NATURAL RESOURCES, CIVIL CONFLICTS, AND ECONOMIC GROWTH

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Natural Resources, Civil Conflicts, and Economic Growth

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Abstract

This paper focus on civil conflicts arising from natural resource appropriation in a growth model with rent-seeking behavior and how fiscal policy can mitigate them. Such conflicts, if destructive, make the development trajectory indeterminate. There are two self-fulfilling equilibria, including a poverty-conflict trap associated with large civil conflicts. The resource curse may emerge because of pessimistic household expectations. However, fiscal policy can help overcome the tradeoff between conflict and economic development and partially solve the conflict-based resource curse. In this regard, there is an appropriate sharing of the government budget between military spending and human capital investment that minimizes conflict incentives.

Keywords: natural resource, civil conflict, economic growth, rent-seeking

JEL codes: O41, Q20, E62

1. Introduction

One of the seminal findings of development economics is probably that of the resource curse, suggesting that countries endowed with considerable natural resources tend to have less economic growth, high corruption and governance inefficiencies than countries with fewer resources (see the review of Van der Ploeg, 2011). Among all the explanations put forward, civil conflicts have received particular scholarly attention. Natural resources are indeed a key factor in triggering, prolonging and financing internal conflicts, especially in developing countries (see, e.g., Collier and Hoeffler, 1998).

However, a large empirical literature has produced mixed results, particularly in the context of renewable resources (involving conflicts over the control of fertile land, water or forests). Some studies suggest that an abundance of renewable resources increase the likelihood of greed-motivated conflicts, which impede economic growth (see, e.g., Brown, 2010; Hendrix and Salehyan, 2012). Conversely, other studies argue that well-managed renewable resources have limited explanatory power for civil violence and can be a source of economic development and growth (Magnus Theisen, 2008; Welsch, 2008).[1]

[1] The empirical literature has taken many directions tying (non-renewable and renewable) resources to conflict including price changes (Brückner and Ciccone, 2010; Bellemare, 2015), or the role of poverty (Humphreys and Weinstein, 2008; Thomas and Sergenti, 2010).

One possible explanation is that abundant renewable resources can improve firms' production and boost factor productivity, which raises wages, reducing the conflict incentives through an opportunity-cost effect (Welsch, 2008). On the other hand, large resources incentivize people to fight for them through a rapacity effect, leading to civil conflicts and destructive consequences that may hinder economic growth.[2] Consequently, the overall effect on the development process is uncertain and mainly depends of determinants of state-building, including the institutional quality (Acemoglu et al., 2005), the degree of political instability (Besley and Persson, 2010) or the dependence on natural resources (Acemoglu et al., 2012).

Theoretically, the framework usually adopted by scholars relies on a tradeoff faced by households between a productive activity and an unproductive appropriation activity.[3] Depending on the relative incomes of these two activities, agents may prefer to substitute productive efforts for unproductive conflict ones to obtain a higher stock of capital (Tornell and Lane, 1999; Strulik, 2008), a larger share of output (Benhabib and Rustichini, 1996) or even to distort the redistribution of income (Dal Bó and Dal Bó, 2011). However, such models are uninformative on the links between resource conflicts and the long-run development process

In this paper, we develop an environmental growth model with a renewable resource that integrates productive and appropriable activities. Our goal is twofold.

On the positive side, we propose another explanation for the fragile link between renewable resources, civil conflicts and economic growth based on self-fulfilling equilibria and expectation-driven dynamics. Intuitively, low expected economic growth implies a low expected return on productive activities, thereby incentivizing citizens to increase their unproductive conflict efforts at the initial time. This initial increase in conflict intensity has destructive consequences on the production process, pushing the economy into a self-fulfilling "*poverty-conflict trap*"—a steady state of low growth and high levels of conflict. This mechanism reverses when the expected economic growth is high. Consequently, the dynamics of an economy plagued by destructive resource conflicts are subject to "animal spirits", in the form of self-fulfilling prophecies. Whether the abundance of renewable resources has a positive or negative impact on the growth process crucially depends on the expectations of households.

From a normative side, we explore how the government can mitigate individual motives for resource conflict while promoting long-term growth through its fiscal policy in-

[2] The rapacity effect states that an increase in the value of the resource—either through an increase in its price, or an increase in its quantity—improves incentives to engage in conflict. Empirically, some scholars confirm the rapacity channel (Collier and Hoeffler, 2004; Lei and Michaels, 2014), while others question the result (Cotet and Tsui, 2013; Bazzi and Blattman, 2014).

[3] This mechanism is well-developed in game-theoretic approaches based on Tullock (1967)-contests or Hirshleifer (1989)-type models (see, e.g., Wick and Bulte, 2006; Torvik, 2002).

struments, especially the public investment in law enforcement sector to secure property rights and in human capital to improve productivity and wages.

Our theoretical framework is based on an endogenous growth setup with rent-seeking behaviors. The key elements of our model are as follows. First, in the spirit of Tahvonen and Kuuluvainen (1991), Bovenberg and Smulders (1995) and Fullerton and Kim (2008), we model the natural resource as a stock that accumulates due to the natures regenerative capacity and depreciates with households' exploitations. Second, households can exert either productive/labor effort that serves as an input to production or unproductive/rent-seeking effort to seize the resource.[4] The outcomes of rent-seeking activities are given by standard contest success functions. Third, the aggregate level of rent-seeking effort (i.e., civil conflict) exerts a negative externality on the total productivity factor. The sensitivity of productivity to conflict is called the *degree of destructiveness.*

Results. Our findings are the following.

First, in a competitive market economy, the behavior of the model crucially depends on the degree of destructiveness. We show that the economy is characterized by two regimes: a lowly destructive conflict regime (LD), and a highly destructive conflict regime (HD).[5] In both of these regimes, long-run steady states are associated with a positive stock of resources, as human exploitation and regeneration are balanced in the long run. In regime LD, there is a single well-determinate steady state, while in regime HD, there are two reachable stable states, including an undesirable low-growth/high-conflict equilibrium (i.e., a *poverty-conflict trap).*

Intuitively, the core mechanism that generates multiplicity lies in the conflict-based externality. Suppose that households expect low economic growth, and thus a low return on private capital, in the long run. Hence, at the initial point in time, households reduce their savings, so the initial consumption-to-capital ratio will be high. Since an increase in the consumption ratio reduces the marginal cost of rent-seeking efforts in their endogenous labor/rent-seeking choice, the rent-seeking effort will be high and the labor effort will be low. This implies that output will be small, leading to a low growth path. This mechanism, which is reversed in the case of high expected economic growth, generates multiple (i.e., two) self-fulfilling equilibria, leading to a selection problem in the form of global indeterminacy. This scheme only holds when the conflict strongly destroys factor productivity, i.e., in regime HD. In contrast, when the externality is weak, i.e., in regime LD, the economy reaches a single well-determinate steady state.

This indeterminacy may contribute to explaining the cross-country heterogeneities

[4]As rent-seeker households can seize the resource stock and thus engender, e.g., land degradation, deforestation, fisheries depletion, or food or water scarcity. For some historians and political scientists, land scarcity and deforestation played a key role in the turmoil in Haiti, in the Chiapas uprising in Mexico, or in the civil wars in Rwanda, Darfur, and Angola (Renner, 2004; Brown, 2010), for example.

[5]Quantitatively, both regimes are empirically plausible.

that we observe in the data in the resource-conflict nexus (as evidenced by Denly et al., 2022). Indeed, two countries in regime HD with similar fundamentals and the same initial level of the resource can experience drastically different short- and long-run trajectories in their development, depending on household expectations. The presence of natural resources can thus be compatible with a desirable high-growth/low-conflict steady state and an undesirable low-growth/high-conflict steady state.

Second, in a second-best environment, the government can mitigate individual incentives for conflict through its fiscal policy. We reveal that the relationship between the level of civil conflict and the public-spending-to-GDP ratio is nonlinear in the form of a U-shaped curve. The intuition is the following. An increase in public investment in the, e.g., military, defense, or law enforcement sectors reduces the efficiency of rent-seeking efforts of households, which discourages them from fighting. However, an increase in public investment requires tax increases to balance the government's budget. Such tax hikes reduce the net return of labor effort (net wages) and thus decrease the opportunity cost of rent-seeking.[6] For a small level of the spending ratio, the first effect prevails over the second opportunity-cost effect, and vise-versa for high spending ratios.

Following the same mechanism, the relationship between long-run economic growth and the public spending ratio describes an inverted U-shaped curve. The government can thus maximize long-run economic growth by setting the public spending at the threshold value. Hence, fiscal policy can help overcome the tradeoff between civil conflict and economic development, namely solve—at least partially—the conflict-based resource curse.

Third, the framework is extended by studying two types of government tax-financed expenditures: (i) investments in the military and defense sectors (ii) and investments in human capital (education, health, infrastructure, etc.). We show that there is a critical division of the government's budget between these two kinds of expenditures that minimizes the level of civil conflict. Effectively, an increase in the share of the budget devoted to military spending leads to a decrease in rent-seeking efforts but crowds out investment in human capital, which slows the rise in wages, thus reducing the opportunity cost of conflict. Hence, from a social peace perspective, the government must prioritize a mixed spending program, rather than investing heavily in one of the two dimensions.

In essence, the message of this paper is that conflicts over renewable resources can make the country's development trajectory subject to "animal spirits", namely households' optimistic or pessimistic views about the future. If households expect low economic growth in the future, the economy will converge toward the poverty-conflict trap. This mechanism is especially true in times of civil war when households' views on potential growth are bleak. However, the government through its fiscal policy can mitigate the incentives for households to fight and improves the long-run economic growth.

[6] Much empirical evidence supports this theoretical prediction that reducing net wages increases the conflict incentive via an opportunity-cost effect (see, e.g., Brückner and Ciccone, 2010; Fjelde, 2015; McGuirk and Burke, 2020).

Outline. Section 2 provides a literature review. Section 3 presents the baseline model, Section 4 defines the equilibrium, Section 5 characterizes the long-run steady states, and Section 6 analyzes the dynamics. Section 7 solves the model from the social planer's perspective, and Section 8 studies how fiscal policy can mitigate rent-seeking incentives. Finally, Section 9 delivers some concluding remarks.

2. Related literature

Studies closely related to ours integrate appropriation behavior into general equilibrium models. In a pioneering work, Tornell and Lane (1999) consider an economy with formal and shadow sectors where powerful groups can appropriate national resources produced in the first sector by extracting fiscal transfers from the government. Dal Bó and Dal Bó (2011) incorporate appropriation activities into an open economy model. Appropriation is modeled as a specific sector that uses labor to produce a redistribution of output. They predict that increases in the price of the capital-intensive (labor-intensive) good lead to an increase of the relative remuneration of capital (labor), thus reducing (increasing) the opportunity cost of joining the appropriative sector. McGuirk and Burke (2020) expand this theory by considering that the same good (food) that is produced using input (land) influences conflict, either through an attempt to control the underlying input ("factor conflict") or the product itself ("output conflict").

Methodologically, compared to these papers, we integrate appropriation into a closed economy with one sector and heterogeneous households. The appropriation behavior corresponds to a rent-seeking effort following a standard Tullock-type contest. The purpose of appropriation is not a better distribution of income, nor to capture the national product, but to seize a natural resource. Moreover, since our aim is to assess the long-run relation between conflict and development, we resort to an endogenous growth model, while there is no growth in the long run in the aforementioned papers.

