Fundamental Resource Curse

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Abstract

This paper proposes a fundamental model of the resource curse problem. Outcomes, such as the formation of coalitions – groups of financiers who engage armies to gain control of the resources – as well as the size of the corresponding armies, are derived endogenously from the economy's fundamentals. The model predicts that inefficient outcomes – in the form of either conflict or a deterrence army solution – will always occur as long as the value of natural resources to capture is positive and the opportunity cost of time – which partly determines soldiers' wages – is finite.

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1 Introduction

This paper proposes a fundamental model of the resource curse problem. We first elaborate on why we see our approach as 'fundamental' and then proceed to describe how we apply it to the natural resource curse.

We label our approach fundamental for the following reasons. First, it relies exclusively on economic first principles (such as the economy's endowments and technology, its population size and skills and the wealth distribution, among other aspects). In particular, we do not assume any institutional arrangement – such as a democracy or a dictatorship – nor an institutional outcome – such as peace or fair elections. Instead, and following the contributions of H. I. Grossman [9], [7], [8], Grossman and Kim [10] and Stergios Skaperdas [20], among others, we take the view that institutions and institutional outcomes (such as the rule of law or the enforcement of property rights) are equilibrium outcomes of an underlying economic problem that we seek to uncover. That is, if property rights are enforced, say, it ought to be the case that not having them enforced was costly enough to some group of agents in the economy so that they were able to successfully engage a 'security force,' being all the while well aware that, once empowered and armed, incentive compatibility requires that such security force be paid some rents that stave off the temptation of stealing. (See H.I. Grossman [9]).

We see this institutional idea best described by the motto "one dollar, one vote." Thus, and while not specifically looking at the outcome of elections, we pursue the notion that economic allocations have to be robust to the desire by economically powerful agents of undoing them. Therefore, our approach adds to the description of the fundamentals of the economy the description of the *technologies for the control of resources*, such as bribing or the engaging an armed force to seek control of the property of others. These technologies can be used by any agent or group of agents in the economy, as long as they have the means to do so. For this purpose, we also allow agents to form groups – which we call coalitions – in order to pool resources to accomplish a common goal (for example, that of paying the wage bill of soldiers in an army). The formation of coalitions is also an endogenous outcome of the analysis.

An equilibrium in our economy is subject to the usual individual rationality conditions. However, it must also be robust to deviations based on usage of the technologies for the control of resources. If a given allocation is an equilibrium, it must be the case that no agent or group of agents has the desire or the means to (possibly further) engage the technologies for the control of resources and get to a different allocation. It immediately follows that equilibrium allocations will be those allocations preferred by the economically powerful, net of the costs required to attain them.[1]

The analysis thus provides a mapping from the economic fundamentals and the technologies for control of resources into equilibrium outcomes. The latter include the description of an allocation (consumption, production, and so on), but also of the number and composition of coalitions, if any, and of the intensity of usage of the technologies for the control of resources. It thus also provides a description of institutional outcomes effectively prevailing in equilibrium (for example of whether or not property rights are respected or whether there are attempts – in equilibrium – to grab other people's resources). Examination of all the equilibria provides an answer to the question of whether inefficient equilibria are inevitable. In other words, does inefficiency (in the form of armed conflict, deterrence armies, bribing of public officials and so on) necessarily follow from the fundamentals of the economy? We believe this approach provides an answer to the question posed by Lucas (1988) concerning the elements in the "nature of a country" that lead to inefficient outcomes.

