Inequality and conflict: Burning resources to support peace

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Abstract: We consider a simple, guns-versus-butter model in which agents choose between "war" and "peace" to study the implications of inequality in resource ownership for equilibrium outcomes. Provided war is destructive, peace can emerge as the stable equilibrium, but only if the distribution of resource ownership is sufficiently even. We establish that, when this condition fails, the richer agent can destroy a portion of its resource endowment to even out the *ex post* distribution and thereby support peace. We also examine the importance of *ex ante* resource transfers and show that they are Pareto superior to burning resources.

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1 Introduction

In parallel with a substantial empirical literature on conflict, there is a growing theoretical literature on the emergence of conflict and its resolution. This literature, spawned largely by Fearon's (1995) seminal work, has explored numerous ways to sustain peace, such as deterrence, negotiation and outright transfers.[1] In this paper, we analyze an alternative way, one that mitigates incentives to deviate unilaterally from it.

Based on a guns-versus-butter model of conflict in which two agents choose their resource allocations and whether to declare "war" or "peace," the analysis emphasizes the inequality of resource ownership as a contributing factor to war. Such inequality implies that the poorer agent has more to gain and less to lose in war. Although this agent might be resource-constrained in its arming choice, the larger potential gains give it a greater incentive to declare war than its richer rival. Even if resource ownership is sufficiently symmetric across the agents to render peace Pareto optimal, one or both of them could have an incentive to deviate unilaterally. And, the presence of such an incentive, which is more likely to be held by the poorer agent, undermines the stability of peace in equilibrium. This result suggests a possible means to promote peace—namely, for the richer agent to burn some of its resource.[2] However, we also establish that an *ex ante* transfer of resources from the rich party to its rival would be superior.

2 A simple model of war and peace

Our analysis builds on a modified version of the one-period, complete-information, game-theoretic model of war and peace in Garfinkel and Syropoulos (2020).[3] In this game, two risk-neutral agents, $i = 1, 2$, each of whom is endowed with R^i units of a productive resource, interact over two stages. In the first stage, agent i has two options: (i) burn some units of its endowment R^i (say, $\Delta \geq 0$) or (ii) transfer some units (again, say Δ) to its rival $j \neq i$. In either case, agent i's *ex post* endowment would be reduced by Δ. By contrast, agent j's *ex post* endowment would remain unchanged (and equal to R^j) in case (i) and would rise by Δ in case (ii). As will become evident below, only the richer agent would ever choose

[1] See, for example, De Luca and Sekeris (2013), Anbarci et al. (2002) and Beviá and Corchón (2010), respectively. While focusing on peacekeeping by third-parties, Bove and Smith (2011) provide a broad perspective on the relevant literature.

[2] The sort of resource burning we have in mind is quite different from the military strategy known as "earth scorching," wherein a defender in a battle destroys its own assets that would otherwise enhance the attacker's likelihood of success in battle. (Consider, for example, Napoleon's invasion of Russia, where the Russians destroyed their own crops, thereby denying the French troops critical food supplies and eventually causing Napoleon's retreat.) Instead, we are interested in resource burning as a welfare-enhancing action to prevent destructive wars. For example, property owners might move their wealth to other parts of the world or even give it away to charity to diminish the value of attack by potential aggressors.

[3] This setting is most relevant for studying interactions between two countries or groups of individuals within countries where the rule of law is weak. It is also relevant to the literature on contests.

to burn some of its resource or make a transfer to its rival. But, for now, we abstract from stage 1 decisions and assume the two agents' endowments are R^i and R^j.

In the second stage, the two agents simultaneously choose their respective resource allocations and whether to declare "war" or "peace." Specifically, each agent i can use R^i to produce, on a one-to-one basis, X^i units of "butter" for consumption and G^i units of "guns," subject to the resource constraint, $X^i+G^i \leq R^i$. War is envisioned as a winner-take-all contest over insecure output, equal to a fraction $(1-\sigma) \in (0,1]$ of butter produced by both agents $X^i + X^j$. It emerges if at least one agent chooses it. Under such circumstances, each agent can produce guns to increase its chances of victory. In contrast, peace preserves the status quo and requires both agents to choose it. As will become clear shortly, no agent has an incentive to arm under peace.