Furthermore, Dal Bó and Dal Bó (2011) and McGuirk and Burke (2020)'s predictions align with the two key effects of the resource-conflict nexus: the rapacity effect, where an increase in the value of the resource incentivizes individuals to engage in conflict, and the opportunity-cost effect, wherein higher wages discourage participation in the appropriation sector. In our model, we differ from these articles on two points. On the one hand, the rapacity effect is triggered by changes in the resource price in Dal Bó and Dal Bó (2011) and McGuirk and Burke (2020), while it is driven by changes in the resource quantity in our model. On the other hand, an increase in the quantity of resource can reduce the level of civil conflicts at equilibrium if conflict efforts are very destructive.

Our novelty also lies in showing that fiscal policy is a useful tool for mitigating incentives for conflict. By investing in the law enforcement sector, the government can reduce conflict efforts up to a threshold, beyond which public investment is no longer beneficial for social peace, because the associated tax hike lowers the opportunity cost of rent-seeking activities. This result differs from Dal Bó and Dal Bó (2011), in which shocks affecting the opportunity costs of appropriation (net wages) increase the appropriable wealth, and hence there is an ambiguous effect of such shocks on conflict. In our setup, increasing net wages does not affect the stock of natural resources in equilibrium, so improving net wages decreases appropriation behavior.

Our study also complements previous researches that identify trust and beliefs as determinants in explaining the endogenous dynamics of war. Acemoglu et al. (2012) develop a dynamic game where a resource-poor country (A) exchanges a good for a non-renewable resource (oil) with a resource-rich country (S). Country A can fight to seize a larger part of the remaining country S's resource. In their model, war may become inevitable, because firms in country S do not internalize their impact on country A's war incentives. Specifically, they ignore that their expectation decision may increase country A's war incentives. Their model differs from ours in many respects. In our closed economy, we do not consider an interstate war but a civil conflict where households can seize a part of a renewable resource. We have no asymmetric information, since households have the same information when choosing their conflict efforts. While war can be inevitable as firms do not internalize their impact on the opponent's conflict incentives in Acemoglu et al. (2012), a long-run war scenario can appear as households do not internalize the impact of their conflict efforts on factor productivity in our setup.

Acemoglu and Wolitzky (2014) propose a theory of conflict snowballs where mistaken signals can trigger conflict between two groups. In their model, as a bilateral conflict intensifies, aggressive actions lose their informativeness, eventually leading one of the groups to cooperate. Provided the other group is not inherently hostile, this shift can put an end to the conflict. This model identifies information issues, such as noisy Bayesian updating and limited memory, as key factors in generating conflict cycles. In our setup, citizens have perfect foresight, and expectation-driven conflict trajectories are not due to information issues, but to the emergence of local and global indeterminacy.

More closely to ours, Rohner et al. (2013) argue that trust is a main determinant of civil conflict. They develop a dynamic trade model involving two ethnic groups where beliefs in each group are transmitted across generations. A conflict reduces trade in the current period, and undetermined futures trust by signaling to the victimized group that the aggressor has a low propensity to trade cooperatively. So a war today lays the foundations for distrust and future conflict. In our study, households have an infinite lifetime, and their trust in the future is not endogenous but reflects their choice of the initial value of the jump variable (consumption) when maximizing their intertemporal flow of utility. Consequently, low trust triggers an increase in future conflicts, not through a generational transmission channel, but because of initial consumption choices that push the economy onto a low-growth/high-conflict path.

As our focus is on an endogenous growth setup, our model is also related to theoretical works addressing the link between property rights enforcement and long-run economic growth in such settings. Strulik (2008) proposes a model where each social group can capture a part of the aggregate capital by exerting rent-seeking effort. In a symmetric configuration, there is no growth due to unforceable property rights—individuals are not incentivized to accumulate capital if the future saving gains are not protected. With two asymmetric groups, society-wide conflict and growth cannot be observed simultaneously. Gonzalez (2007) considers a model where each individual can allocate part of the resource (physical capital) to improve the quality of property rights via a Tullock-based contest. He shows, following Grossman and Kim (1996), that improving the quality of property rights is not necessarily beneficial to economic growth, since capital must be diverted from productive investment.

Our work challenges these results in different ways.

First, compared to Strulik (2008), even considering symmetric agents, we show that (i) long-run economic growth is positive, and (ii) growth and conflict can be observed together. This is because in Strulik, the property of accumulated factors (i.e., capital) is not secured, so there may be no incentive to invest in new capital in a conflict environment. In our model, in contrast, the property rights over the accumulable factors are well defined, so economic growth is compatible with conflict.

Second, we qualify Gonzalez (2007)'s results. In our basic model with fiscal policy, improving the quality of property rights by tax-financed public spending can be beneficial for long-run growth if such spending is sufficiently low and harmful otherwise, as in Gonzalez. The fact that improved property rights are detrimental to growth comes from a crowding-out effect in Gonzalez—capital investment must be allocated to appropriative competition and not to production—while in our case it is an opportunity-cost mechanism—an increase in public investment requires tax hikes that reduce the net wages.

Third, we emphase more complex scenarios than the existing literature that focuses on a unique well-determinate steady state by adding a conflict-based externality on the production technology. In our setup, the multiplicity of steady states associated with both local and global indeterminacy can appear. This contribution provides a new perspective on the resource curse, since developing economies—which are often countries with abundant renewable resources—may be plunged into a poverty trap because of households' pessimism about potential growth.[7]

[7] Our work also contributes to the extensive literature on conflict as rent-seeking competition. Among a multitude of works, we can mention Tullock (1967), Hirshleifer (1989), Skaperdas (1992, 1996), Esteban and Ray (1999), or the contributions in the selection of essays in Garfinkel and Skaperdas (2009). Such competition has been introduced in equilibrium models (see, e.g., Grossman and Kim, 1995; Grossman and Mendoza, 2003; Garfinkel et al., 2008, among other). They all abstract from economic growth and disregard renewable resources. Our contribution also lies in making the contest decisiveness parameter endogenous, which has hitherto been assumed to be exogenous.

Finally, our normative exploration considering fiscal policy instruments as possible tools to mitigate conflict incentives can be connected to the literature on state capacity and economic development. The influential political-economy model of Besley and Persson (2010) predict that public investment in legal or fiscal capacities can prevent social conflict by increasing wages. In our second-best environment, we disregard fiscal capacity, and public investment in legal capacity influences conflict incentives by securing property rights, which reduces the efficiency of rent-seeking activities. Besley and Persson (2010)'s model presents a different mechanism. A large improving legal capacity increases fiscal resources that relax the government's budget constraint. In turn, the government can implement peace-promoting redistribution policies through wage increases.

Additionally, our analysis of fiscal policy provides a theoretical basis for the empirical political science literature that studies how public expenditure can limit social conflict (see Bodea et al., 2016, for a review). Some studies suggest, e.g., that public spending on the military sector reduces civil conflicts by promoting the enforcement of laws, maintaining peace, or imposing order (see, e.g, Hendrix, 2010; Fearon and Laitin, 2003). Other works challenge this claim due to a crowding-out effect: increasing military investment crowds out investment in human capital, such as in infrastructure, health, or education, which has a strong pacifying effect (Henderson and Singer, 2000; Taydas and Peksen, 2012). Our results support the two empirical findings, depending on government budget allocation.

3. The model

We consider a closed economy populated by $N > 1$ representative agents, indexed by $i \in \{1, \cdots, N\}$, and a government. Each representative agent consists of a household and a competitive firm. All agents are infinitely lived and have perfect foresight. The population remains fixed over time, and we denote individual quantities by lower-case letters and aggregate quantities by corresponding upper-case letters.

3.1. Natural resources

We consider a renewable resource that can be exploited by households (e.g., the stock of timber, fish, woods, land, crops). This stock of resources (R_t) accumulates due to the regenerative capacity of nature and depreciates through human exploitation (E_t), namely

$$\dot{R}_t = f(R_t) - E_t, \tag{1}$$

where a dot over a variable represents a time derivative.

Regeneration. $f(\cdot)$ is the environmental regeneration function. Following Bovenberg and Smulders (1995), Fullerton and Kim (2008), and Menuet et al. (2023), we consider the standard quadratic form

$$f(R_t) = \eta R_t(\bar{R} - R_t), \tag{2}$$

where $\eta > 0$ is a scale parameter and $\bar{R} > 0$ is the virgin state, which is the maximal stock of resources that can be kept intact by natural regeneration itself (i.e., $f(\bar{R}) = E_t = 0$). From (2), initially, the regeneration process increases with the level of resources and then decreases as the level approaches the virgin state.

Exploitation. We assume that the full amount of natural resources cannot be exploited by households. The government (or international institutions) can define some ceiling, such as fishing or harvesting quotas, or decide to protect a natural area in which human presence and exploitation are limited or even prohibited. Thus, at each period of time, a share $\varepsilon \in [0, 1]$ of the resource stock can be exploited by households. Owing to imperfect property rights, the natural resources are rivalrous but non-excludable, such that the exploitation acitivity is subject to social conflicts: each household can be induced to appropriate a part $\beta_{t,i} \in [0, 1]$ of the exploitable stock of resources (εR_t) for its well-being by exerting rent-seeking effort; hence, $E_t = \sum_{i=1}^{N} \beta_{t,i}\varepsilon R_t$.

Consequently, using (1) and (2), the natural resource evolves according to

$$\dot{R}_t = R_t \left[\eta(\bar{R} - R_t) - \varepsilon \sum_{i=1}^{N} \beta_{t,i} \right]. \tag{3}$$

3.2. Households

Each household i derives utility from private consumption ($c_{t,i}$) and the appropriated resource ($\beta_{t,i}\varepsilon R_t$). It starts at the initial time with a positive stock of private human-made capital ($k_{0,i} > 0$) and seeks to maximize its separable intertemporal utility

$$U_i = \int_0^\infty e^{-\rho_i t} \left\{ \log(c_{t,i}) + \frac{1}{1 - v_i} (\beta_{t,i}\varepsilon R_t)^{1-v_i} \right\} dt, \tag{4}$$

where $\rho_i \in (0, 1)$ is the subjective discount rate and $v_i \in (0, 1)$ the constant elasticity of intertemporal substitution in captured resources.[8]

In addition, household i exerts rent-seeking effort ($x_{t,i}$) to appropriate the resource. As is typical in conflict models, $\beta_{t,i}$ is assumed to be a contest success function

$$\beta_{t,i} = \frac{\exp(a x_{t,i})}{\sum_{j=1}^{N} \exp(a x_{t,j})}. \tag{5}$$

From (5), $a \geq 0$ is the *decisiveness* parameter of the contest: if a is small, rent-seeking activities have a limited impact on the expected allocation of the resource, whereas for a high value of a, small differences in rent-seeking efforts are expected to be decisive.[9]

[8] The flow of utility is then concave in consumption and natural resources. Households can harvest wood, catch fish, or obtain crops for their own consumption or for sale. In such cases, the exploitation of resources is assumed to provide additional utility.