As mentioned, our focus is on the economics of the problem: how resources are allocated across sectors and people and the intensity of usage of the technologies for the control of resources. We believe that, in doing so, we are effectively computing feasible bounds on institutions. Consider as an example a vote on redistributive taxation. If redistributive taxation were to both pass an election *and* be implemented, it would mean that the rich would find it too expensive to bribe the tax collecting officials. Instead of examining the properties of a given election mechanism whose results could be overturned by bribing, we directly examine whether the rich would try to deter income redistribution in the presence of a bribing technology. If that were not the case (if the rich accepted income redistribution), then it would also trivially follow that redistributive taxation

[1] Here, we differ from Acemoglu and Robinson [2] by assuming that the only power that is relevant to accomplish control of resources is economic power; that having the means to engage control technologies is the only source of (*de facto*) power, and that *de jure* power is nothing more than the manifestation of economic power.

would be approved by universal voting. But, once the technologies for the control of resources are considered, the converse need not follow and is thus uninformative about the effective economic outcomes in the economy. In this sense, we see the actual political process as a black box that need not be directly examined: the possibility of side-payments to "correct" the outcome of, say, the voting process is all that is needed to implement the preferred allocation from the point of view of the group with greatest economic power. In the context of election outcomes, this is the "theorem" our environment has to offer, extremely dissimilar from, say, the median voter result. More generally, we believe that, by focussing directly on the underlying economics of the problem, while also including the technologies that allow agents to manipulate outcomes in their favor, is an effective way of endogeneizing institutions. Once the set of all feasible allocations (including the usage of technologies for the control of resources) is characterized, then one can take a step back and ask the next question of finding a suitable institutional environment that would support given equilibria.[2]

Finally, and previous to the description of the model, we clarify our usage of the resource "curse." We see natural resources as a "curse" whenever their discovery or existence leads to nonutility enhancing usage of resources, such as in military activities. Thus, we do not abide by the more conventional meaning where a curse occurs whenever natural resources lead to a reduction in gross domestic product (GDP). In our model, generally, expenditures on military activities will never exceed the flow of natural resources. But although one could claim that GDP does not decline, its composition changes dramatically in that there is an engagement of wasteful activities. One could hardly argue that these are utility enhancing. This type of potential misclassification and measurement is well known to be a shortcoming of GDP accounting methods.

In our model of an economy rich in natural resources, we consider a population of size N, an exogenous pool of income of size Y, an army technology that can be used to seize resources and which maps the armed forces in the economy into a probability of success (a contest success function), and income k associated with a person's human capital and

[2] As Saint-Paul [19] put it in his review of Persson and Tabellini [15] and Drazen's [5] books on Political Economy, the new Political Economy "typically generates predictions about how policies that are actually pursued will depend on the distribution of agent's incomes and endowments, and *political institutions*." (my italics) The approach described here is an attempt at endogeneizing institutions and institutional outcomes from economic fundamentals.

which cannot be taken away from the individual. At first, agents can freely and costlessly associate to pool income in order to finance the wage bill of an army. For analytical tractability, we consider linear utility. All equilibria of this game are analyzed. Absent other frictions, the model predicts that there will always be inefficient activities, either in the form of identical multiple armies fighting each other or in the form of a deterrence army in charge of existing resources. Army sizes are uniquely determined. If competing armies operate, their number will always exceed two. There are multiple equilibria in the sense that, *ex ante*, it is not possible to pin down the identity of the agents who will be soldiers and those who will pay their wage bill, for example. Inefficient outcomes only disappear, in the limit, provided k – the opportunity cost of time – goes to infinity; then, engaging an army becomes too expensive. In the limit, the number of competing armies goes to two but the number of soldiers engaged converges to zero. Therefore, in a contemporaneous comparison across countries, developed countries (those with higher k) should be virtually conflict free while still having a significant amount of wasteful expenditures, whereas developing countries (with low k) should be plagued by conflict or else have sizable deterrence-type armed forces seeking to retain control of Y. Thus, while in our model large pools of exogenous income are always a curse (because they lead to a proportional amount of wasteful expenditures), manifestation of this curse will vary greatly across countries with different k.[3] We see this frictionless environment as a natural and useful benchmark with which to compare other settings.

