Environmental Conservation and Conflict

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Abstract

In this paper we consider explicitly the conflictual dimension in a model of renewable natural resource exploitation. In particular, we study how the opportunity for resource users to prepare beforehand for a later conflict over the resource can modify incentives for conservation. We show that if conflict is possible, the range of resource regeneration rates that support conservation at equilibrium reduces. For relatively low regeneration rate, conservation is supported by a larger set of relative capacity levels if conflict is not possible. This pattern is reversed for large regeneration rate. When the regeneration rate is large enough, sharing through fighting supports the conservation equilibrium even for substantially unequal relative capacity levels.

1 Introduction

The crucial role of natural resources for the survival of the human race has boosted over the last decades social science research on the incentives and conditions under which environmental conservation can occur.

The feature that underlies the conservation issue is that it entails large positive externalities. In other words, anybody reducing air pollution or fishing effort, or foregoing forests conversion to agriculture is supporting a private cost in terms of larger production costs or reduced consumption today. The benefits of conservation are however, shared among all potential users, both current and future generations. This public good nature of environmental conservation leads to the standard inefficient under-provision of it by the society.

Were property rights perfectly defined and enforced, economically efficient solutions would emerge at equilibrium, as the seminal paper by Coase (1960) shows: the owner of the resources would be fully compensated by the other agents for the foregone current consumption. The nature of many of the resources at stake is however truly public. Think, for instance, at clean air. And

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even where property rights might be better defined (e.g. fisheries), monitoring and enforcement activities might entail prohibitive costs. As a consequence, the typical overexploitation defined "tragedy of the commons" results (Hardin, 1968).

Studies like Olstrom (1990) and Baland and Platteau (1996; 1997; 1999) explore the characteristics of resource users that might increase the incentive for conservation. In particular, Baland and Platteau (1997) argue that economic inequality across users might be beneficial for conservation, as the largest users sufficiently internalize the positive externality of foregoing current consumption (see also Olson, 1965).

More recently, Dayton-Johnson and Bardhan (2002) show that it is for intermediate levels of inequality across users that the incentive for conservation reaches its minimum: the smaller users do not sufficiently internalize the benefits of conservation and exerts its maximal effort in resource current consumption. The relatively larger users anticipate the depletion determined by the smaller users and consequently join them in exerting their maximal effort in current consumption. Full depletion of the resource follows.

The existing literature on conservation of common resources provides some interesting insights on the features of users, which increase the likelihood of natural resources conservation. And yet, it fails to address one crucial aspect linked to natural resource shrinking. When a resource shrinks, potential users become more and more aggressive to compete for what is left (de Soysa and Gleditsch, 1999). If the resource is crucial for survival, then the allocation of the remaining stock might turn into a real fight for life.

The risks linked to the pressure on natural resources were presented already by Malthus (1798) in his essay focusing on population growth: population grows at a larger rate than natural resources leading to tougher competition over them, which in turn would lead to declines in economic performance.

Diamond (1997) documents in his widely known "Guns, Germs, and Steel" how past civilizations collapsed, when some key resources went depleted because of unsustainable consumption rates. Easter Island, for instance, completely destroyed his stock of trees and according to some studies this crucially determined the breakdown of the society. Myopic local elites failed to anticipate that once the natural resources' stock levels reach critical levels, to impulse for survival would lead to harsh conflict on the resources available.

Recently, a study by Barnett and Neil Adger (2007) discusses the aspects of climate change that will affect human security and consequently increase the likelihood of violent conflicts. The analysis of internal conflicts by Collier (2004; 2009) shows that the likelihood of conflict for a country increases with the existence of valuable resources. If natural resources become scarce, their value will increase making conflicts over them more likely to emerge.

This work tries to link these two strands of literature: we set up a two period model in the same spirit of Dayton-Johnson and Bardhan (2002), in which two agents decide their current consumption of a renewable natural resource in the first stage, and deplete the rest of the resource in period two according to their relative capacity. Agents have the capacity to deplete completely the resource in the first period if they wish to do so. Full depletion in period one is assumed to result in a minimal consumption in period two.