[9] There is an axiomatic foundation of contest functions by Skaperdas (1996). Following Garfinkel and

Beyond engaging in conflicts, household i also exerts productive labor effort $l_{t,i}$, which returns the hourly wage rate ($w_{t,i}$), consumes ($c_{t,i}$), and invests in capital ($\dot{k}_{t,i}$, we omit capital depreciation), the return on which is $q_{t,i}$ (the rental rate of capital). Hence, we have the following budget constraint:

$$\dot{k}_{t,i} = q_{t,i}k_{t,i} + w_{t,i}l_{t,i} - c_{t,i}, \tag{6}$$

and since households are endowed with $\bar{l} > 0$ units of time,

$$x_{t,i} + l_{t,i} = \bar{l}. \tag{7}$$

Defining by $\lambda_{t,i}$ the costate variable of the current Hamiltonian, the first-order conditions (FOCs) for the maximization of the household's program are

$$1/c_{t,i} = \lambda_{t,i}, \tag{8}$$

$$\frac{1}{\beta_{t,i}}\frac{\partial \beta_{t,i}}{\partial x_{t,i}}(\beta_{t,i}\varepsilon R_t)^{1-v_i} = w_{t,i}\lambda_{t,i}, \tag{9}$$

$$\dot{\lambda}_{t,i} = (\rho_i - q_{t,i})\lambda_{t,i}, \tag{10}$$

$$\lim_{t\to+\infty} e^{-\rho_i t}\lambda_{t,i}k_{t,i} = 0. \tag{11}$$

The FOCs (8)-(11) have the standard interpretation. Eq. (8) states that the marginal utility of consumption ($1/c_{t,i}$) equals its marginal cost (the shadow price of capital $\lambda_{t,i}$). Eq. (9) determines the optimal behavior of fighting activity: at each period t, the gain from seizing an additional share of resources by exerting one more unit of rent-seeking effort ($\frac{1}{\beta_{t,i}}\frac{\partial \beta_{t,i}}{\partial x_{t,i}}(\beta_{t,i}\varepsilon R_t)^{1-v_i}$) just equals the marginal cost, which is the opportunity cost related to the loss of labor income (the real wage $w_{t,i}$ expressed in terms of the marginal utility of consumption $\lambda_{t,i}$). Thus, from an individual perspective, an increase in wages (*opportunity-cost effect*) or an increase in the resource level (*rapacity effect*) reduces the inducement to engage in conflict by inducing households to substitute away from rent-seeking effort toward productive effort. Finally, Eq. (10) describes the evolution of the shadow price of capital, and Eq. (11) is the usual transversality condition.

3.3. Firms

The output of an individual firm i ($y_{t,i}$) is produced using physical capital ($k_{t,i}$) and human capital ($h_{t,i}$) according to a Cobb-Douglas technology, namely

$$y_{t,i} = A_t k_{t,i}^{\alpha} h_{t,i}^{1-\alpha}, \tag{12}$$

Skaperdas (2009) and Hwang (2012), a is determined by institutional and political factors. We make this parameter endogenous in Section 8.

where $\alpha \in (0,1)$ is the elasticity of output to physical capital, and A_t is the total productivity factor. Following Romer (1986), human capital is produced both by labor effort ($l_{t,i}$) and the economy-wide stock of capital ($\bar{K}_t := \sum_{i=1}^{N} k_{t,i}/N$), namely $h_{t,i} = l_{t,i}\bar{K}_t$.[10]

Since there is a finite number N of firms, they internalize the impact of their own labor supply $l_{t,i}$ and capital stock $k_{t,i}$ on the corresponding aggregates, while they consider $\bar{K}_t$ in the human capital to be given because it reflects a positive externality. The aggregate production is then $Y_t = A_t(\sum_{j=1}^{n} k_{t,j})^{\alpha}(\bar{K}_t \sum_{j=1}^{n} l_{t,j})^{1-\alpha}$. Anticipating the symmetric equilibrium where each firm has $1/N$ of the aggregate production, the first-order conditions for profit maximization are

$$r_{t,i} = \alpha \frac{Y_t/N}{k_{t,i}}, \tag{13}$$

$$w_{t,i} = (1-\alpha)\frac{Y_t/N}{l_{t,i}}. \tag{14}$$

We next assume that civil conflict—measured by the sum of rent-seeking efforts (i.e., $S_t := \sum_{i=1}^{N} x_{t,i}$)—exerts a negative externality on productivity, namely $A_t = A(S_t)$, with $A'(\cdot) \leq 0$. This assumption is supported by considerable evidence suggesting that civil conflicts destroy productivity (see, e.g., Fang et al., 2020). Indeed, firm-level productivity is influenced by technology, organizational structure, management practices (Bloom and Van Reenen, 2010), and the number of workers as well as their skills (Iranzo et al., 2008), etc. All of these are affected by conflicts (see Collier, 1999). For example, Klapper et al. (2013) show that social conflicts in Côte d'Ivoire between 1998 and 2003 led to an average 16–23 percent drop in firm total factor productivity. Similarly, the impact of conflicts in Sub-Saharan Africa in the period 1989–2017 reduced productivity growth by 1.3 percentage points (Newiak et al., 2019). Additionally, a number of historical examples suggest that resource conflicts undermine the long-term sustainability of societies via a decline in overall productivity.[11]

In our specification (12), the externality is on total productivity and thus includes the external effect of conflict on human capital. It is empirically well established that civil conflicts reduce human capital accumulation, notably via educational attainment (Bundervoet et al., 2009; Akresh and de Walque, 2008). For example, Leon (2012) shows that the average individual accumulates 0.31 fewer years of education in adulthood if faced with conflict.

[10] We could introduce the resource into the production function as an externality or input. In this case, if the elasticity of output to the resource is sufficiently low, our results remain qualitatively unchanged.

[11] One of the most striking examples is Easter Island. Even before the islands were colonized, the local populations exploited their renewable resources, leading to near-total deforestation. The loss of forest dried up springs and watercourses, accelerated soil erosion and reduced harvests. Lacking wood, the islanders were unable to build boats and fish offshore, ultimately leading to famine and the collapse of their society (Brander and Taylor, 1998).

To take such stylized facts into account in a simple way, we consider the following functional form:

$$A(S_t) = \tilde{A}(N\bar{l} - S_t)^{\theta}, \tag{15}$$

where $\tilde{A} > 0$ is a scale parameter and $\theta > 0$ reflects the sensitivity of productivity to conflict that we called the *degree of destructiveness*. If θ is small, the conflict is weakly destructive as productivity is slightly damaged. At the limit $\theta = 0$, productivity does not depend on conflict ($A(S_t) = \tilde{A}$). In contrast, for high values of θ, the basis of economic growth is substantially affected since conflict is highly destructive to factor productivity.

4. Equilibrium

We identify decentralized symmetric equilibria in which all household-firm units behave similarly; hence we subsequently drop the i subscript (namely, $\rho_i = \rho$, $v_i = v$, $\beta_{t,i} = \beta_t$, $c_{t,i} = c_t$, $l_{t,i} = l_t$, $y_{t,i} = y_t$, $k_{t,i} = k_t$, $x_{t,i} = x_t$, $q_{t,i} = q_t$, $r_{t,i} = r_t$,...). Using the aggregate variables $C_t = Nc_t$, $L_t = Nl_t$, $K_t = Nk_t$, $X_t = Nx_t$, and $Y_t = Ny_t$, the equilibrium is defined as follows.

Definition 1. A symmetric competitive equilibrium is a path

$$\{R_t, \lambda_t, C_t, L_t, K_t, X_t, A_t, Y_t, w_t, q_t, r_t\}_0^{\infty},$$

that solves Eqs. (3), (7), (8), (9), (10), (12), (13), (14), and (15) and satisfies the goods market equilibrium $\dot{K}_t = Y_t - C_t$, $q_t = r_t$, and the transversality condition (11).

From (7), (12) and (15), the aggregate production function is

$$Y_t = \tilde{A} K_t L_t^{1-\alpha+\theta}, \tag{16}$$

allows generating an endogenous growth paths because the social return of capital is not decreasing.

In equilibrium, the rental rate of capital simply equals the real interest rate ($q_t = r_t$, since there is no capital depreciation). From (8) and (10), the optimal behavior of households leads to the standard dynamic Keynes-Ramsey rule

$$\frac{\dot{C}_t}{C_t} = r_t - \rho, \tag{17}$$

and, using (5) and (14), the static labor/rent-seeking tradeoff (9) becomes

$$a\left(\frac{N-1}{N}\right)\left(\frac{\varepsilon R_t}{N}\right)^{1-v} = N\left(\frac{w_t}{C_t}\right) \qquad (18)$$
$$= N\left[\frac{(1-\alpha)\tilde{A}L_t^{\theta-\alpha}}{C_t/K_t}\right],$$

hence,

$$X_t = \bar{L} - L_t = \bar{L} - \hat{A}R_t^{\frac{1-v}{\theta-\alpha}}\left(\frac{C_t}{K_t}\right)^{\frac{1}{\theta-\alpha}}. \qquad (19)$$

where $\hat{A} := \left(\frac{a(N-1)\varepsilon^{1-v}}{(1-\alpha)\tilde{A}N^{3-v}}\right)^{1/(\theta-\alpha)}$ and $\bar{L} = N\bar{l}$.

From (19), the relationship between civil conflict X_t and the consumption-to-capital ratio C_t/K_t (or the natural resource R_t) depends on the sign of the gap $\theta - \alpha$. The intuition is as follows. An increase in the consumption ratio reduces the marginal cost of fighting (the right-hand side of 18), namely the opportunity cost related to the loss of labor income. Similarly, an increase in the natural resource raises the marginal gain from fighting (the left-hand side of 18). In both cases, households are induced to substitute working activity for rent-seeking activity. For Eq. (18) to hold, the real wage (w_t) must rise. Since $w_t = (1-\alpha)\tilde{A}\ K_t[1-X_t]^{\theta-\alpha}$, the increase in the wage is achieved by a decrease (resp. an increase) in rent-seeking activity in the case of $\theta > \alpha$ (resp. $\theta < \alpha$). Intuitively, following a rise in the consumption ratio or the natural resource, households reduce their rent-seeking efforts if the conflict is highly destructive, i.e., $\theta > \alpha$, and increase them if the conflict is weakly destructive, i.e., $\theta < \alpha$.

By denoting $Y_{kt} := Y_t/K_t$ and $C_{kt} := C_t/K_t$ as the stationary ratios per unit of capital, introducing (19) into (16), it follows that

$$Y_{kt} = AR_t^{(1-v)(1+\mu)}C_{kt}^{1+\mu}, \qquad (20)$$

where $A := \tilde{A}\hat{A}^{1-\alpha+\theta}$ and $\mu = 1/(\theta-\alpha) \lesseqgtr 0$.

The relationship between the consumption ratio (or the natural resource) and the output ratio comes from the labor/rent-seeking tradeoff (18), as we have just discussed. If $\theta > \alpha$ (i.e., $\mu > 1$), an increase in C_{kt} or R_t decreases the rent-seeking effort, boosting the labor input and the output ratio. This mechanism reverses if $\theta < \alpha$ (i.e., $\mu < -1$).

From (3) and (5), in the symmetric equilibrium, the overall stock of the non-preserved resource is exploited (i.e., $\sum_{i=1}^{N}\beta_{t,i} = 1$), and the law of motion of resources is

$$\dot{R}_t = R_t\left[\eta(\bar{R} - R_t) - \varepsilon\right]. \qquad (21)$$

Finally, using the goods market equilibrium $\dot{K}_t = Y_t - C_t$, the reduced-form of the model is obtained by Eqs. (13), (17), (20) and (21) (we henceforth omit time indexes)

$$\begin{cases} \dfrac{\dot{C}_k}{C_k} = \dfrac{\dot{C}}{C} - \dfrac{\dot{K}}{K} = C_k - \rho - (1-\alpha)AR^{(1-v)(1+\mu)}C_k^{1+\mu}, & \text{(a)} \\ \\ \dfrac{\dot{R}}{R} = \eta(\bar{R} - R) - \varepsilon. & \text{(b)} \end{cases} \tag{22}$$

We determine the steady-state solutions of the model in the following Section and analyze local and global dynamics in Section 6.