Assuming costly access to finance has several important implications. First, army sizes will generally differ, reflecting heterogenous financial wealth. Further, binding financial constraints restrict the identity of the individuals financing armies to the set of wealthy people in the economy: the poor will be either soldiers or else individuals not directly involved in the armed quest for Y. If successful attempts at taking control of Y took place in the past, it is unreasonable to expect financial constraints to affect this group of agents. Thus, if one were to observe unstable control over a large pool of

[3] We note that the result that natural resources lead to a proportional increase in wasteful activities is not disproved nor confirmed by existing empirical work. Empirical studies, such as Sacks and Warner [18] and Gylfason [11], have generally examined the effects of natural resources on GDP growth rates and disregarded GDP composition. While in conflict areas the predictions of the model are trivially validated, for our model to fit the real world a country such as Norway would have to have seen a large increase in lobbying expenditures following the discoveries of oil. Establishing these facts is part of our ongoing research agenda.

resources, this would indicate that the army technology is less productive than previously assumed. It could be that geographical conditions (accessibility to the resources, for example) make it impossible to retain control of Y with probability one irrespective of the army size engaged; or it could be that large groups of armed soldiers become unmanageable in the quest for resources. We take the latter view and propose a modified contest probability function where the productivity of one's own armed forces is lower than before.[4] Under this specification, it turns out that full deterrence is no longer optimal. Whatever the setting, be it under the possibly partial deterrence army or under armed conflict among multiple armies, inefficiency use of resources follows from the fact that Y is positive and k is finite. Therefore, inefficiency in the use of resources is in the "nature of countries" with large pools of exogenous income and where the opportunity cost of time is not very high.

Related Literature This paper is closest to the cited contributions of Grossman, Grossman and Kim, and Skaperdas, where institutions and institutional outcomes are endogeneized.[5] The approach proposed here is more general in that it starts one step back and allows for endogenous group formation (coalitions). We find this additional step natural and necessary in order to relate outcomes to the fundamentals of the economy: by endogeneizing group formation, we can be certain that the existence of, say, a dictator or of a small set of powerful groups is based on economic fundamentals and thus examine also the conditions for these groups to be demoted or to stay in power rather than relying on a *ad hoc* preexisting power structure. The current work is less general in that specific functional forms are used and the scope of the problem is more narrowly defined (on the resource curse).

In Economics, the explanations for the resource curse often rely on reasons for why governments fail to take a set of appropriate actions that would control – if not eliminate – potential negative side effects of the resource wealth. These include a decline in the terms of trade because of an increase in exports, "imported" instability from inter-

[4] If one were to accept that common ethnicity is a force for cohesion, for example, this would be captured by the modified probability contest function.

[5] Skaperdas [20] is the closest. He examines equilibria arising from the interaction of two agents who can devote resources to joint productive activities or to military activities aimed at seizing control of the former.

national commodity markets, the incapacity of the primary sector to generate income growth in other sectors as multinationals would take profits out of the country, as well as the "Dutch disease" – an increase in the real exchange rate coupled with a sucking up of labor and capital toward the resource sector, raising the production costs of agriculture and manufacturing, reducing their exports and raising the costs of nontradeable goods.[6] These explanations all rely on the inability of the government and even private individuals to get insurance against price and exchange rate changes (and, occasionally, on other inadequate behavior of the government such as its inability to tax multinationals and appropriate the resource wealth). No basic reason is offered to justify such suboptimal behavior. Because the discovery of natural wealth is identical to an increment in a country's endowments – yet of a free disposal nature – it is difficult to explain the existing poor performance of resource rich countries on the basis of standard economic arguments – at least without invoking some negative externality or other reasons for market malfunctioning. Thus, our starting point deviates from the standard approach by considering directly the reasons for market malfunction – represented in attempts to steal resources – and thus not accepting that property rights will continue to be enforced after the discovery of a large pool of natural resources.