The probability that agent i wins the contest over $(1-\sigma)(X^i + X^j)$ under war is determined by the following conflict technology:

$$\phi^i = \phi^i(G^i, G^j) = \begin{cases} G^i/(G^i+G^j) & \text{if} \quad G^i+G^j > 0; \\ R^i/(R^i+R^j) & \text{if} \quad G^i+G^j = 0, \end{cases} \tag{1}$$

for $i \neq j = 1,2$. Along the lines of Tullock (1980), this specification assumes that, when $G^i + G^j > 0$, agent i's winning probability is increasing in its own guns ($\phi^i_{G^i} > 0$) and decreasing in its rival's guns ($\phi^i_{G^j} < 0$). Equation (1) also implies that the conflict technology is symmetric in its arguments and concave in G^i, with $\phi^i_{G^iG^j} \gtreqless 0$ as $G^i \gtreqless G^j$ for $i \neq j = 1,2$. However, when $G^i + G^j = 0$, each agent's winning probability is determined by its relative resource endowment.

If at least one agent declares war, the agents deploy their guns to contest $(1-\sigma)(X^i+X^j)$. Assume that, when $G^i+G^j > 0$, a fraction $1-\gamma \in (0,1)$ of the contested butter is destroyed; but, when $G^i + G^j = 0$, war has no destructive consequences (i.e., $\gamma = 1$).[4] Either way, agent i's expected payoff under war is

$$U^i = \phi^i \gamma (1-\sigma)(X^i + X^j) + \sigma X^i, \quad i \neq j = 1,2. \tag{2}$$

If both agents choose peace, then each one consumes its own butter X^i, for a payoff of

$$V^i = X^i = R^i - G^i, \quad i = 1,2. \tag{3}$$

Note that, for any given any distribution (R^i, R^j), $V^i = U^i$ holds if $G^i = 0$ for $i = 1,2$.

[4] See Garfinkel and Syropoulos (2020), who also allow a fraction of secure output $\sigma(X^i + X^j)$ to be destroyed when $G^i + G^j > 0$.

3 Peace as the stable equilibrium

To find the equilibrium of this game, we solve the model backwards, first studying the outcomes under war and peace for given (R^i, R^j) and then identifying the conditions under which peace arises as the *stable* equilibrium of this subgame—i.e., an equilibrium that is immune to both unilateral deviations and coalitional deviations (Bernheim et al., 1987). In the subsequent section, we examine how first-stage decisions affect the stability of peace.

3.1 Arming incentives and payoffs under war and peace

From (2), guns production by agent i under war positively influences its payoff through its probability of winning ϕ^i in (1), but also negatively through its effect on both its secure and contested butter X^i:

$$U^i_{G^i} \equiv \frac{\partial U^i}{\partial G^i} = \phi^i_{G^i}\gamma\left(1-\sigma\right)\left(X^i + X^j\right) - \left[\phi^i\gamma\left(1-\sigma\right)+\sigma\right], \text{ for } i \neq j = 1, 2. \tag{4}$$

Using (1) and (4) with the constraint $X^i = R^i - G^i \geq 0$, one can confirm the following best-response function for agent i:

$$B^i_w\left(G^j; \gamma, \sigma, R^i, R^j\right) = \min\left\{R^i, \widetilde{B}^i_w\left(G^j\right)\right\}, \text{ for } i \neq j = 1, 2, \tag{5a}$$

where $\widetilde{B}^i_w(G^j)$ denotes agent i's unconstrained best-response function, implicitly defined by $U^i_{G^i} = 0$ in (4) and given by

$$\widetilde{B}^i_w\left(G^j\right) = -G^j + \sqrt{G^j\theta\left(R^i + R^j\right)}, \text{ with } \theta \equiv \frac{\gamma\left(1-\sigma\right)}{\gamma\left(1-\sigma\right)+\sigma} \in (0, 1]. \tag{5b}$$