5. Characterization of steady-state(s)

We define the steady state as follows.

Definition 2. A steady state s is a symmetric competitive equilibrium where consumption, capital, and output grow at the common (endogenous) rate γ^s, and the stock of the natural resource is constant, such that $\dot{C}_k = \dot{R} = 0$ in (22). For any steady state s, the economy is characterized by a balanced-growth path (BGP): $\gamma^s := \dot{C}/C = \dot{K}/K = \dot{Y}/Y$.

At this stage, the study of system (22) is straightforward, since the law of motion of the natural resource (22.b) does not depend on C_k. In steady state, the resource stock is either $R^* = 0$ or $R^* =: \hat{R} = (\eta\bar{R} - \varepsilon)/\eta$. Two configurations follow: if $0 < \varepsilon < \bar{\varepsilon} := \eta\bar{R}$, the only stable steady state is the second ($R^* = \hat{R} > 0$); however, if $\varepsilon > \bar{\varepsilon}$, the only stable steady state is the first ($R^* = 0$).[12] Intuitively, in the case of $\varepsilon > \bar{\varepsilon}$, the human exploitation of the resource exceeds the environmental regeneration capacity, so the resource is depleted in the long run. In contrast, if $0 < \varepsilon < \bar{\varepsilon}$, the regeneration and the exploitation can be balanced in the long run, so the resource stock converges toward a positive level.

Before studying the general configuration, two particular cases deserve attention.

Proposition 1. *(Peaceful steady state)*
(i) If $\varepsilon = 0$, there is a unique well-determinate steady state (called P_0) where $R^* = \bar{R}$.
(ii) If $\varepsilon > \bar{\varepsilon}$, there is a unique well-determinate steady state (called P_1) where $R^* = 0$.
In the both cases, the economic growth rate is $\gamma^* = \alpha\tilde{A} - \rho$.

Proof: If $\varepsilon = 0$, there is no exploitation, so the incentive to exert rent-seeking effort disappears (the LHS of Eq. 18 is zero): $X = 0 \Rightarrow L = 1 \Rightarrow Y_k = \tilde{A}$. Similarly, if $\varepsilon > \bar{\varepsilon}$, the stock of the resource asymptotically vanishes ($R^* = 0$) as we have seen, and the rent-seeking incentives also disappear. In these two cases, using (17), the long-run economic growth rate is $\gamma^* = \alpha\tilde{A} - \rho > 0$ (as the discount rate is assumed to be small).

[12] Indeed, from (22.b), we derive $\left.\frac{\partial \dot{R}}{\partial R}\right|_{R=0} = \bar{\varepsilon} - \varepsilon = -\left.\frac{\partial \dot{R}}{\partial R}\right|_{R=\hat{R}}$.

Appendix A will ensure that the steady state is well determinate. □

The peaceful environment can come in the long run either from a ban on exploitation ($\varepsilon = 0$)—steady state P_0—or from a total depletion of the resource ($\varepsilon > \bar{\varepsilon} \Rightarrow R^* = 0$)—steady state P_1. From a policy perspective, banning exploitation ($\varepsilon = 0$) is the best policy from both the perspectives of resource preservation (in the long-run, the virgin state $R^* = \bar{R}$ is reached) and long-run economic growth. However, as we will see in Section 7, such a policy is not necessarily welfare-maximizing.

Let us now focus on the intermediate case $0 < \varepsilon < \bar{\varepsilon}$. From Eq. (22.a), the consumption ratio is invariant over time if and only if

$$C_k - \rho = (1-\alpha)Y_k(R, C_k). \tag{23}$$

This equation characterizes a positive or negative link between C_k and R, depending on the sign of $\theta - \alpha$, as depicted in the phase diagram in Figure 1. There are two cases.

If $\theta < \alpha$, as we have seen, Y_k negatively depends both on the natural resource (R) and the consumption ratio (C_k); hence, Eq. (23) leads to an unambiguous decreasing mapping between C_k and R (see Figure 1a). In this case, any positive stock of resource is associated with one value of the consumption ratio, hence the uniqueness of the steady state.

If $\theta > \alpha$, in contrast, Y_k positively depends on both R and C_k, so that an increase in the consumption ratio increases both sides of Eq. (23), producing a non-monotonic relationship between C_k and R (see Figure 1b). Intuitively, in the goods market equilibrium ($\dot{K}/K = Y_k - C_k$), for a fixed output ratio, an increase in consumption reduces the investment and the growth rate of physical capital. On the other hand, higher consumption results in higher output that boosts capital accumulation. This ambiguous effect leads to the bell-shaped curve in the phase diagram (see Figure 1b).

The following proposition describes the long-run solutions of the model.

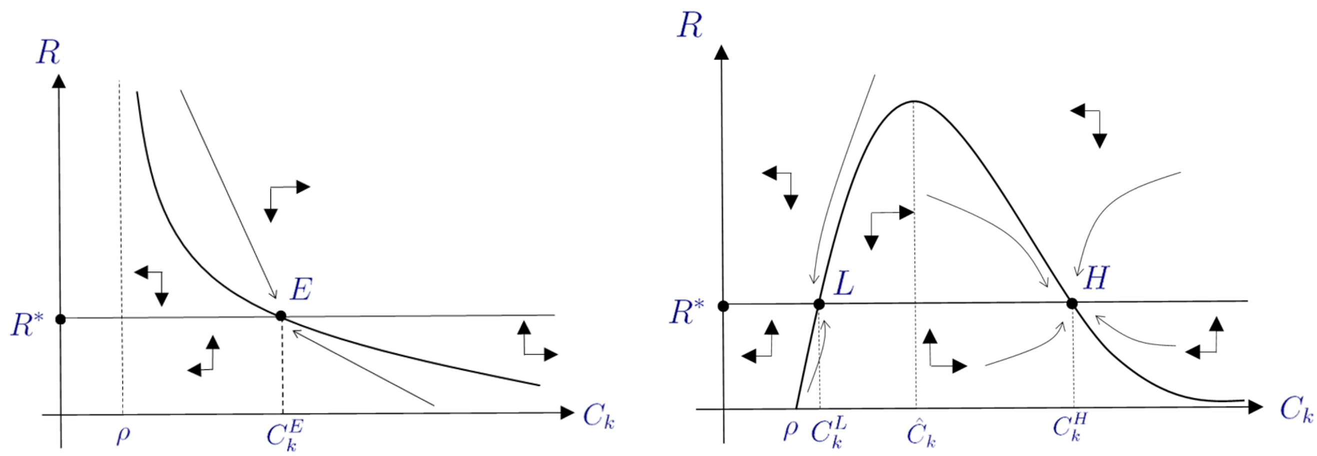
Proposition 2. *(Existence) Let* $0 < \varepsilon < \bar{\varepsilon}$*. There are two regimes:*

- *Lowly destructive conflict (regime LD: $\theta < \alpha$): there is a unique steady state (E).*
- *Highly destructive conflict (regime HD: $\theta > \alpha$): there are two steady states (L and H).*

Proof: See Appendix A.

Three points deserve particular attention.

First, there is a unique steady state in regime LD, while regime HD is associated with multiplicity. As the $\dot{C}_k = 0$ locus describes an inverted U-shaped curve (see Figure 1b), the stock of the resource R^* is compatible with two consumption ratios: the low steady state L (C_k^L, R^*) and the high steady state H (C_k^H, R^*). Since economic growth is higher in H than in L and social conflict is lower,[13] steady state L can be viewed as a *poverty conflict trap*. Methodologically, the fundamental point is that the conflict-based externality (θ) is needed for the multiplicity (i.e., two equilibria) to emerge. Effectively, this externality implies that the returns-to-scale of the aggregate production function can be increasing, hence the possible emergence of multiplicity and indeterminacy.



(a) $\theta < \alpha$ (LD)

(b) $\theta > \alpha$ (HD)

Figure 1: Phase diagram

Second, the two regimes are empirically plausible. Focusing on the external effect of conflict on human capital—which can be usually measured as the number of years of schooling—the value of θ could be approximated by the loss of years of study due to the conflict (see Justino, 2011, for a review). Table 1 presents the losses in years of schooling linked to civil conflicts as found by several empirical studies for key conflicts that are (partly) linked to natural resource issues. These values can be proxi of our parameter θ.[14] These findings, although small, indicate that some conflicts are highly destructive in terms of human capital (as in Perú, Guatemala, or Rwanda, where θ is higher than capital share α), while others are less so (as in Nepal or Colombia). Hence, both regimes are empirically plausible for developing economies subject to civil conflict.

[13]We have $\gamma = \alpha Y_k - \rho$ with $\partial Y_k / \partial C_k > 0$.

[14]Of course conflict affects other means of production by destroying the quality of infrastructure, networks, public goods, etc., so the value of θ is likely to be higher.

Study	Country	Period	Loss of years of schooling	Capital share
Leon (2012)	Perú	1974-2007	0.31	0.22
Chamarbagwala and Morán (2011)	Guatemala	1960-1978	0.27(man) 0.12(girl)	0.14
		1979-1984	0.71(man) 0.47(girl)	0.15
		1985-1996	1.09(man) 1.17(girl)	0.15
Akresh and de Walque (2008)	Rwanda	1994 Genocide	0.5	0.14
Islam et al. (2016)	Cambodia	1970-1979	0.9(man) 0.6(girl)	0.12
Shemyakina (2011)	Tajikistan	1999-2003	0.23 (man) 0.65(girl)	0.18
Bertoni et al. (2019)	Nigeria	2009-2016	0.6	0.16
Weldeegzie (2017)	Ethiopia	1998-2000	0.62	no data
Dabalen and Paul (2014)	Côte d'Ivoire	2002-2006	0.2-0.9	0.17
Rodriguez and Sánchez (2012)	Colombia	1990-2003	0.15	0.21
Yamada and Matsushima (2020)	Myanmar	1993-2013	no effect	0.25
Valente (2014)	Nepal	1996-2006	no effect	0.14
Foltz and Opoku-Agyemang (2011)	Uganda	1999-2005	-0.2	0.21

Note: Capital shares are average values over the identified period (source: World Bank). 'No effect' means that there is no statistically significant effect.

Table 1: Loss of school years due to civil conflicts & capital share (to GDP)

Third, in regime HD, the economy is subject to two bifurcations: at $\varepsilon = 0$ and $\varepsilon = \bar{\varepsilon}$. A bifurcation means that a slight change in parameter values causes a sudden shift in the behavior of the economy. The cases $\varepsilon = 0$ and $\varepsilon = \bar{\varepsilon}$ mimic *pitchfork bifurcations*: if ε is slightly below $\bar{\varepsilon}$, there are two steady states (L and H), while there is only one (P_1) if $\varepsilon > \bar{\varepsilon}$. Similarly, if ε is slightly above 0, there are two steady states, while there is only one (P_0) if $\varepsilon = 0$.

These bifurcations are usually represented in a diagram (Figure 2) that depicts the stationary locus of economic growth (left graph) and natural resources (right graph) and shows how steady states move in comparative statics following changes in ε. At P_0 (i.e., $\varepsilon = 0$), as we have seen in Proposition 1, there is no human exploitation, so economic growth is maximized and the stock of resources reaches the virgin state ($R^* = \bar{R}$). At P_1 (i.e., $\varepsilon > \bar{\varepsilon}$) society is also peaceful such that economic growth still reaches its maximum level. The reason is not that exploitation is forbidden but that there is no more of the resource in the long run ($R^* = 0$). In the intermediate case ($0 < \varepsilon < \bar{\varepsilon}$), multiplicity emerges: along the low steady state (L), an increase in ε causes the long-run economic growth to decrease, and vise-versa along the high steady state (H). This comes from the bell curve in the phase diagram (Figure 1b): as ε increases, human exploitation is higher, reducing the long-run resource stock (R^*). This results in a decrease in the consumption ratio at L and an increase in it at H. Since economic growth positively depends on the consumption ratio in regime HD, the result follows.