We first identify the inequality levels in capacity across the two agents that support conservation and do not lead to full depletion in the first period. The most original contribution, however, lies in the second part of the paper, where we model explicitly the potentially ensuing conflict over resources that might (endogenously) emerge in the second period. Agents decide in period one how much of the resource they want to consume and how much of it they want to invest in military spending. In period two, agents fight over the resource left. The share of resource gained through fighting in linked to their relative military strength.

We show that if conflict is possible, the range of regeneration rates that support conservation reduces. In other words, there are regeneration rates for which conservation is possible if agents can not arm and fight and no longer sustained when conflict is allowed for.

Furthermore, for relatively low regeneration rate, conservation is supported by a larger set of relative capacity levels when conflict is not possible. In other words, there exist inequality levels in capacity across agents, for which conservation emerges at equilibrium when resources are shared according to the capacity levels and for which full depletion results when sharing in period two occurs through fighting.

Interestingly, this pattern is reversed for relative large regeneration rate. The intuition behind the reversal is that if fighting technology is directly linked to capacity, the share of resource gained through fighting for very poorly performing agents is larger than the share enjoyed when allocation occurs according to capacity. When the regeneration rate is large enough, conservation occurs at equilibrium also for these substantially unequal relative capacity levels.

The remaining of the paper is organized as follows. The next section presents the model without conflict and identifies the range of relative capacity levels that may support conservation. In the third section we amend the model allowing agents to invest in military spending, and we present the main results of the paper. Section four concludes.

2 A simple model of resource management

We set up a two-period model of natural resource conservation. The resource r, regenerates at a rate e from one period to the other, implying that under full conservation $(1+e)r$. Two agents, i and j are exogenously endowed with resource-use capacities c^i and c^j, respectively, and we assume that these capacities are sufficient for either player to fully consume the maximal total available resources $(1+e)r$. The players, decide over their current and future consumption of the renewable natural resource. In the first time period the players' respective use of r are depicted by x^i $(\leq c^i)$ and x^j $(\leq c^j)$. In the second time period the available resources equal $(1+e)(r-x^i-x^j)$, and the players decide their respective use of the resource, y^i $(\leq c^i)$ and y^j $(\leq c^j)$. To keep the analysis tractable, we take the players' utility to be linear in their consumption of the resource.

Solving the game backwardsly, irrespectively of the amount of resources available, the players have no incentive to conservate in the second time period and will therefore use their respective full capacities. We assume that the sharing of the resource is then proportional to the players capacities meaning that individual i is able to capture a share $s = c^i/(c^i + c^j)$ of $(1 + e)r$.

In the first time period, the life-time utility of player i is therefore given by:

$$u^{ic} = x^i + (1 + e)s(r - x^i - x^j) \qquad \text{if} \qquad r > x^j + x^i \tag{1}$$

$$u^{id} = \tfrac{c^i}{c^i + x^j} r \qquad \text{otherwise} \tag{2}$$

Where the superscripts c and d stand for *conservation* and *depletion* respectively.

If $r \leq x^j + x^i$, then the best response of i is to use his full capacity in the first time period in order to secure the highest possible share of r. In that case, his utility equals sr. The optimal choice of player i when $r > x^j + x^i$ is straightforward: if the marginal utility of current resource exploitation exceeds the marginal cost in terms of tomorrow foregone consumption, player i is willing to fully deplete the resource, thus violating the condition for having conservation. If, however, the opposite holds true, player i's optimal choice in the first time period is to fully conservate the resource. Formally, player i's reaction functions are thus given by:

$$x^i(x^j) = x^{ic}(x^j) = 0 \qquad \text{if} \quad (1 + e)\frac{c^i}{c^i + c^j}(r - x^i - x^j) > \frac{c^i}{c^i + x^j} r \tag{3}$$

$$x^i(x^j) = x^{id}(x^j) = c^i \qquad \text{otherwise} \tag{4}$$

The same results can be derived for player j.

Since both players are endowed with a sufficiently large capacity to deplete entirely the resource in the first period, full depletion constitute always an equilibrium for this conservation game. Indeed, any player prefers to use its maximal capacity in resource consumption if the other player is expected to go for full depletion.