It is straightforward to show that, at most, only one of the two agents will be constrained by its resource endowment in its arming choice. Specifically, for any given R^j, define

$$R^i_L = \frac{\theta}{4-\theta}R^j \quad \text{and} \quad R^i_H = \frac{4-\theta}{\theta}R^j, \tag{6}$$

where subscripts "L" and "H" indicate respectively "low"and "high" threshold levels of agent i's resource.[5] Then, as one can confirm, when $R^i \in [R^i_L, R^i_H]$, neither agent is resource constrained in its guns choice, and $G^i_w = G^j_w = \frac{1}{4}\theta(R^i + R^j)$. By contrast, when $R^i < R^i_L$ (resp., $R^i > R^i_H$), then $G^i_w = R^i$ and $G^j_w = \widetilde{B}^j_w(R^i)$ (resp., $G^j_w = R^j$ and $G^i_w = \widetilde{B}^i_w(R^j)$).

[5] Note that $R^i_L \leq \frac{1}{3}R^j < R^j < 3R^j \leq R^i_H$ because $\theta \in (0, 1]$ by (5b).

In turn, one can confirm the following equilibrium payoffs under war:

$$U_w^i(R^i, R^j) = \begin{cases} \gamma\,(1-\sigma)\,R^i\left(\sqrt{\frac{R^i+R^j}{\theta R^i}}-1\right) & \text{if} \quad R^i < R_L^i; \\ \frac{1}{4}\gamma\,(1-\sigma)\left(R^i+R^j\right)+\sigma R^i & \text{if} \quad R^i \in \left[R_L^i, R_H^i\right]; \\ \left[\gamma\,(1-\sigma)+\sigma\right]\left(R^i+R^j\right)\left(1-\sqrt{\frac{\theta R^j}{R^i+R^j}}\right)^2 & \text{if} \quad R^i > R_H^i, \end{cases} \tag{7}$$

for $i \neq j = 1, 2$. Inspection of (7) reveals that, given R^j, U_w^i is always increasing in R^i.[6] Therefore, neither agent would wish to burn any portion ($\Delta > 0$) of its resource under war. Likewise, a transfer of Δ resources by agent i to agent j would reduce R^i and raise R^j without affecting the sum $R^i + R^j$. Since U_w^i would fall once again, neither agent i would find making a transfer to its rival under war appealing.

Turning to peace, one can see from (3), that producing guns is costly, as it detracts from the production of butter and provides no benefits. Thus, $G_p^i = 0$ for $i = 1, 2$ and $V_p^i = R^i$. But, while each agent i's payoff under peace, like that under war, is increasing in R^i, an agent might want to burn or transfer its resource, if by doing so it could avoid costly war.

Such an incentive would arise only if initially (i.e., before resources are burned or transferred) both agents prefer peace over war. In Online Appendix A, we show that $V_p^i(R^i) > U_w^i(R^i, R^j)$ if R^i is large enough. We also show there that a necessary condition for peace to Pareto dominate war is that the distribution of resources be sufficiently even.[7]

3.2 When is peace possible without resource burning or transfers?

To be sure, war always satisfies the best-response property of a Nash equilibrium in the second stage of the game. However, it need not be immune to coalitional deviations and thus need not arise as a stable equilibrium. By the same token, even when peace is Pareto dominant over war meaning that the two agents have no incentive to deviate from peace coalitionally, the emergence of peace as the stable equilibrium requires, in addition, that neither agent have an incentive to deviate from it unilaterally.

To proceed, denote agent i's arming and payoff under such a deviation respectively by G_d^i and U_d^i. Because $G_p^j = 0$, an optimal deviation by agent i would, by (1), involve producing just an infinitesimal quantity of guns $G_d^i = \varepsilon > 0$ and declaring war. For ε arbitrarily close to zero, the "no-unilateral deviation" condition for agent i can be written as[8]

$$U_d^i(R^i, R^j) \approx \gamma\,(1-\sigma)\left(R^i + R^j\right) + \sigma R^i \leq R^i = V_p^i(R^i), \quad \text{for } i = 1, 2. \tag{8}$$

[6] Garfinkel and Syropoulos (2020) provide a more detailed analysis of U_w^i, including its dependence on destruction $1 - \gamma$ and output insecurity $1 - \sigma$.