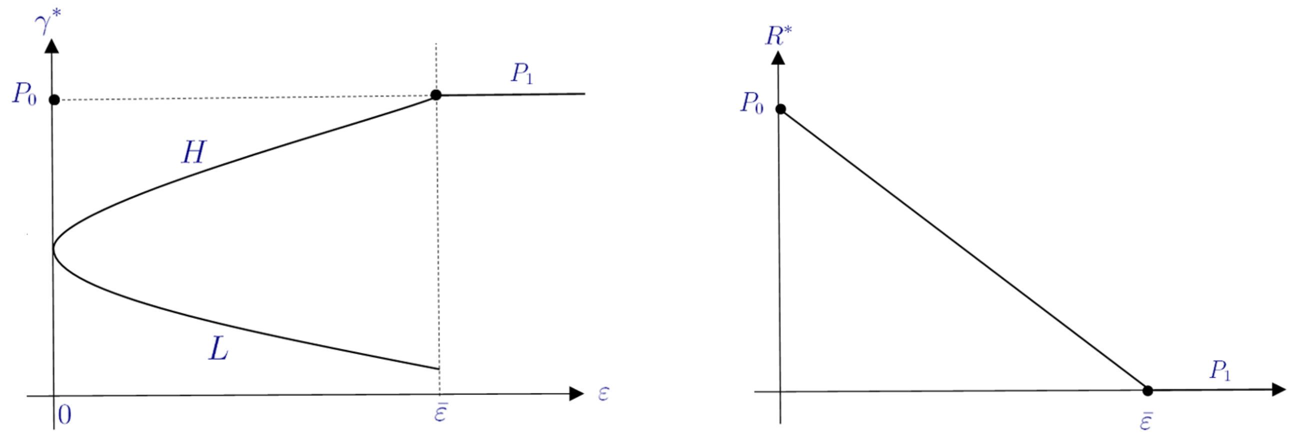


Figure 2: Bifurcation diagram as a function of ε in regime HD

From a policy perspective, the protection of resources from human exploitation as an instrument of development policy must be used with caution for two reasons. On the one hand, a small change in ε can lead to radical shifts in the long-run state: if ε is slightly below $\bar{\varepsilon}$, the economy may fall into a poverty trap with high civil conflict (L), so economic growth will be perpetually low, whereas for a value slightly above $\bar{\varepsilon}$, the economy may reach a high-growth state in the long run (P_1). On the other hand, if $\varepsilon \in (0, \bar{\varepsilon})$, the economy is subject to a multiplicity of long-run solutions, associated with undesirable indeterminacy, as we will see in the next section.

6. Stability analysis

To study the behavior of the model outside the steady state, we first proceed to a local stability analysis and then infer global dynamics.

6.1. Local dynamics

By linearization in the neighborhood of steady state $s \in \{E, L, H\}$, system (22) behaves according to $(\dot{C}_k, \dot{R}) = \mathbf{J}^s(C_k - C_k^s, R - R^s)$, where $\mathbf{J}^s$ denotes the Jacobian matrix evaluated at steady state s. The reduced-form system incudes one predetermined variable (the natural resource R) and one jump variable (the consumption ratio $C_k = C/K$). Thus, for the steady state s to be well determined, $\mathbf{J}^s$ must contain two opposite-signed eigenvalues. The following theorem establishes the topological behavior of each steady state.

Proposition 3. *(Local Stability)*
- *Regime LD: E is a saddle point (well determinate).*
- *Regime HD: L is a saddle point (well determinate), while H is stable (indeterminate)*

Proof: See Appendix A.

6.2. Global dynamics

Capitalizing on the local analysis, we can now evaluate the global dynamics. Let us now assume that the economy is initially endowed with a strictly positive stock of the resource ($R_0 > 0$) and $\varepsilon \in (0, \bar{\varepsilon})$.

Regime LD — There is a unique equilibrium (E) that is a saddle point. For any (positive) predetermined stock of the resource ($R_0 > 0$), the initial consumption ratio (C_{k0}) jumps to place the economy on the saddle path converging toward E. The economy is well determinate from both a local and a global perspective.

Regime HD — There are two equilibria: L is a saddle point and H is stable. There are then *local indeterminacy* (in the vicinity of H) and *global indeterminacy.* Indeed, for a given predetermined (positive) stock of the resource ($R_0 > 0$), the initial consumption ratio (C_{k0}) can jump either to the single transition path that converges to L or to one of the multiple paths that converge to H while respecting the transversality condition.

In this case, the behavior of the economy is subject to "animal spirits", in the form of optimistic or pessimistic views of households at the initial time. The intuition is as follows. Let us suppose that households initially expect high economic growth (i.e., steady state H). Then, the output ratio is expected to be high, which corresponds to a high expected return on private capital. Thus, at the initial time, households increase their saving, such that the initial consumption-to-capital ratio will be low. In the endogenous labor/rent-seeking choice, a decrease in the consumption ratio increases the marginal cost of fighting. Hence, households initially reduce their rent-seeking efforts and increase their labor productive efforts. This implies that the initial output ratio will be high, leading to a self-fulling increase in economic growth. As a result, we have a belief-driven transitional path toward the high equilibrium (H). This mechanism, which reverses in the case of low expected economic growth, generates multiple self-fulfilling equilibria, leading to a selection problem in the form of global indeterminacy.

In a decentralized economy, the presence of the natural resource can lead to both local and global indeterminacy. If the conflict strongly affects factor productivity, the short- and long-run behavior of the economy is then subject to households' "animal spirits", in the form of self-fulfilling prophecies that generate multiple balanced-growth paths in the future. This feature exemplifies the well-known "history versus expectation" mechanism (Krugman, 1991; Matsuyama, 1991), in which the selection of the long-run equilibrium depends alternatively on the set of initial conditions (in our setting, the initial endowment of natural resources) or self-fulfilling expectations.

As regime HD is empirically plausible, our simple model offers a new explanation for the fragile link between natural resources, civil conflicts and economic growth. An abundance of renewable resources (i.e., R_0 is high) is compatible either with a high-growth path if households are optimistic on the future (i.e., the economy converges to steady state H), or with a low-growth path if households are pessimistic (i.e., the economy converges to the poverty-conflict trap L). Hence, the resource curse may emerge due to pessimistic household expectations. This is especially the case in times of conflict when households anticipate lower growth in the future.

From a policy perspective, the best solution to address both of the above perils seems to lie with prohibiting human exploitation by protecting the overall resource ($\varepsilon = 0$). Leaving aside for the moment the potential difficulties in implementing such a policy, the choice to ban exploitation does not maximize social welfare, since households derive their utility from the natural resources captured. To prove this point, we next focus on the (first-best) choice problem.

7. The centrally planned economy

Let us consider a social planer who possesses complete information and chooses all quantities directly—including the path of the values of ε that are now time-varying—taking all the relevant information into account. In particular, the social planner recognizes that agents are symmetric and $C_t = Nc_t$, $L_t = Nl_t$, $K_t = Nk_t$, $X_t = Nx_t$, and $Y_t = Ny_t$, so that she considers the aggregate production function (16).

From the planer's perspective, as agents are symmetric, there is no incentive to engage in social conflict, because the contest success function (5) leads to a uniform sharing of the resource at the symmetric configuration (i.e., $x_{t,i} =: x_t \Rightarrow \beta_{t,i} = 1/N, \forall i$). Hence, rent-seeking efforts are zero ($X_t = 0$), and households devote all their available time to productive activity ($L_t = 1$). The centralized economy is then a peaceful environment. The planer considers an AK-type production function, namely, $Y_t = \tilde{A}K_t$, and maximizes the utility of the representative agent (since all agents have the same utility function by symmetry), using (4)

$$U = \int_0^\infty e^{-\rho t} \left\{ \log\left(\frac{C_t}{N}\right) + \frac{1}{1-v}\left(\frac{\varepsilon_t R_t}{N}\right)^{1-v} \right\} dt,$$

subject to the constraints on the goods market equilibrium

$$\dot{K}_t = \tilde{A}K_t - C_t,$$

and the law of motion of the natural resource (3)

$$\dot{R}_t = R_t \left[\eta(\bar{R} - R_t) - \varepsilon_t \right].$$

The planer chooses the aggregate level of physical capital (K_t), consumption (C_t), and the natural resource (R_t). She also sets her instrument of environmental policy (ε_t), which corresponds to the part of the resource that is uniformly distributed to households. Let ξ_t and ψ_t be the shadow (social) prices of private physical capital and the natural resource. The first-order conditions of the planer's program are

$$1/C_t = \xi_t, \qquad /C_t \tag{24}$$

$$\varepsilon_t^{-v}\left(\frac{R_t}{N}\right)^{1-v} = \psi_t R_t, \qquad /\varepsilon_t \tag{25}$$

$$R_t^{-v}\left(\frac{\varepsilon_t}{N}\right)^{1-v} + \psi_t[\eta(\bar{R} - 2R_t) - \varepsilon_t] = \rho\psi_t - \dot{\psi}_t, \qquad /R_t \tag{26}$$

$$\dot{\xi}_t/\xi_t = \rho - \tilde{A}, \qquad /K_t \tag{27}$$

under the set of transversality conditions

$$\lim_{t\to+\infty} e^{-\rho t}\xi_t K_t = 0, \text{ and } \lim_{t\to+\infty} e^{-\rho t}\psi_t R_t = 0.$$

First-order conditions (24)-(27) have the standard interpretation. Eq. (24) equates the marginal utility of consumption to the (social) shadow price of an additional unit of physical capital. From (25), the optimal choice of natural resource preservation (ε_t) is such that the marginal gain of an additional unit of resource to be appropriated ($\varepsilon_t^{-v}(R_t/N)^{1-v}$) equals its marginal cost (namely, the social shadow value of the resource $\psi_t R_t$). Hence, the shadow price is $\psi_t = \varepsilon_t^{-v} R_t^{-v}/N^{1-v}$. Dividing Eq. (26) by ψ_t, we obtain

$$\eta(\bar{R} - 2R_t) = \rho - \frac{\dot{\psi}_t}{\psi_t}.$$

At equilibrium (i.e., $\dot{\psi}_t = 0$), we obtain the optimal value of the resource stock

$$R^{op} = \frac{\eta\bar{R} - \rho}{2\eta}.$$

Note that R^{op} negatively depends on the subjective discount rate (ρ).[15] Intuitively, if households are myopic (i.e. ρ increases), the present value of future resource withdrawals decreases, and they are induced to increase the current consumption of the natural resource, reducing the long-run stock of the resource. This result is well-known in resource management: if agents are less concerned about the future, they increase the current pressure on natural capital, which decreases resource stocks.

Finally, from (27) and (24), we derive the so-called Keynes-Ramsey relationship

$$\frac{\dot{C}_t}{C_t} = \tilde{A} - \rho,$$

where the marginal return to physical capital is simply $Y/K = \tilde{A}$ since there is no conflict. Along a balanced-growth path where consumption, physical capital, and output growth

[15] We assume that $R^{op} > 0$ because the subjective discount rate is small enough.

are at the same endogenous rate, the optimal economic growth is $\gamma^{op} = \tilde{A} - \rho$.

