $\alpha - \overline{T}$ plane becomes positive. We assume an interior solution of the game exists, which is at the intersection point of the two reaction functions in figure 3.

In figure 3 $(\alpha_1, \overline{T}_1)$ represents the Nash equilibrium of the game. Now the question we ask is how does this equilibrium change with changes in parameter values in the model.

First, we look at the change in the efficiency of government combat forces. Suppose the government increases the efficiency of the combat forces so that θ rises. Clearly from (7), as θ rises and consequently $\phi'(e)$ falls, the equilibrium effort level rises given $\overline{T}$. So, given $\overline{T}$, the equilibrium value of α falls and the reaction function of the government shifts to the left. Nothing happens to the terrorist's reaction function. So the new equilibrium looks like figure 4. The equilibrium moves from $(\alpha_1, \overline{T}_1)$ to $(\alpha_2, \overline{T}_2)$. At the new equilibrium, the effort level rises, i.e. the probability of success in combat operations rises and the terrorist's choice of $\overline{T}$ falls. The terrorist chooses shorter rotation length because his perception of probability of realization of profit from timber falls as α falls. As a result $[\pi(T^*) - \tilde{\pi}(\overline{T})]$, i.e. the social loss rises. Society also supplies higher effort to suffer higher loss from the

https://doi.org/10.1017/S1355770X05002767 Published online by Cambridge University Press

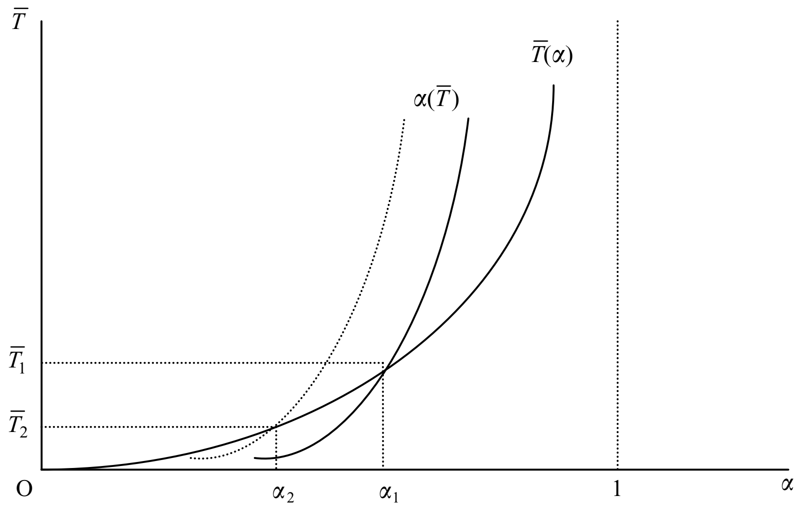

Figure 4. *Stepping up the combat operation*

combat operation. We note this result in the next proposition of our model as:

Proposition 2: *As the efficiency of the government's combat operation rises, the terrorist chooses shorter rotation lengths and the social loss increases*.

Now, we consider the effect of the government's effort in controlling the sale of timber sold by the terrorist on the market. Suppose the government tries to restrict the sale of timber on the market by the terrorist by imposing a ban on illegal timber.[13] In such a situation, it is certain that the market price of timber rises. But, now there is a difference between the consumers' price and producers' price. The consumers' price is higher than the market price would have been had there been no restriction. But, the producers' price (the price the terrorist receives) is lower than the market price in the 'no restriction' situation. The retailer expropriates the rent created by the difference between the producers' price and the consumers' price, because he bears the entire risk of selling the illegal timber.[14] So, it is always the case that, if the restriction is imposed, the price of timber falls for the terrorists.[15] As a result of this, it is evident from equation (4) that both the marginal benefit and the marginal cost for the terrorist fall. But, since $\overline{\delta} \to 0$, the fall in the marginal cost remains dominated by the falling marginal

[13] We assume, in particular, that the government announces that those detected selling illegal timber will be punished. The punishment, of course, is finite.

[14] The equilibrium looks very similar to the equilibrium with import quota on foreign trade as discussed in Helpman and Krugman (1989; chapter 2), but generated through a different process altogether.

[15] The society faces a further source of welfare loss in terms of higher consumers' price of timber at the market.

https://doi.org/10.1017/S1355770X05002767 Published online by Cambridge University Press