[7] It is straightforward to show further that, provided a fraction of output is insecure (i.e., $\sigma < 1$), this range is non-empty even when war is not destructive (i.e., $\gamma = 1$).

[8] Without loss of generality, we assume that agents choose peace at points of indifference.

One can show that $U_d^i(R^i, R^j) > U_w^i(R^i, R^j)$ holds for all $R^i, R^j > 0$.[9] Thus, when condition (8) is satisfied for both agents, neither one considers unilateral or coalitional deviations from peace appealing. In this case, peace is the stable equilibrium.[10]

To dig a little deeper, define $\underline{R}^i$ and $\overline{R}^i$, for any given R^j, as follows:

$$\underline{R}^i \equiv \frac{\gamma}{1-\gamma} R^j \quad \text{and} \quad \overline{R}^i \equiv \frac{1-\gamma}{\gamma} R^j, \quad \text{for } i \neq j = 1, 2, \tag{9}$$

where $\underline{R}^i \leq R^j \leq \overline{R}^i$ iff $\gamma \leq \frac{1}{2}$ (with equality if $\gamma = \frac{1}{2}$). In turn, (8) and (9) imply $U_d^i(R^i, R^j) < V_p^i(R^i)$ for $\underline{R}^i < R^i$ and $U_d^j(R^i, R^j) < V_p^j(R^i)$ for $R^i < \overline{R}^i$. Thus, we have

Proposition 1 (Stability of peace.) *Assume $\gamma \in (0, \frac{1}{2}]$. Then, for any given $R^j > 0$, unarmed peace is the stable equilibrium in pure strategies in the second stage of the game iff $R^i \in [\underline{R}^i, \overline{R}^i]$.*

This proposition establishes that, when war is sufficiently destructive and the initial distribution of resources is sufficiently even, unarmed peace emerges as the unique stable equilibrium of the game.[11] The implication noted above that $dV_p^i/dR^i > 0$ for both agents i implies that, in this case, neither agent would have an incentive to burn its own resource endowment or to make a transfer to the rival in the first stage. It also follows from this proposition and our previous discussion that, if $\gamma \in (\frac{1}{2}, 1)$ such that $\underline{R}^i > \overline{R}^i$, war is the unique stable equilibrium for any distribution $R^i, R^j > 0$. Even if $\gamma \in (0, \frac{1}{2}]$, a sufficiently asymmetric distribution of resources (i.e., $R^i \notin [\underline{R}^i, \overline{R}^i]$) again renders war the unique equilibrium in pure strategies. Importantly, in this latter case, it is the relatively poor agent who has an incentive to deviate unilaterally from peace.[12] However, in this case, the richer agent could have an incentive to take an action in the first stage of the game to eliminate this incentive and thereby support peace.

[9] See Online Appendix A.

[10] Since $U_d^i(R^i, R^j) > U_w^i(R^i, R^j)$ always holds, the range of resources for which peace is immune to unilateral deviations is smaller than the range that renders coalitional deviations unappealing to both agents. Accordingly, both agents could view peace as being superior to war, but the less affluent agent could have incentive to deviate from peace nonetheless.

[11] Note that Proposition 1 does not consider the extreme case where war wipes out all contested output ($\gamma = 0$). However, since in this case the value of the "prize" under war to both agents equals 0, peace arises in equilibrium for all configurations of endowments. Even for γ arbitrarily close to zero, peace emerges for practically all resource distributions.

[12] When the initial resource distribution is sufficiently even to render peace Pareto dominant over war, but not sufficiently even to wipe out the profitability of a unilateral deviation to the poorer agent, the model does not admit a coalition-proof equlibrium in pure strategies. In this case, mixed-strategy equilibria in arming, leading to positive probabilities of both peace and war, could dominate the war outcome (e.g., De Luca and Sekeris, 2013). Here, however, we focus on pure-strategy equilibria.