In this vein, our approach also has points of contact with the rent-seeking literature. There, a typical model involves a fraction of the agents in the economy – rent-seekers – devoting themselves to stealing the income of the remainder – entrepreneurs (see, e.g. Acemoglu [1] and Torvik [23]). It is often the case here that exogenous institutions and institutional quality are important factors in determining whether or not a country grows, and also in modulating the effects of resource discovery, as in Mehlum, Moene and Torvik [14]. As indicated above, our goal is to provide bounds on institutions defined by the economic power of agents or groups of agents.

There is also a vast Political Economy literature on the resource curse, but whose arguments are often poorly formalized, if at all. It likewise assumes that resource wealth is associated with elements of governmental incapacity. (See Ross [17].) A formal analysis of how a large pool of resources affects the interaction of incumbent leaders or prevailing institutions with the remainder of society is offered in Tornell and Lane [22], Robinson,

[6] See Ross [17] and references therein for a survey.

Torvik and Verdier [16], Hodler [12], Caselli [3] and Caselli and Cunningham [4]. As mentioned, we seek to further the microfoundations of political configurations on economic power; thus, we purposefully ignore existing structures such as a government – at least until a "government" proves to be a player worth identifying as such in the general game of maximizing one's income subject to the constraints imposed by others.[7] Our contributions is perhaps closest to Hodler, who examines the effects of a resource boom in fractionalized economies where a given number of groups fight over the natural wealth. Our model has quite a few points of contact with his, yet we endogeneize the number of groups fighting over the resources. We also prefer to ignore fractionalization (for example based on ethnic differentiation) as a starting point so as to seek a benchmark where – at least initially – it is only economic forces affecting resource allocation.[8]

The paper is organized as follows. We present the main model in the next section. In section 3, we introduce our modified contest success function and examine its implications. In section 4, we discuss extensions of our framework and in 5 we conclude.

2 A Fundamental Model of the Natural Resource Rich Economy

There is a population of size N. Each period, there is a resource flow of Y. This is exogenous income associated with natural resources. Other income sources are as follows. There is a stock of public capital K which measures infrastructure quality in the country. This infrastructure gives a lower bound on the income that individuals may get. For simplicity, we ignore endogenous labor supply and instead assume that, if an individual decides to work, we will get k units of the consumption good. Income k cannot be taken away from any individual, it is associated with a person's human capital.[9]

[7] We do not argue that governments should be ignored but simply that, if they are to be included, the need to individualize one of the players as a government should come with arguments for why such a player should have different costs/benefits in trying to get control of Y compared to other players

[8] We discuss ethnicity in section 3.

[9] Under the assumption of linear utility, below, and absent frictions such as lack of access to the capital market, discussed later, the wealth distribution has no bearing on the results. Thus, at this point, assuming that individuals are identical regarding their outside income comes without loss of generality.

There is only one good in the economy, and both the resource flow Y and individual production k are measured in the same units. We expect Y to be large compared to k, so that individuals have a strong incentive to try to get hold of Y. We consider later what happens as k grows large, which we interpret as the process of development.

Utility is identical across individuals and linear in consumption:[10]

$$u(c) = c.$$

Technologies for control of resources are functions $f \in F$. We consider one, only, the building of an army. Armies require people and guns. Consider army i, engaging S_i soldiers and G_i guns. The output of the army is given by $A_i = f(S_i, G_i)$, where $f(\cdot)$ is Leontieff:

$$A_i = \min\{S_i, G_i\}.$$

A gun uses g units of the consumption good. Because of the Leontieff technology, it follows that, optimally,

$$S_i = G_i = A_i.$$

The probability of securing control of natural resources p is given by the outcome of a contest success function (csf),[11] as follows. Let n denote the number of armies in the economy, and $\{A_j\}_{j=1}^n$ be the list of army sizes in the economy. Then,

$$p_i \equiv p\left(A_i; \{A_j\}_{j=1}^n\right) = \frac{A_i}{\sum_j A_j}, \; p \in [0,1].$$

One important feature of this function is symmetry: armies of identical size have the same probability of getting control of Y. Further, probability p_i is increasing in the size of army i and decreasing in the size of the *sum* of the remaining armed forces. Probability p_i is also concave in A_i. Importantly, $p_i(A_i, \{0, ..., 0, A_i, 0, ..., 0\}) = 1$. Thus, if only one army is in place, it will get control of the natural resources with probability one. In the absence of frictions, this property of the contest function makes the building of at least one army inevitable. We return to this point below.