It is now interesting to compare the planner's choices with the equilibrium in a competitive economy and to examine whether the central planner's optimum can be decentralized.

Regarding natural resource, in the case of $0 < \varepsilon < \bar{\varepsilon} := \eta \bar{R}$, the equilibrium stock of the resource in the market economy is $R^* = (\eta \bar{R} - \varepsilon)/\eta$ and does not depend on the discount rate (ρ) because households do not internalize the law of motion of the natural resource. On the other hand, the optimal value ($R^{op} = (\eta \bar{R} - \rho)/2\eta$) is independent of ε_t, since the social planner chooses it optimally and the optimization problem is linear in ε_t, as we have seen. Clearly, the market economy is less environmentally friendly than the centralized economy because $R^* < R^{op} \Leftrightarrow \varepsilon < (\eta \bar{R} + \rho)/2 < \bar{\varepsilon}$.

Against this background, by considering ε as the environmental policy instrument of the government, the stock of the resource in the market economy equilibrium matches the first-best optimum if

$$\varepsilon = \varepsilon^{op} = \frac{\eta \bar{R} + \rho}{2}.$$

As ρ is small, we ensure that $\varepsilon^{op} \in (0, \bar{\varepsilon})$, such that the optimum level of the resource can be reached in a competitive market economy.

Regarding economic growth, the optimum level appears when society is peaceful. In a competitive economy, how can the government limit—and in the best case avoid—individual incentives for conflict? Formally, such incentives are the marginal gain from fighting (the left-hand side of 18) when households choose the combination of productive and rent-seeking efforts. This gain is null when the exploitation of the resource is prohibited (i.e., $\varepsilon = 0$). However, this solution is not the first-best, as we have seen ($\varepsilon^{op} > 0$). Additionally, such a policy is of course very difficult to implement. It is predictable that a non-zero part of the natural resource will be illegally exploited by poachers or bandits despite a strict ban. This is especially true in developing countries, where the opportunity cost of illegal actions is low, linked to weak revenues from legal activities.

Regarding Eq. (18), as the outcome of rent-seeking activities is modelled by the contest success function (Eq. 5), another possibility for the government to reduce individual incentives for conflict is to decrease the efficiency of rent-seeking activities via the decisiveness parameter (a). Following Hirshleifer (2000), Hwang (2012) and Menuet et al. (2021), the decisiveness parameter is determined both by institutional and technological factors affecting households' ability to obtain a significant gain from their fighting effort. Such factors include law enforcement, police, or military technologies. Obviously, it is more difficult to obtain a significant gain by fighting against fellow citizens when the armed forces or police are efficient at maintaining public order. This idea is supported by empirical evidences showing that civil conflicts are more likely to appear in areas where state authority is weak (Fjelde and Nilsson, 2012) or there is little domestic military presence (Buhaug et al., 2009). In this way, the government can (indirectly) control the decisiveness parameter by improving the military, defense, or law enforcement sectors through public investment. However, high public expenditures might not be sustainable in the current fiscal context in both developed and developing countries where fiscal space is limited (Ghosh et al., 2013).

In summary, the decision to protect natural resources (i.e., setting the value of ε) allows policymakers to achieve the (first-best) value of the natural resource, while fiscal policy could makes it possible to reduce the individual incentives to fight (i.e., setting the value of a) and helps the government to encourage economic growth to converge toward its optimal, i.e., non-conflictual, level. We examine this last issue in the next section.

8. Mitigating fighting incentives through fiscal policy

Having explored a first-best scenario, let us now study how the government can reduce conflict incentives thought its fiscal policy instruments in a second-best context. As our emphasis is on the consequences of these policy instruments in the steady state, we can focus on the well-determinate regime LD ($\theta < \alpha$). Indeed, the findings we will highlight apply along the high steady state (H), which is welfare-dominant, in the indeterminate regime HD.

8.1. Military spending

In this subsection, the government provides public investment (G_t) in the military, defense, or law enforcement sectors to make households' rent-seeking efforts less effective. Namely, we assume that the decisiveness of the contest now negatively depends on the public-spending-to-output ratio (G_t/Y_t), i.e., $a = a(G_t/Y_t)$, with $a'(\cdot) < 0$. The public investment is financed by taxation on labor income following a balanced-budget rule

$$G_t = \tau_t w_t L_t, \tag{28}$$

where $\tau_t \in (0, 1)$ is the tax rate. Household i's budget constraint (6) becomes

$$k_{t,i} = q_{t,i} k_{t,i} + (1 - \tau_t) w_{t,i} l_{t,i} - c_{t,i}.$$

In symmetric equilibrium, using Eq. (14), the balanced-budget rule (28) is written as $G_t = \tau_t(1 - \alpha)Y_t$. To close the model we assume that the tax rate adjusts the government's budget constraint, and we consider a constant public-spending-to-output ratio ($G_t/Y_t =: g$), namely,

$$\tau_t = \tau = g/(1 - \alpha), \text{ for any } t.$$

We assume that $g < 1 - \alpha$ to ensure that $\tau \in (0, 1)$.

In this context, the households' labor/rent-seeking tradeoff (18) becomes

$$a(g)\left(\frac{N-1}{N}\right)\left(\frac{\varepsilon R_t}{N}\right)^{1-v} = (1-\tau)N\left(\frac{w_t}{C_t}\right), \tag{29}$$

namely, using (14),

$$a(g)\left(\frac{N-1}{N}\right)\left(\frac{\varepsilon R_t}{N}\right)^{1-v} = N(1-\alpha-g)\left[\frac{\tilde{A}L_t^{\theta-\alpha}}{C_{kt}}\right]. \tag{30}$$

Then, we derive

$$X_t = \bar{L} - \hat{A}\left[\frac{1-\alpha-g}{a(g)R_t^{1-v}C_{kt}}\right]^{1/(\alpha-\theta)}. \tag{31}$$

where $\hat{A}$ is redefined as $\hat{A} = \left(\frac{\varepsilon^{1-v}(N-1)}{\tilde{A}N^{3-v}}\right)^{1/(\theta-\alpha)}$.

From (31), as $\alpha > \theta$, the public spending (as a ratio per unit of output) exerts two conflicting effects on civil conflict.

The first effect is direct: an increase in g makes rent-seeking activities less effective, which reduces the marginal gain from fighting (as $a'(\cdot) < 0$, the left-hand side of 30). Households are then induced to substitute away from rent-seeking activity toward productive activity; hence, there is a negative link between g and X_t.

The second effect is indirect via taxation: an increase in g requires tax increases to balance the government's budget. Such tax increases reduce the net return to productive labor effort ($(1-\alpha)(1-\tau) = (1-\alpha-g)$) and thus decrease the opportunity cost of rent-seeking (the right-hand side of 30). This induces households to substitute away from working activity toward rent-seeking activity; hence, there is a positive link between g and X_t.

To obtain an analytic result, we will use a CES form $a(g) = ag^{-\delta}$ hereafter, where $\delta > 0$ measures the efficiency of public spending on contest decisiveness and $a > 0$ is a scale parameter.

Proposition 4. *The relationship between the civil conflict (X_t) and the spending ratio (g) is described by a U-shaped curve.*

Proof: From (31), we compute $\partial X_t/\partial g \geq 0 \Leftrightarrow g \geq g^m := \delta(1-\alpha)/(\delta+1)$.

Proposition 4 states the direct effect prevails for small values of the public spending ratio ($g < g^m$), while the indirect opportunity-cost-based effect prevails for high values of the ratio ($g > g^m$), as depicted in Figure 3a. At $g = g^m$, the two effects are balanced, and civil conflict is minimized. From a social peace perspective, the government must implement the public spending ratio g^m.

As $L_t = \bar{L} - X_t$, by symmetry, the relationship between labor input and the output ratio (Y_{kt}) and g is described by an inverted U-shaped curve where the maximum is reached at $g = g^m$.

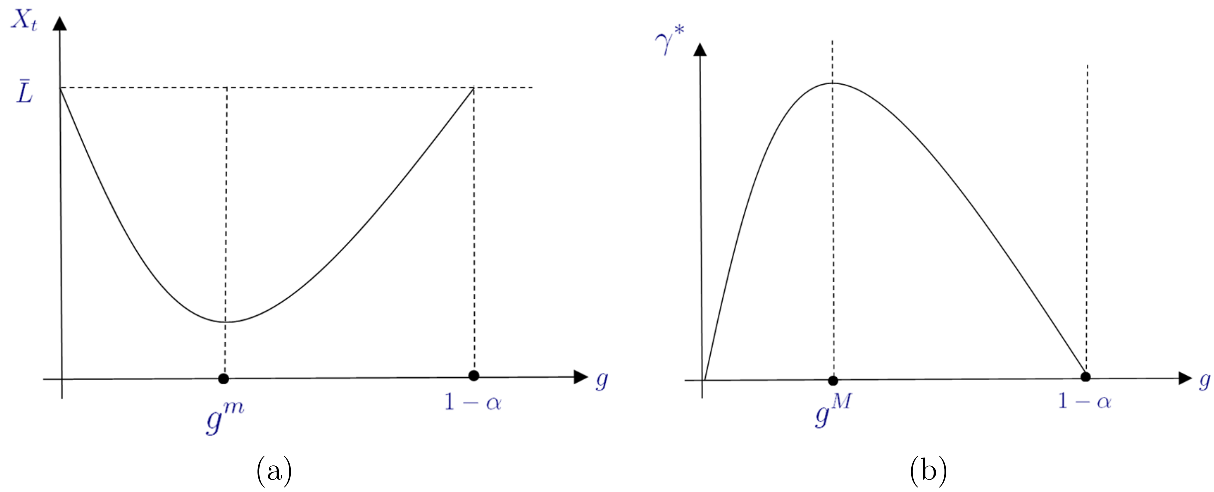


Figure 3: Effect of the public spending ratio (g)

From (16), it follows that

$$Y_{kt} = A\left[\frac{1-\alpha-g}{ag^{-\delta}R_t^{1-v}C_{k,t}}\right]^{\frac{1+\alpha-\theta}{\alpha-\theta}}, \tag{32}$$

where $A := \tilde{A}\hat{A}^{1-\alpha+\theta}$. Using the goods market equilibrium $\dot{K}_t = Y_t - C_t - G_t$, the new reduced form of the model is obtained by Eqs. (13), (17), (21) and (32) (we omit time indexes)

$$\begin{cases} \dfrac{\dot{C}_k}{C_k} = \dfrac{\dot{C}}{C} - \dfrac{\dot{K}}{K} = C_k - \rho - (1-\alpha-g)Y_k, & \text{(a)} \\ \\ \dfrac{\dot{R}}{R} = \eta(\bar{R}-R) - \varepsilon. & \text{(b)} \end{cases} \tag{33}$$

According to the analysis performed in Sections 5 and 6, there is a unique well-determinate steady state where the equilibrium value of the resource is still $R^* = (\eta\bar{R} - \varepsilon)/\eta$ and does not depend on fiscal policy. In contrast, the steady-state economic growth rate (γ^*) nonlinearly depends on g, as stated in the following proposition.

Proposition 5. *The relation between the long-run growth rate (γ^*) and the public spending ratio (g) is described by an inverted U-shaped curve.*

Proof: See Appendix B.