4 Burning resources and transfers

To fix ideas, let the *ex ante* richer agent be designated by i (so $R^i > R^j$). The following lemma follows readily from the properties of $U_w^i(R^i, R^j)$ and $V_p^i(R^i)$:

Lemma 1 *Assume* $\gamma \in (0, \frac{1}{2})$. *For any given* $R^j > 0$, *there exists a unique* $R_*^i \in (\overline{R}^i, R^i + R^j)$ *that solves* $V_p^i(\overline{R}^i) = U_w^i(R_*^i)$ *and implies the following:* $V_p^i(\overline{R}^i) > U_w^i(R^i)$ *for* $R^i \in (\overline{R}^i, R_*^i)$ *while* $V_p^i(\overline{R}^i) < U_w^i(R^i)$ *for* $R^i \in (R_*^i, R^i + R^j)$.

The assumption $\gamma \in (0, \frac{1}{2})$ ensures that war is sufficiently destructive to make peace immune from coalitional deviations for at least some sufficiently even initial resource distributions. Lemma 1 indicates that, when this assumption holds but the initial distribution of resources is not sufficiently even make a unilateral deviation unprofitable to agent j and thus to support peace as a stable equilibrium, agent i could have an incentive reduce its own endowment to induce its rival to stick to peace.[13] In particular, building on Lemma 1, we have our central results:

Proposition 2 (Burning vs. transferring resources.) *Assume* $\gamma \in (0, \frac{1}{2})$ *and suppose* $R^i \in (\overline{R}^i, R_*^i]$. *Then:* (a) *peace emerges as the stable equilibrium if the richer agent* i *burns* $\Delta_B = R^i - \overline{R}^i$ *units of its resource* R^i*; and,* (b) *there exists a resource transfer* $\Delta_T = \gamma \Delta_B < \Delta_B$ *which supports peace and Pareto dominates resource burning.*

By Proposition 1, our assumption that $R^i > \overline{R}^i$ implies agent j has an incentive to deviate unilaterally from peace. However, as stated in part (a) of Proposition 2, by burning $\Delta_B = R^i - \overline{R}^i = R^i - \frac{\gamma - 1}{\gamma} R^j$ units of its resource (so that its own *ex post* endowment becomes $R^i - \Delta_B = \overline{R}^i$), agent i could remove this incentive. In doing so, agent i could secure a payoff of $V_p^i(\overline{R}^i)$, which is greater than its payoff under war $U_w^i(R^i, R^j)$ since $R^i \leq R_*^i$ (Lemma 1).[14] Indeed, both agents prefer peace with resource burning over war. Turning to part (b), consider now a resource transfer Δ by the affluent agent i to its rival. While such a transfer reduces i's *ex post* endowment, it expands (by an equal amount) j's *ex post* endowment and thus, by (9), raises both $\overline{R}^i(\Delta)$ and $V_p^i(\overline{R}^i(\Delta))$.[15] The solution Δ_T to $R^i - \Delta_T = \overline{R}^i(\Delta_T)$, which is the minimum transfer that ensures agent j would not deviate from peace, satisfies $\Delta_T = \gamma \Delta_B$. Clearly, since peace requires at a minimum that war be sufficiently destructive (i.e., $\gamma \leq \frac{1}{2}$), this transfer is smaller than Δ_B and, thus, Pareto superior to resource burning.

[13] Based on a similar line of reasoning, Jackson and Morelli (2007) and Beviá and Corchón (2010) show how transfers can support peace. However, with an aim to explore how political biases held by countries' leaders can influence the possibility of peace with transfers, Jackson and Morelli take the countries' military power as given; Beviá and Corchón consider arming choices, but only after the war/peace choice has been made. Thus, neither analysis considers incentives for unilateral deviations (with optimizing adjustments in arming) from peace as a factor in limiting the effectiveness of transfers.

[14] Conversely, when $R^i > R_*^i$, agent i finds peace via resource burning too costly.

[15] Of course, as mentioned earlier, the transfer also reduces U_w^i, but this is unimportant here.