As a consequence, an equilibrium with conservation can arise only if no player finds it profitable to deviate to full depletion. Formally, if j is expected to conservate, player i equally conservates if $s(1 + e) > 1$. The former condition is derived by setting $x^i = x^j = 0$ in (3). Similarly, provided i conservates, j also opts for his conservation strategy if $(1 - s)(1 + e) > 1$. Combining those two conditions, we deduce that the conservation equilibrium survives only if:

$$s \in \left[\frac{1}{1 + e}, \frac{e}{1 + e}\right]$$

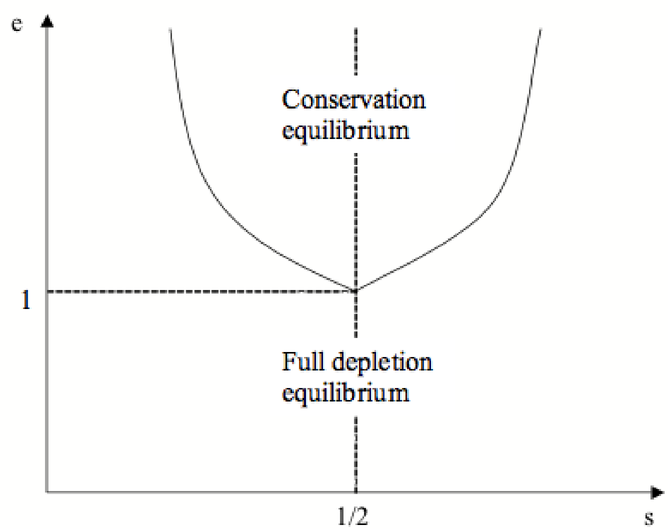
Given that in our setting the players' capacities are exogenous and their use involves no cost, we assume throughout the paper that whenever the conservation equilibrium exists, the players coordinate on that equilibrium rather than on the depletion one.

The following proposition summarizes the results of the benchmark model.

Proposition 1. *Conservation is more likely for relatively equal players and for higher regeneration rates of the renewable resource.*

Notice first that low regeneration rate decrease the opportunity cost of full depletion, making more likely that a player finds it optimal to go for instantaneous full depletion. Furthermore, It is the player endowed with a relatively lower capacity going first for full depletion. Indeed, he has a lower opportunity cost of conservation, as the share of resources captured in period two is proportional to players' capacity. As a consequence, equally endowed players support the conservation equilibrium even for relatively low regeneration rates.

In Figure 1 we describe the zones for parameters e and s, in which either equilibrium is relevant.



3 Natural resources and conflict

In the previous section we assume that the second period sharing rule directly tracks the players' relative capacities. While this may be true in some contexts, the partition of scarce resources often occurs through fighting. Accordingly, in what follows players choose in the first time period the amount of resources to devote to increasing their military strength. Accordingly, in the second time period the remaining resources are allocated through fighting. If players i invests in time period 1 m^i to military spending, and player j invests m^j resources in this activity, then the share of resources obtained by player i in the second time period is given by:

$$p(m^i, m^j) = \frac{sm^i}{sm^i + (1-s)m^j} \tag{5}$$

The complementary share $1 - p$ of the resources is captured by j. The military spendings are weighted by an efficiency parameter that Hirshleifer (2000) defines as the "per-unit battle efficiency". To link directly this augmented model to the one presented in the previous section, we assume that the players' relative fighting efficiency is directly linked to their respective capacities. This assumption implies that a player endowed with a higher capacity to grab resources should equally be better performing in fighting. Notice that whenever the players' military spendings are equal, the resulting resources sharing is the same as in the previous section. Later on in the paper we will discuss the consequences of relaxing this assumption with the help of a graphical representation.

To distinguish the results from the previous section we denote player i's first period effort by y^i. The utility of player i is now given by:

$$u^{ic} = y^i + p(m^i, m^j)(1+e)(r - y^i - y^j - m^i - m^j) \tag{6}$$
$$\text{if } r > y^i + y^j + m^i + m^j$$
$$u^{id} = \frac{c^i}{c^i + y^j} r \qquad \text{otherwise} \tag{7}$$

As in the previous section, if $r \leq y^i + y^j + m^i + m^j$, player i finds it optimal to use full capacity in the first time period since no resources will be conserved anyway. Furthermore, since there are no resources left to fight over in the second period, it follows that $m^i = 0$ under this scenario. The sharing of resources occurs then as before according to relative capacities of the players. The utility of player i equals sr.