As depicted in Figure 3b, the government can mitigate individual motives for conflict and thus improve economic development via its fiscal policy. By implementing tax-financed public spending in the military and defense sector, it reduce the efficiency of individuals' rent-seeking activities, boosting the labor supply, output and thus economic growth in the long run. This positive effect only prevails for small values of public spending (i.e., $g < g^M$). Indeed, for high values (i.e., $g > g^M$), the tax hikes required to balance the budget reduce the net wages and the opportunity cost of rent-seeking activities.

The normative message is that fiscal policy can be a useful tool to tackle social conflict from a macroeconomic perspective. By setting the spending ratio at $g = g^M$, the government moves the long-term development level closer to that of the social planner, at which social conflict disappears. Therefore, fiscal policy can help overcome the tradeoff between civil conflict and economic development, i.e., solve—at least partially—the conflict-based resource curse.

Our theory showing that public spending can mitigate incentives for civil conflict is supported by empirical evidence. In our specification, public spending reflects investments in the police or military sector intended to reduce the efficiency of rent-seeking activities. Some authors (see, e.g., Fearon and Laitin, 2003; Hendrix, 2010) suggest that military spending is a key factor of state capacity to pacify violent conflict via coercion and policing. Other works (such as Henderson and Singer, 2000; Taydas and Peksen, 2012) note, in contrast, that higher military conflict may increase the risk of conflict due to a crowding-out effect in the government's budget: large military expenditures crowd out social spending, economic growth and citizen welfare, such that they can be induced to initiate violence and conflicts. In our model, the adverse effect of public spending on conflict is not related to a crowding-out mechanism but to an opportunity-cost effect due to the endogenous productive/rent-seeking choice of households.[16]

Beyond issues related to the level of public spending, the consensus that seems to emerge from the empirical literature is that the type of public expenditure is an important variable in determining the effect of fiscal policy on conflict. Fjelde and De Soysa (2009) find that government spending on political goods and trustworthy institutions are more significant predictors of civil peace than are states' coercive capacities. In this way, increased spending on water sanitation, securing basic health needs, or providing a strong education system, for example, could be a better policy than investing in the military sector (Stasavage, 2005). The intuition is that public spending on human capital accumulation promotes economic development, workers' skills, etc., reducing the likelihood of domestic violence (as emphasized by Taydas and Peksen, 2012). Thus, whether to invest in the defense sector or in improving human capital to achieve social peace is an open question in the empirical literature.

[16] This is consistent with empirical support showing that reducing net wages increases the incentive for civil conflict (see, e.g., Fjelde, 2015; McGuirk and Burke, 2020).

8.2. Composition of government spending

In this subsection, we precisely ask which type of spending–military- or human-capital-oriented—is more likely to mitigate civil conflict. To this end, we assume that the government provides two types of expenditures: G_t^M and G_t^H that denote investment in the military sector (as before) and in human capital, respectively. The individual production function is now $y_{t,i} = A_t k_{t,i}^{\alpha} h_{t,i}^{1-\alpha}$, where human capital is augmented by the externality of public spending, namely $h_{t,i} = \bar{K}_t l_{t,i} (G_t^H / Y_t)^{\sigma}$, where $\sigma > 0$ measures the strength of the externality.

Assuming the same hypothesis, the government's budget constraint is written as $g/(1-\alpha) = \tau$, where g is now the total public spending-to-output ratio (i.e., $g = (G_t^H + G_t^H)/Y_t$). The productive/rent-seeking tradeoff (30) becomes

$$a\left(\frac{G_t^M}{Y_t}\right)\left(\frac{N-1}{N}\right)\left(\frac{\varepsilon R_t}{N}\right)^{1-v} = N(1-\alpha-g)\left(\frac{G_t^H}{Y_t}\right)^{\sigma(1-\alpha)}\left[\frac{\tilde{A}L_t^{\theta-\alpha}}{C_{kt}}\right].$$

Both types of government spending are beneficial to social peace: the ratio of military spending (G_t^M/Y_t) reduces the efficiency of rent-seeking effort (because $a'(\cdot) < 0$), while human capital spending (G_t^H/Y_t) increases wages, which raises the opportunity cost of rent-seeking activities. However, there is still the negative effect of total spending due to the tax hikes to balance the budget, reducing net wages (i.e., $(1-\alpha)(1-\tau) = (1-\alpha-g)$).

To determine the best policy choice, we consider military spending to be a (constant) share $\lambda \in [0, 1]$ of total spending and human capital spending to equal the share $1 - \lambda$. That is, $G_t^M/Y_t = \lambda g$ and $G_t^H/Y_t = (1-\lambda)g$. Hence, the new level of civil conflict is written as

$$X_t = \bar{L} - \hat{A}\left[(1-\lambda)g\right]^{\sigma(1-\alpha)/(\alpha-\theta)}\left[\frac{1-\alpha-g}{(\lambda g)^{-\delta} R_t^{1-v} C_{kt}}\right]^{1/(\alpha-\theta)}. \qquad (34)$$

where $\hat{A} = \left(\frac{\varepsilon^{1-v}(N-1)}{\tilde{A}N^{3-v}}\right)^{1/(\theta-\alpha)}$. Following the same reasoning as in the above subsection, we can establish the following proposition.

Proposition 6. *There is a critical value $\hat{\lambda} \in (0, 1)$ such that $\partial X_t/\partial\lambda < 0$ if $\lambda \in [0, \hat{\lambda})$ and $\partial X_t/\partial\lambda \geq 0$ if $\lambda \in [\hat{\lambda}, 1]$.*

Proof: See Appendix B.

Proposition 6 shows that the relationship between the level of civil conflict (X_t) and λ describes a U-shaped curve with a minimum at $\lambda = \hat{\lambda}$, as depicted in Figure 4. The intuition is as follows. An increase in the share of the budget devoted to military spending (i.e., λ rises) implies two opposite effects.

First, the marginal gain from fighting decreases as the efficiency of rent-seeking efforts declines; hence, households are induced to substitute away from rent-seeking effort toward labor-productive effort (*direct effect*). Second, an increase in λ reduces the public investment in human capital and thus slows wage growth, reducing the opportunity cost of conflict; hence, households are induced to substitute away from labor productive effort and toward rent-seeking effort (*crowding-out effect*). For a high level of λ (i.e., $\lambda > \hat{\lambda}$), the reduction in human capital investment is so large that the crowding-out effect prevails over the direct effect. For a small level (i.e., $\lambda < \hat{\lambda}$), the reverse is true.

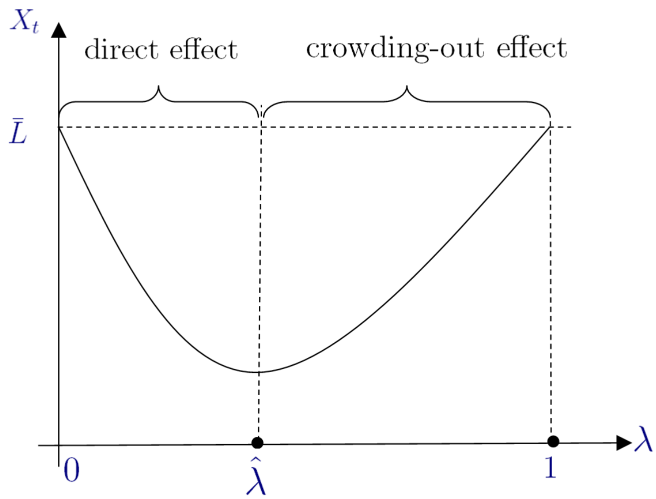


Figure 4: Effect of λ on civil conflict (X_t)

This result has an interesting policy implication. If the government follows a social peace objective, it is not optimal to invest either in the defence sector or in human capital. Because of the crowding-out effect of military spending, the government must adopt a mixed spending program, consisting of investments in both dimensions. This implication provides a theoretical basis for the empirical debates surrounding the effectiveness of public spending and state capacity in mitigating civil conflicts. Indeed, in our model, both military and social spending are effective in reducing rent-seeking incentives. This is why the government must prioritize a mixed spending program, rather than investing heavily in one of the two dimensions.

9. Concluding remarks

The interplay among natural resources, civil conflicts, and economic development is investigated in a large empirical literature but rests on weak theoretical foundations. Our contribution is to address this issue by introducing rent-seeking behavior regarding the seizure of a renewable resource into an endogenous growth model.

This simple setup offers at least two theoretical explanations for the mixed empirical results on the natural-resources/civil-conflict nexus (as evidenced by the meta-analyses of Ross, 2015; O'Brochta, 2019; Vesco et al., 2020). First, the short- and long-term trajectory of economic development may be indeterminate due to the destructive effect of civil conflicts, so the same stock of resources may be compatible with a long-term situation with substantial conflict and little growth (equilibrium L) or a more peaceful growth-friendly situation (equilibrium H). In this context, the link between the natural resource and conflict is mainly fueled by household expectations about the future level of conflict or growth. Second, fiscal policy may also explain cross-country heterogeneities: countries where the government spends a lot (or little) on the military sector experience high levels of civil conflicts. Similarly, the level of conflict will be high if the government budget is mainly devoted either to military spending or social spending. Such testable predictions could be investigated in future econometric works.

Against this background, guiding households' expectations seems crucial to reduce the risk of conflict in resource-rich countries. The political science literature has empirically emphasized that agents' expectations about levels of civil conflict are affected, among other things, by third-party interventions, mediations, or diplomatic efforts (see, e.g., Paris, 2004; Regan and Aydin, 2006). All these aspects could be serve as policy tools for the economy to escape the poverty trap by guiding households' expectations toward the high-growth/low-conflict steady state. Methodologically, introducing such features in general equilibrium models could be worthy of future research.

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Appendix A. Steady state(s)

Proof of proposition 1.

Let $\varepsilon = 0$**.** In this case, we have $X = 0$, i.e., $L = 1$, and the aggregate production function (20) is written as $Y_{kt} = \tilde{A}K_t$. Hence, system (22) becomes

$$\begin{cases} \dfrac{\dot{C}_k}{C_k} = C_k - \rho - (1-\alpha)\tilde{A}, & \text{(a)} \\ \\ \dfrac{\dot{R}}{R} = \eta(\bar{R} - R). & \text{(b)} \end{cases}$$

The steady states are $(R^*, C_k^*) \in \{(\bar{R}, \rho + (1-\alpha)\tilde{A}), (0, \rho + (1-\alpha)\tilde{A}), (0,0), (\bar{R}, 0)\}$. By linearization in the neighborhood of each steady state, the system behaves according to $(\dot{C}_k, \dot{R}) = \mathbf{J}(C_k - C_k^*, R - R^*)$, where $\mathbf{J}$ denotes the Jacobian matrix evaluated in the steady state. The reduced-form system incudes one predetermined variable (the natural resource R), and one jump variable (the consumption ratio $C_k = C/K$). We compute

$$\mathbf{J} = \begin{pmatrix} 2C_k^* - \rho - (1-\alpha)\tilde{A} & 0 \\ 0 & \eta\bar{R} - 2\eta R^* \end{pmatrix},$$

hence, the two eigenvalues are $\lambda_1 = 2C_k^* - \rho - (1-\alpha)\tilde{A}$ and $\lambda_2 = \eta\bar{R} - 2\eta R^*$. First, if $C_k^* = 0$, the eigenvalue related to the jump variable (consumption ratio) is negative ($\lambda_1 = -\rho - (1-\alpha)\tilde{A} < 0$) such that the steady state is indeterminate. Second, if $R = 0$, the eigenvalue related to the predeterminate variable (the natural resource) is positive, giving rise to an explosive process. Third, for $(R^*, C_k^*) = (\bar{R}, \rho + (1-\alpha)\tilde{A})$, we have $\lambda_1 = \rho + (1-\alpha)\tilde{A}) > 0$ and $\lambda_2 = -2\eta\bar{R} < 0$, hence, the saddle-path property.