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A Online Appendix

A comparison of war and peace payoffs. Let us fix $R^j > 0$. As noted in the paper and as one can confirm from (7) in the text, U_w^i is increasing in $R^i > 0$. Furthermore, a careful inspection of (7) reveals that U_w^i is: (i) concave in $R^i \in (0, R_L^i)$; (ii) linear in $R^i \in [R_L^i, R_H^i]$; and, (iii) convex in $R^i \in (R_H^i, \infty)$. Additionally, $\lim_{R^i \to 0} U_w^i = \lim_{R^i \to 0} V_p^i = 0$ with $\lim_{R^i \to 0} \left\{ \frac{dU_w^i/dR^i}{dV_p^i/dR^i} \right\} > 1$, whereas $\lim_{R^i \to \infty} \{U_w^i / V_p^i\} = \gamma(1-\sigma) + \sigma < 1$. These observations together with the continuity of U_w^i and V_p^i in R^i imply that there exists a unique value of agent i's resource endowment, denoted by R_0^i, that ensures $U_w^i \gtreqless V_p^i$ as $R^i \lesseqgtr R_0^i$, thereby confirming our claim in the text. This critical value is shown in Fig. A.1.[1]

Using the result that $G_w^i = R^i$ for $R^i \in (0, R_L^i]$, one can also show (by differentiating U^j in (2) and invoking the envelope theorem) that $dU_w^j/dR^i < 0$ for such values of R^i, as shown in Fig. A.1. Furthermore, $dU_w^j/dR^i > 0$ for $R^i > R_L^i$ and U_w^j crosses V_p^j from below at some R_{00}^i ($> R_0^i$) as R^i becomes sufficiently large (not shown in Fig. A.1). Hence, there exists a non-empty set of R^i values, $R^i \in \left[R_0^i, R_{00}^i\right]$, for which peace Pareto dominates war and consequently for which the two agents have no incentive to deviate coalitionally from peace.

A comparison of unilateral-deviation and peace payoffs. As illustrated in Fig. A.1 and noted in the text, we always have $U_d^i > U_w^i$ for $i = 1, 2$. This ranking arises since $dU^i\left(B_w^i\left(G^j\right), G^j\right)/dG^j < 0$ and agent i's payoff U_d^i (resp., U_w^i) is its payoff when it responds optimally to $G_p^j = 0$ (resp., $G_w^j > 0$) along $B_w^i\left(G^j\right)$.

One can easily compare the deviation and peace payoffs (U_d^i and V_p^i, respectively), because they are linear in R^i. Provided $\gamma \leq \frac{1}{2}$, there exists a non-empty subset $[\underline{R}^i, \overline{R}^i]$ of i's resource endowment, given any $R^j > 0$ ($j \neq i = 1, 2$), such that $V_p^i > U_d^i$ for both agents and all $R^i \in [\underline{R}^i, \overline{R}^i]$, as illustrated in Fig. A.1. For $R^i > \overline{R}^i$, the less affluent agent (j) has an incentive to deviate from peace unilaterally, while agent j prefers peace.[2]

Proof of Lemma 1. For any given $R^j > 0$, we know that $U_w^i(R^i)$ is continuous and increasing in R^i. Furthermore, assuming $\gamma < \frac{1}{2}$ such that $\underline{R}^i < \overline{R}^i$, we also know that $U_w^i(\overline{R}^i) < V_p^i(\overline{R}^i)$. From (7), we have, in addition, that $\lim_{R^i \to \infty} U_w^i(R^i) = \infty$. By the continuity of U_w^i and V_p^i in R^i, it then follows that there exists a unique R_*^i that solves $V_p^i(R_*^i) = U_w^i(R_*^i)$. ||

Fig. A.1 illustrates the determination of R_*^i that applies in the case of resource burning.