If, however, the natural resource is not fully depleted in period 1, then player i's problem is the following:

$$max_{y^i, m^i} \quad y^i + p(m^i, m^j)(1+e)(r - y^i - y^j - m^i - m^j) \tag{8}$$
$$\text{s.t. } r > y^i + y^j + m^i + m^j$$

Optimizing yields the following first order conditions:

$$\frac{\partial u^{ic}}{\partial y^i} = 1 - p(m^i, m^j)(1+e) = 0 \tag{9}$$

$$\frac{\partial u^{ic}}{\partial m^i} = \frac{s(1-s)m^j}{(sm^i + (1-s)m^j)^2}(1+e)(r - y^i - y^j - m^i - m^j)$$

$$-p(m^i, m^j)(1+e) = 0 \tag{10}$$

Using condition (10) and the analogous condition for player j, we obtain the military spending reaction function for players i, in terms of the resource consumption levels in period 1, y^i and y^j:

$$m^i = m^i(m^j, y^i, y^j) \tag{11}$$

Given the linear nature of the utility function, as in the benchmark model players will either full deplete the resource in period 1 or forego consumption initially to ripe the full benefits of the grown resource in period 2. Since both players have the capacity of full depletion, conservation can occur only if both players refrain from resource consumption in the first period.

To address explicitly the conditions under which conservation is an equilibrium, we first derive the equilibrium military spending levels crossing the reaction functions[1], after setting current consumption levels to zero in (11):

$$m^{i*} = \frac{r}{2}\frac{\sqrt{1-s}}{\sqrt{s}+\sqrt{1-s}} \tag{12}$$

$$m^{j*} = \frac{r}{2}\frac{\sqrt{s}}{\sqrt{s}+\sqrt{1-s}}$$

Substituting the optimal military spending and given $y^j = 0$ player, the condition for i to set his current resource consumption to $y^i = 0$, is given by:

$$\frac{(1+e)s\sqrt{1-s}}{s\sqrt{1-s}+(1-s)\sqrt{s}}\frac{r}{2} > r \tag{13}$$

Indeed, we should also compare that no profitable deviation is available to player i, when player j is choosing $y^j = 0$. Deviating to fully deplete the resource on his own should not be profitable. The left hand side of condition (13) represents the utility of i to conserve the resource when j conserves. The right-hand side is the utility of full depletion when i is the only player consuming in period 1.

Finally, notice that if the above condition is satisfied then, the first order condition for i, (9) is negative , confirming that i wants to postpone resource depletion.

Following a similar procedure, it can be shown that also for the player j the relevant condition is the following:

$$\frac{(1+e)(1-s)\sqrt{s}}{2(s\sqrt{1-s}+(1-s)\sqrt{s})} > 1 \tag{14}$$

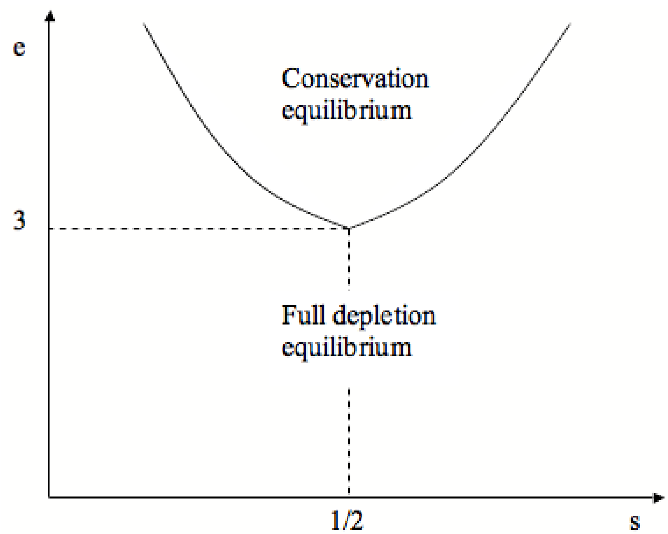
Combining the two previous conditions yelds the set of values of s that can support conservation:

[1]It can be shown that military reaction functions are continuous and concave in their own action in the relevant set $m \in [0, R]$.

$$s \in \left[\frac{4}{5-2e+e^2}, \frac{1-2e+e^2}{5-2e+e^2}\right] \quad (15)$$

Notice that this set is non-empty for $e > 3$. Below such regeneration rate no conservation can occur, irrespective of the relative capacity and the relative fighting efficiency.