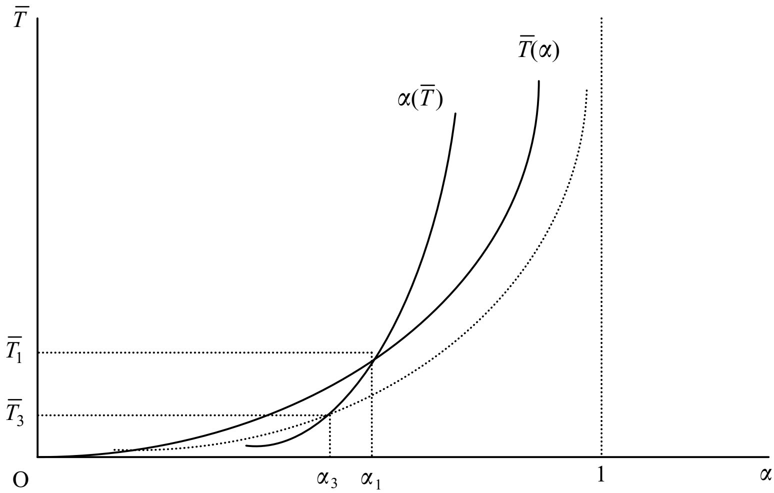

Figure 5. *Restricting the sale of timber*

benefit so that the marginal profit becomes negative. Given the value of α, $\overline{T}$ falls, which in turn implies that the reaction function of the terrorist moves to the right. This equilibrium is described in figure 5. The equilibrium moves from $(\alpha_1, \overline{T}_1)$ to $(\alpha_3, \overline{T}_3)$. So at the equilibrium the government puts more effort into combat operations and the terrorist conserves the trees for a fewer number of periods. Therefore, in this case $[\pi(T^*) - \tilde{\pi}(\overline{T})]$ falls and the social loss increases. Society also loses by putting more effort into combat operation. We note this result in the following proposition of our model as:

Proposition 3: *If the government is able to restrict the sale of timber by the terrorist in the market, the terrorist keeps the trees in the forest for a fewer number of periods and the social loss increases.*

Therefore, both the policies discussed in this paper on the part of the government have negative implications in terms of forest conservation.

3. Conclusions

The paper discusses the impact of forest-based terrorism on forest conservation. It concludes that, if the terrorist establishes full control over the forest, any rotation length chosen by them is sub-optimal from the point of view of society. It calculates the social loss compared to the situation when society has full control over the forest. Then it considers the case when the government, on behalf of society, tries to recover the loss by conducting combat operations against the terrorist. Conducting combat operations is costly. The paper constructs a game in which the government chooses the optimum combat effort, which in turn determines the probability of recovering the forest from the terrorist. The terrorist chooses the optimum rotation length as a reaction. The paper finds the Nash equilibrium. Then it performs comparative static exercises with respect to some government policies *vis-à-vis* the terrorist. It finds out that, if the government strengthens

https://doi.org/10.1017/S1355770X05002767 Published online by Cambridge University Press

its combat forces and if it is able to ban the sale of timber by the terrorist in the market, forest conservation will be negatively affected. Society also loses. So, one of the implications of our paper is, if the forest is completely under control of the terrorist and the government cannot free it completely through combat operations, from the point of view of forest conservation it may not be optimum for the government to step up combat operations as it increases the uncertainty to the terrorist about the timber flow and increases their incentive to destroy the forest without waiting. Our result is similar to Neher (1978). Neher develops a model of muggery and concludes that a reduction in security actions against organized mugging is better for the society, if it is not possible to weed it out completely, as it reduces the incidence of mugging. In addition, in this paper we find that a ban on the sale of timber by the terrorist may not be good for society due to a similar kind of effect on the forest conservation behavior of the terrorist.

This work has several limitations. It considers the impact of terrorism only on the timber resources of the forest, but neglects the case of the biodiversity inside the forest. In reality, in most of the cases observed, the animals are adversely affected due to terrorism. The terrorist kills animals for his own survival, which leads to extinction of some of the species. So, the impact on the entire biodiversity remains to be calculated. In this paper we have discussed some policy measures on behalf of the government, which have negative impacts on forest conservation. It remains to be explored which is the optimum policy for forest conservation in the presence of terrorism. These remain as our future research agenda.

References

Brown, G.M. (2000), 'Renewable natural resource management and use without markets', *Journal of Economic Literature* **38**: 875–914.

Conrad, J.M. (1999), *Resource Economics,* Cambridge: Cambridge University Press.

Conteras-Hermosilla, A. (2000), 'Underlying causes of forest decline', Occasional Paper, CIFOR, Bogor, Indonesia.

Grossman, H. (1991), 'A general equilibrium model of insurrection', *American Economic Review* **81**: 912–921.

Hartman, R. (1976), 'The harvesting decision when a standing forest has value', *Economic Inquiry* **16**: 52–58.

Helpman, E. and P. Krugman (1989), *Trade Policy and Market Structure*, Cambridge, MA: MIT Press.

Neher, P.A. (1978), 'The pure theory of muggery', *American Economic Review* **68**: 437–445.

Ostrom, E. (1999), 'Self governance and forest resources', Occasional Paper, CIFOR, Bogor, Indonesia.

Tornell, A. (1998), 'Reform from within', Working Paper No. 6497, National Bureau of Economic Research, Washington, DC.

Van Kooten, G.C., R. Sedjo, and E. Bulte (1999), 'Tropical deforestation: issues and policies', in H. Folmer and T.H. Tietenberg (eds), *The International Yearbook of Environmental and Resource Economics 1999/2000: A Survey of Current Issues (vol. 3)*, Aldershot: Edward Elger.