Consequently, the unique well-determinate steady state is then $(R^*, C_k^*) = (\bar{R}, \rho + (1-\alpha)\tilde{A})$ that we called P_0.

Let $\varepsilon > \bar{\varepsilon}$**.** In this case, there is still no social conflict, and hence $X = 0$ and $L = 1$. Thus, system (22) becomes

$$\begin{cases} \dfrac{\dot{C}_k}{C_k} = C_k - \rho - (1-\alpha)\tilde{A}, & \text{(a)} \\ \\ \dfrac{\dot{R}}{R} = \eta(\bar{R} - R) - \varepsilon. & \text{(b)} \end{cases}$$

The steady states are $(R^*, C_k^*) \in \{(\hat{R}, \rho + (1-\alpha)\tilde{A}), (0, \rho + (1-\alpha)\tilde{A}), (0,0), (\hat{R}, 0)\}$, where $\hat{R} = (\eta\bar{R} - \varepsilon)/\eta < 0$. The jacobian matrix is written as

$$\mathbf{J} = \begin{pmatrix} 2C_k^* - \rho - (1-\alpha)\tilde{A} & 0 \\ 0 & \eta\bar{R} - 2\eta R^* - \varepsilon \end{pmatrix}.$$

As before, if $C_k^* = 0$, the steady state is indeterminate since the eigenvalue related to the consumption ratio ($\lambda_1 = -\rho - (1-\alpha)\tilde{A}$) is negative. Considering the point $(\hat{R}, \rho + (1-\alpha)\tilde{A})$, the eigenvalues are $\lambda_1 > 0$ and $\lambda_2 = \varepsilon - \eta\bar{R} > 0$, characterizing an unstable dynamics. Considering the point $(0, \rho + (1-\alpha)\tilde{A})$, we have $\lambda_1 > 0$ and $\lambda_2 < 0$, hence, the saddle-path property.

Consequently, the unique well-determinate steady state is then $(R^*, C_k^*) = (0, \rho + (1-\alpha)\tilde{A})$ that we called P_1. □

Proof of Proposition 2. Let $0 < \varepsilon < \bar{\varepsilon}$. Using (20) and (22.a), the $\dot{C}_k = 0$ locus leads to the following relationship:

$$\frac{\dot{C}_k}{C_k} = C_k - \rho - (1-\alpha)Y_k = 0,$$
$$\Leftrightarrow R = \psi(C_k) =: \left\{ \frac{1}{C_k} \left[\frac{C_k - \rho}{(1-\alpha)A} \right]^{1/(1+\mu)} \right\}^{1/(1-v)}. \tag{A.1}$$

where $1 + \mu = (\theta + 1 - \alpha)/(\theta - \alpha)$.

There are two cases, depending on the sign of $\theta - \alpha$.

First: $\theta < \alpha \Rightarrow 1 + \mu < 0$. In this case, ψ describes a continuous decreasing mapping on $C_k \in (\rho, +\infty)$, where $\psi(\rho) = +\infty$ and $\psi(+\infty) = 0$, as depicted in Figure 1a. Hence, according to the intermediate value theorem, there is one and only one value $C_k^E > 0$ such that $\psi(C_k^E) = R^* = (\eta\bar{R} - \varepsilon)/\eta > 0$. This value defines the unique steady state called E. The steady-state economic growth rate is positive, since the discount rate is small enough (formally $\rho \to 0^+$), because $\gamma^E = \alpha A (R^*)^{(1+\mu)(1-v)} (C_k^E)^{1+\mu} - \rho$.

Second: $\theta > \alpha \Rightarrow \mu + 1 > 0$. In this case, using (A.1), we compute

$$\psi'(C_k) > 0 \Leftrightarrow C_k < \hat{C}_k := \rho \left(\frac{1+\mu}{\mu} \right).$$

Namely, ψ describes an inverted U-shaped curve on $C_k \in (\rho, +\infty)$, with $\psi(\rho) = \psi(+\infty) = 0$, as depicted in Figure 1b. The maximum is reached at $\hat{R} = \psi(\hat{C}_k)$. We ensure that $\hat{R} > R^*$ for any $\varepsilon \in (0, \bar{\varepsilon})$, provided that ρ is small enough. Consequently, according to the intermediate value theorem, there are two and only two critical levels $C_k^L \in (\rho, \hat{C}_k)$ and $C_k^H \in (\hat{C}_k, +\infty)$, such that $\psi(C_k^L) = \psi(C_k^H) = R^*$. These defines steady states L and H, respectively. □

Proof of proposition 3. Let $0 < \varepsilon < \bar{\varepsilon}$. Using (22), the Jacobian matrix evaluated at steady state s is

$$\mathbf{J}^s = \begin{pmatrix} CC^s & CR^s \\ 0 & RR^s \end{pmatrix},$$

where

$$CC^s = C_k^s - (1+\mu)(C_k^s - \rho),\ CR^s = -(1+\mu)(1-v)\frac{C_k^s}{R^s}(C_k^s - \rho),\ RR^s = \varepsilon - \eta\bar{R}. \quad \text{(A.2)}$$

Hence, the two eigenvalues are $\lambda_1^s = C_k^s - (1+\mu)(C_k^s - \rho)$ and $\lambda_2^s = \varepsilon - \eta\bar{R}$.

Regime LD (i.e., $1+\mu < 0$). In this case, as $C_k^E > \rho$, it follows that $\lambda_1^E > 0$ and $\lambda_2^E < 0$. Hence, E is a saddle point (well-determinate).

Regime HD (i.e., $1+\mu > 0$). In this case, we have $CC^s > 0 \Leftrightarrow C_k^s < \hat{C}_k$. According to Proposition 1, as $C_k^L < \hat{C}_k$, we have $\lambda_1^L > 0$ and $\lambda_2^L < 0$; hence, L is a saddle point (well-determinate). In contrast, as $C_k^H > \hat{C}_k$, we have $\lambda_1^H < 0$ and $\lambda_2^H < 0$; hence, H is stable (indeterminate). □

Appendix B. Fiscal policy

Proof of Proposition 5. From (32) and (33), the steady-state consumption ratio (C_k^*) is given by an implicit function $\Psi(C_k^*, g) = 0$, where

$$\Psi(C_k, g) = C_k - \rho - (1-\alpha-g)Y(C_k, g), \quad \text{(B.1)}$$

with

$$Y(C_k, g) = A\left[\frac{1-\alpha-g}{ag^{-\delta}(R^*)^{1-v}C_{k,t}}\right]^{\frac{1+\alpha-\theta}{\alpha-\theta}}. \quad \text{(B.2)}$$

From (B.1), we compute

$$\partial_2\Psi(C_k, g) = Y(C_k, g)\left[1 - (1-\alpha-g)\frac{\partial_2 Y(C_k, g)}{Y(C_k, g)}\right]. \quad \text{(B.3)}$$

From (B.2), we derive, using $g^m = \delta(1-\alpha)/(1+\delta)$,

$$\frac{\partial_2 Y(C_k, g)}{Y(\ C_k, g)} = \left(\frac{1+\alpha-\theta}{\alpha-\theta}\right)\frac{g^m - g}{(1-\alpha-g)(\delta+1)g}.$$

Introducing in (B.3), it follows that

$$\partial_2\Psi(C_k, g) = Y(C_k, g)\left[1 - \left(\frac{1-\theta+\alpha}{\alpha-\theta}\right)\frac{g^m - g}{(\delta+1)g}\right].$$

From (B.1), according to the implicit function theorem, we have

$$\frac{\partial C_k^*}{\partial g} = -\frac{\partial_2 \Psi(C_k^*, g)}{\partial_1 \Psi(C_k^*, g)} = -\frac{Y(C_k^*, g)}{\partial_1 \Psi(C_k^*, g)} \left[1 - \left(\frac{1-\theta+\alpha}{\alpha-\theta}\right) \frac{g^m - g}{(\delta+1)g}\right]. \tag{B.4}$$

Finally, let us focus on the economic growth rate along the balanced-growth path. Given the Keynes-Ramsey rule, the steady-state growth rate is $\gamma^* = \alpha Y_k(C_k^*, g) - \rho$. In the steady state, we have, using (B.1), $Y(C_k^*, g) = \frac{C_k^* - \rho}{1-\alpha-g}$. Hence,

$$\frac{\partial \gamma^*}{\partial g} = \frac{1}{(1-\alpha-g)^2} \left[\frac{\partial C_k^*}{\partial g}(1-\alpha-g) - C_k^* + \rho\right],$$

namely, using (B.4),

$$\begin{aligned}
\frac{\partial \gamma^*}{\partial g} \geq 0 &\Leftrightarrow -\frac{Y(C_k^*, g)}{\partial_1 \Psi(C_k^*, g)}(1-\alpha-g) \left[1 - \left(\frac{1-\theta+\alpha}{\alpha-\theta}\right) \frac{g^m - g}{(\delta+1)g}\right] - C_k^* + \rho \geq 0, \\
&\Leftrightarrow -\frac{C_k^* - \rho}{\partial_1 \Psi(C_k^*, g)} \left[1 - \left(\frac{1-\theta+\alpha}{\alpha-\theta}\right) \frac{g^m - g}{(\delta+1)g}\right] - C_k^* + \rho \geq 0, \\
&\Leftrightarrow \left(\frac{1-\theta+\alpha}{\alpha-\theta}\right) \frac{g^m - g}{(\delta+1)g} - 1 - \partial_1 \Psi(C_k^*, g) \geq 0.
\end{aligned}$$

From (B.1), we have $\partial_1 \Psi(C_k^*, g) = 1 + (1-\alpha-g)Y(C_k^*, g)/C_k^*$, namely, at steady state $\partial_1 \Psi(C_k^*, g) = 1 + (C_k^* - \rho)/C_k^*$. Therefore, we obtain

$$\frac{\partial \gamma^*}{\partial g} \geq 0 \Leftrightarrow \left(\frac{1-\theta+\alpha}{\alpha-\theta}\right) \frac{g^m - g}{(\delta+1)g} - 2 - \frac{C_k^* - \rho}{C_k^*} =: \zeta(g) \geq 0.$$

We have $\zeta(0) = +\infty$, $\zeta(g^m) < 0$, and $\zeta'(\cdot) < 0$. As $\zeta(g)$ is a continuous mapping on $(0, g^m]$, according to the intermediate value theorem, there is a unique critical value, denoted by $g^M \in (0, g^m)$, such that $\zeta(g) > 0$ if $g \in (0, g^M)$ and $\zeta(g) \leq 0$ if $g \in [g^M, g^m)$.

Consequently, the link between γ^* and g is described by an inverted U-shaped curve, with a maximum at g^M. □

Proof of Proposition 6. From (34), we compute

$$\frac{\partial X_t}{\partial \lambda} = \hat{A} g^{\frac{\sigma(1-\alpha)}{\alpha-\theta}} \left[\frac{1-\alpha-g}{g^{-\delta} R_t^{1-v} C_{kt}}\right]^{\frac{1}{\alpha-\theta}} (1-\lambda)^{-1+\frac{\sigma(1-\alpha)}{\alpha-\theta}} \lambda^{-1+\frac{\delta}{\alpha-\theta}} \left[\frac{\sigma(1-\alpha)+\delta}{\alpha-\theta}\right] (\lambda - \hat{\lambda}),$$

where $\hat{\lambda} = \delta/[\sigma(1-\alpha)+\delta] \in (0,1)$. □

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