As for the benchmark model we describe the in Figure 2 the values of the regeneration rate and the fighting efficiency s for which either type of equilibrium occurs.



The results of Proposition 1 hold qualitatively also for the augmented model: more similar players will more likely postpone resource depletion to the second period. Similarly, larger regeneration rates increase the profitability of conservation and hence foster it.

The opportunity to invest in military spending to change the share of resources captured at period 2, however, modifies significantly the range of parameters under which conservation emerge at equilibrium. Next proposition deals with that.

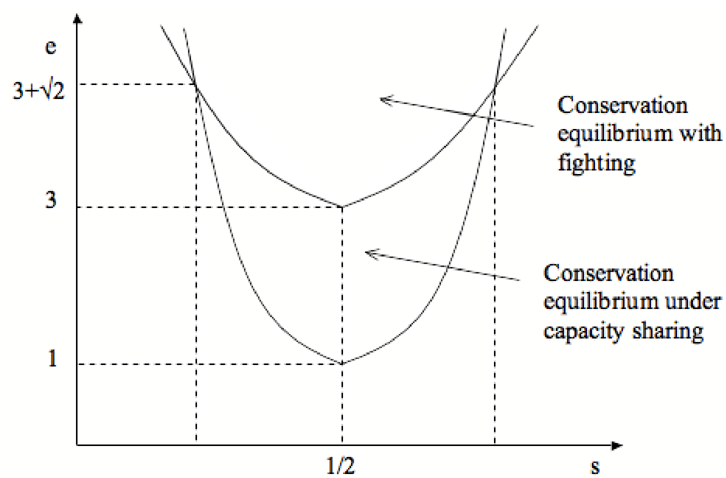
Proposition 2. *For intermediate regeneration rates, full depletion occurs for a broader range of relative capacity levels in the conflict model as compared to model in which resources are shared according to capacity. For high regeneration levels, the opposite is true.*

Proof. We prove that there exists a regeneration rate above below which conservation occurs for a broader range of capacity levels in the benchmark model than in the conflict model, and below which the opposite is true. This is relatively straightforward. We simply need to compare the lower bound of the set of s that support conservation under the two model, since both sets are symmetric around $s = 1/2$. Both sets are increasing in e. We need to find the value of $e > 0$ that equates the two lower bounds.

$$\frac{4}{5 - 2e + e^2} \leq \frac{1}{1 + e}$$
$$e \leq 3 + 2\sqrt{2}$$

□

We overlap the two previous figure in Figure 3 to guide the discussion. Notice first that for $e \in [1, 3]$ under the benchmark model conservation was the equilibrium for at least a range of relative capacity levels. If, however, players are allowed to devote part of the resource to military spending with the aim of increasing the share of resources captured in period 2, then full depletion in period 1 certainly results.



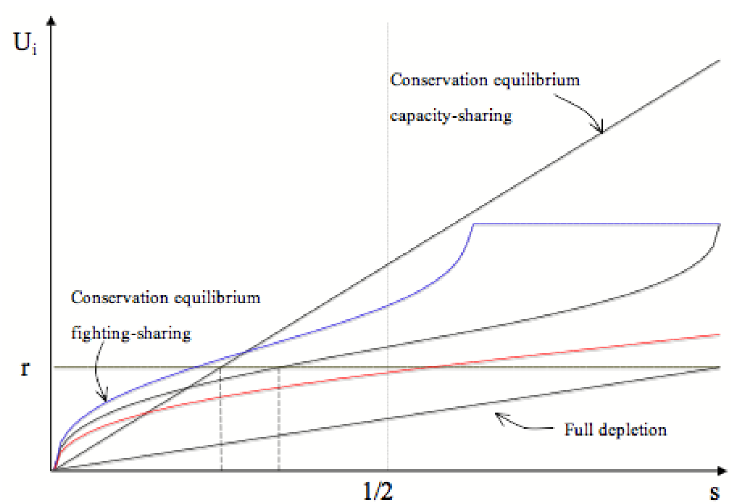
Furthermore, for intermediate levels of regeneration rates, $e \in [1, 3 + 2\sqrt{2}]$, the set of relative fighting efficiency and capacity that support conservation is smaller in the conflict model. Notice that *b*oth players would be better off if they refrain from arming and share the grown resource in period 2 according to their relative capacity. In other words, were players able to commit not to arm, they would both forego consumption at period 1 and wait for the regenerated resource. Unfortunately, such a commitment is not credible. If j refrains from arming and postpones consumption to period 2, i finds it optimal to invest a minimal amount of resource in arms to capture near to all resources in the next period. Inefficient investment in military strength results, and since this decreases significantly the resources left to regenerate in period 1, it reduces the expected payoff of conservation, making full depletion an attractive option even for similar capacity levels.