[1] By using (7) to solve explicitly for the value of R_0^i that satisfies $U_w^i(R_0^i, R^j) = V_p^i(R_0^i) = R_0^i$, one can verify $R_0^i \geq R_L^i$ when output is sufficiently secure (i.e., $\sigma \geq \frac{1-\gamma}{2-\gamma}$); otherwise, we have $R_0^i < R_L^i$. In the figure, we assume $R^j = 0.5$ and $\gamma = \sigma = 0.4$, which implies $R_0^i \geq R_L^i$. Note further that R_H^i falls outside of the range of R^i displayed in the figure. Thus, the figure does not show the strictly convex portion of U_w^i.

[2] As shown in the figure, for $R^i < \underline{R}^i$ where $R^i < R^j$ holds, agent i (now the poorer agent) has an incentive to deviate unilaterally, whereas agent j has no such incentive.

As argued in the text, when agent i transfers some of R^i to its rival j instead, $\overline{R}^i(\Delta)$ rises, implying that we travel NE along V_p^i. Thus, $R_*^i(\Delta)$ that solves $V_p^i(\overline{R}^i(\Delta)) = U_w^i(R_*^i(\Delta))$ is also larger. Accordingly, resource transfers are more effective to support peace than shown in the figure below that focuses on resource burning.

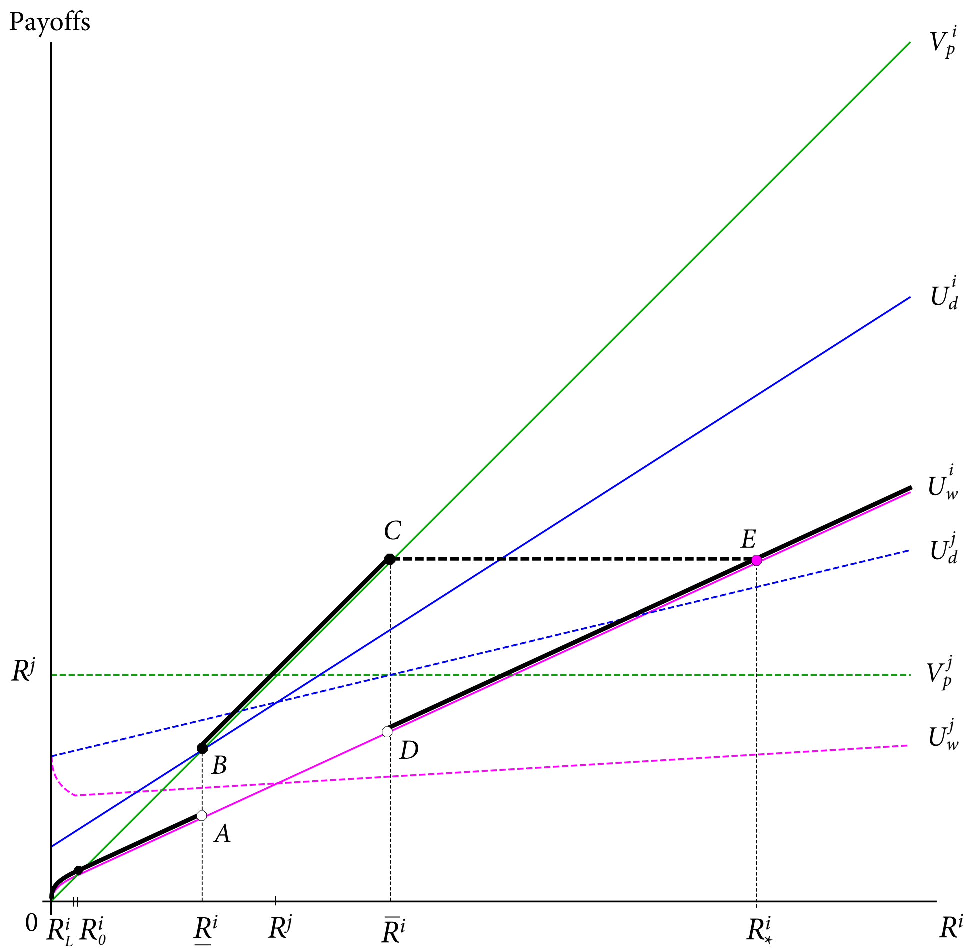

Figure A.1: Resource Burning