A soldier of army A_i who gets wage payment w_i has expected utility of $p_i w_i$. The outcome in case of army defeat is thus normalized to zero.[12]

[10] Linear utility was used for it allows for closed form solutions.

[11] See Skaperdas [21].

[12] Our results would go through as long as the utility outcome under battle loss were less than in the case of military success, w_i, perhaps due to injury in battle.

Individuals in the economy may organize themselves into coalitions with the sole purpose of pooling resources to engage an army – and pay for its guns and soldiers. Each coalition will sponsor one army.[13] Thus, there will be as many coalitions as there are armies and we will refer to the number of one or the other interchangeably.

Next, we tackle the case where natural resources have not been claimed by anybody in the economy. This situation resembles a new discovery of such resources where perhaps armed control has not yet been displaced to guard Y. In section 2.2 below, we consider the alternative scenario where the resources have been successfully claimed by an individual or coalition.

2.1 Unclaimed Natural Resources

Timing This is an extensive game with a finite horizon. In the first stage, people choose whether they wish to join a coalition. In stage 2, coalitions form armies by making wage offers to other people in the population who have not joined a coalition. Members of a coalition work and collect income k which they use to pay for guns and salaries. In the third stage, fighting occurs (provided there is more than one army), and payoffs are realized.

Equilibrium Equilibria in our economy will be subgame perfect Nash-equilibria of the dynamic game described above.

Armed Conflict We proceed to analyze the equilibria of the game by backward induction.

Stage 3 At the last stage of the game, if more than one army has been hired, there is fighting over Y and payoffs follow. If only one army has been engaged, there is no fighting and the existing army takes control of Y. If no army has been engaged, proceeds of $y \equiv Y/N$ are given to each agent.

Stage 2 At stage 2, individuals who did not get matched with others in coalitions may receive wage offers from coalitions formed in stage 1. They have the option of accepting

[13] As discussed below, this carries no loss of generality.

and working as soldiers, or rejecting. If they reject, they will receive income k from their human capital at stage 3; further, if no coalitions formed in stage 1, they would also receive the additional *per capita* income y from natural resources in stage 3. If not made a wage offer, an individual simply works and receives k in the following period, possibly added of y in case the peaceful outcome occurs.

Expected utility of soldiers fighting for coalition i is $p_i w_i$. We assume that there are many more individuals unattached to coalitions than wage offers so that those who receive wage offers lack bargaining power when negotiating with coalitions: they take the wage as given. Therefore, wage offers exactly compensate soldiers for their opportunity cost of fighting.

What would be the wage offer that coalitions would have to make soldiers in order for them to accept fighting? If other soldiers accept fighting, this implies that only the coalition getting hold of Y will benefit from natural resources. The opportunity cost of fighting is then income k, with a certainly equivalent of k/p_i. Given the assumption of no bargaining power on the part of noncoalition members, this wage offer is accepted in equilibrium.[14]

Consider now existing coalition i, formed of N_i members who have engaged A_i soldiers and bought A_i guns. Say this coalition pays w_i to its soldiers.[15] Then, the total resource cost to the coalition from engaging an army equals

$$C_i = gA_i + w_i A_i = (g + w_i) A_i. \tag{1}$$

The objective of the coalition is to maximize the expected *per capita* benefit of its members, net of operational and financial costs. We assume that membership is the least expensive form of financing and so coalitions take on members as the means to finance their military operations.[16] The opportunity cost of funds is normalized to zero,

[14] We note that, absent bargaining power on the part of noncoalition members, the situation where *all* noncoalition members would reject a wage offer so that peace would prevail is not an equilibrium. Absent bargaining power, individuals could claim the opportunity cost of fighting as a salary. If the candidate equilibrium were one where all noncoalition members reject wage offers, then the opportunity cost of peace would be $k + y$. But then any coalition could easily offer $k + y + \varepsilon$, for $\varepsilon > 0$ arbitrarily small; this offer would be accepted and it would give the coalition control of Y. Thus, collective rejection of a wage offer that compensates for the opportunity cost of fighting cannot be part of the equilibrium.