Interestingly, however, for $e > 3 + 2\sqrt{2}$ conflict support conservation for highly asymmetric capacity levels, for which full depletion would occur, if players expected to share the resource according to their relative capacity.

Allowing players to devote part of the resource to military spending implies that they have to opportunity to endogenously determine the share of resources they get in period 2 through the conflict. Since the stock of resources at stake is the same for both players, the initially less advantaged in terms fighting efficiency will invest relatively more in arms to partially reduce the gap with the opponent. This implies, in turn, that the share of resources captured by the less efficient player ($s < 1/2$) is larger than the share he would have got according to capacity. When the regeneration rate is large enough this force more than compensate the waste of resources due to military spending and determines the result claimed.

For the purpose of this paper we assumed that relative fighting efficiency perfectly matches relative capacity. It is now time to briefly discuss the implications of this assumption and the consequences of relaxing it. To ease the discussion once again we will refer to a graph

In Figure 4 we draw the utility of individual i under the difference scenarios for a value of $e < 3 + \sqrt{2}$.



We draw i's deviation utility, if j sticks to conservation, as the horizontal dashed line at $U_i = r$. Conservation is an equilibrium for the values of $s < 1/2$ for which the conservation utility is higher than the deviation utility. Accordingly, in Figure 4, conservation is possible for a larger set of s in the benchmark model. Indeed the crossing between the deviation payoff and the utility of conservation when resources are shared proportionally to capacities (denoted by "conservation equilibrium - capacity sharing") occurs before the crossing with the utility of conservation in the fighting model ("conservation equilibrium - fighting sharing").

If we relax the assumption matching capacities with fighting efficiency parameters, we modify the equilibrium sharing under fighting. In particular, perhaps intuitively, increasing the fighting efficiency of i above s increases the share of resources he is capturing through fighting. We draw a change of this nature with the blue curve in Figure 4. Reducing i's fighting efficiency leads instead to the opposite result (red line in the graph).

In terms of our results, it is worth mentioning that if fighting efficiency parameters are no longer equal to capacities, then the set of s that supports conservation as an equilibrium is not symmetric around $s = 1/2$ anymore. This in turn may lead to different scenarios as compared to the one summarized in the previous propositions. Indeed, as you can observe from Figure 4, if i's fighting efficiency exceed sufficiently his capacity (as it is the case for the case depicted in blue), the conservation equilibrium under fighting is sustainable for larger inequality in capacity as compared to the capacity sharing model (the crossing of the blue curve with the deviation payoff occurs before the crossing with the lien describing the utility of conservation for the benchmark model).

4 Conclusions

In this paper we model explicitly the potential conflict over resources that might (endogenously) emerge if the stock of a commonly used natural resource shrinks. Agents choose their military spending and fight over the resource left. The share of resource gained through fighting in linked to their relative military strength.

We show that if conflict is possible, the range of regeneration rates that support conservation reduces. Indeed, there exist regeneration rates for which conservation is possible if agents can not arm and fight and no longer sustained when conflict is allowed for.

Furthermore, for relatively low regeneration rate, conservation is supported by a larger set of relative capacity levels if conflict is not possible. In other words, there exist inequality levels in capacity across agents, for which conservation is an equilibrium if natural resources are shared peacefully according to the relative capacity levels of players and for which full depletion results when sharing in period would occur through fighting.

This pattern is reversed for large regeneration rate. If fighting technology matches capacity, the share of resource gained through fighting for very poorly performing agents is larger than the share enjoyed when allocation occurs according to capacity. When the regeneration rate is large enough, sharing through fighting supports the conservation equilibrium even for these substantially unequal relative capacity levels.

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