[15] We assume that the entirety of the wage is paid upfront to soldiers. Results would remain qualitatively unchanged if only a fraction $\delta > 0$ were paid upfront and the remaining $(1 - \delta) w_i$ of the soldier's compensation were paid in case of victory.

[16] Organizations are effectively profit maximizing firms and thus face a pecking order of financial costs.

allowing us to disregard financial costs in the coalition's objective function.[17] Say that coalition i has N_i members. Given linear utility, it is optimal to treat all members symmetrically and we thus assume that members' contributions to the coalition are identical.[18] Then, expected profits per coalition member equal

$$\frac{\pi_i}{N_i} = \frac{p_i Y - C_i}{N_i}. \tag{2}$$

From (2), it follows that coalitions desire to have the fewest possible members. Since each member has income k, the lowest number of members that allows for the full financing of C_i is given by C_i/k. Replacing this in the expression for π_i we get:

$$\frac{\pi_i}{N_i} = \frac{p_i Y - C_i}{\frac{C_i}{k}} = k\left(\frac{p_i Y}{C_i} - 1\right). \tag{3}$$

Could a coalition do better with fewer than C_i/k members? It can be shown that the first-order condition from maximizing π_i/N_i differs from the one associated with the maximization of π_i alone by the factor $p_i Y/C_i$. Since a zero profit condition will be imposed in equilibrium, this factor will become unity making the arg max of both problems identical. For simplicity, we proceed by maximizing the absolute value of profits π_i.

2.1.1 The Problem of the Coalition

Consider coalition i, facing armed forces $A_{-i} \equiv \sum_{j \neq i} A_j$. Its problem is to:

$$\max_{A_i, w_i} \pi_i = \left(\frac{A_i}{A_i + A_{-i}} Y - C_i\right) \tag{4}$$

s.to:

$$C_i = (g + w_i) A_i \tag{5}$$

$$p_i w_i \geq k. \tag{6}$$

Constraint (6) is the participation constraint of soldiers: it ensures that their expected utility matches at least the outside alternative of working and collecting k.

Own funds are the least costly.

[17] We will discuss financial costs later on.

[18] This assumption carries no loss of generality. As long as the number of members required to exactly finance C_i is a linear function of C_i, it is possible to write coalition *per capita* profits as the ratio of absolute profits divided by a multiple of the cost C_i. The result of Lemma **??**, below, then applies.

Replacing the constraints in the objective function, we get:

$$\frac{A_i}{A_i + A_{-i}} Y - \left(g + \frac{k}{\frac{A_i}{A_i + A_{-i}}} \right) A_i = \frac{A_i}{A_i + A_{-i}} Y - (g + k) A_i - k A_{-i}.$$

The first-order condition with respect to own army size A_i is:

$$\frac{A_{-i}}{(A_i + A_{-i})^2} Y - (g + k) = 0$$

which, solving for A_i, yields:

$$A_i = \sqrt{\frac{Y}{g + k} A_{-i}} - A_{-i}. \tag{7}$$

2.1.2 Symmetric n-Coalition Equilibrium

In a symmetric equilibrium with n coalitions with equal army size, A, we have $A_i = A$ and $A_{-i} = (n - 1) A$. The probability of success in battle is then:

$$p = \frac{A}{nA} = \frac{1}{n}.$$

Using (7) to solve for A^* we get:

$$A = \frac{n - 1}{n^2} \frac{Y}{g + k}. \tag{8}$$

Therefore, in a symmetric equilibrium, and taking n as given,

$$A^* = A^* \left(\overset{+}{Y}, \overset{-}{g}, \overset{-}{k}, \overset{-}{n} \right),$$

where the derivative with respect to n assumes there will be more than two coalitions (which will always be the case as shown below). Intuitively, the higher the prize Y to be attained the greater the coalition size, whereas the greater the gun and wage costs of the coalition, g and k, as well as the reciprocal of the probability of success, n, the lower its optimal size.

Concerning the costs,

$$\begin{aligned} C_i &= (g + w_i) A_i \\ &= (g + kn) A_i. \end{aligned}$$

For a fixed coalition size A_i, total cost is increasing in the relative price of guns and on kn – since this is the wage rate that leaves soldiers indifferent between fighting or not. Since higher k and g reduce optimal coalition size, it is not immediately clear what their total effect on C_i is. Inserting the optimal coalition size found above into the expression for the cost:

$$\begin{aligned} C_i &= (g + kn) \frac{n-1}{n^2} \frac{Y}{g+k} \\ &= \frac{g+kn}{g+k} \frac{n-1}{n^2} Y. \end{aligned}$$

Since n exceeds unity (see below), it follows that higher k and lower g raise C_i, holding n constant. The effect of n is ambiguous. The effect of Y is unambiguously positive since it raises coalition size. Thus,

$$C_i = C_i \left(\overset{+}{k}, \overset{-}{g}, \overset{+}{Y}, n \right).$$

Note that n is being held fixed, for the time being, and n determines the probability of success in a symmetric equilibrium. Therefore, when g increases, optimal coalition size A_i declines (still with constant n), and the total effect on the cost is favorable: C_i declines as well. This is partly the consequence of the Leontieff technology specified for the army operations: the reduction in army size A_i caused by higher gun costs leads to a parallel reduction in the number of soldiers hired and corresponding reduction in the wage bill; the latter effect more than offsets the higher gun cost. Lower C_i will induce entry of more coalitions in equilibrium, as shown below, since, in equilibrium, costs must equal expected return $pY = Y/n$. When k increases, on the other hand, despite the reduction in coalition size for constant n, costs nonetheless increase. Thus, there must be exit of coalitions in equilibrium for the conflict becomes less profitable.

This intuition on the effects of k and g on the equilibrium number of coalitions n^* can be formally demonstrated as follows. Expected profits of the coalition are:

$$E\pi = pY - C = Y \frac{kn(2-n) + g}{n^2 (g+k)}.$$

It follows that:

$$\pi = \pi \left(\overset{-}{n}, \overset{+}{g}, \overset{-}{k}, \overset{+}{Y} \right).$$

Since the opportunity cost of capital has been normalized to zero, coalition members will accept to finance the coalition as long as expected profits are positive. Free entry of coalitions will drive expected profits to zero. Solving for the equilibrium n, we get:

$$E\pi = 0 \implies n = 1 \pm \sqrt{1 + \frac{g}{k}}.$$

The positive root must be selected for n to take on a positive value. Finally, the equilibrium value of n is

$$n^* = 1 + \sqrt{1 + \frac{g}{k}}. \tag{9}$$

We have that, as anticipated, n^* depends positively on g and negatively on k. Interestingly, n^* exceeds unity. Further, a higher price of guns leads to an *increase* in the equilibrium number of coalitions, but, if we consider the expression for A^* in (8), we see that the size of each coalition is getting smaller and smaller (both the direct effect of g on A^* and the indirect effect through n^* lead to a smaller army size).

The effect of higher k on A^* appears ambiguous. Holding n fixed, it reduces coalition size, but it also reduces n, which raises coalition size. Substituting (9) in (8), we get:

$$A^* = \frac{1}{\left(1 + \sqrt{\frac{1}{k}(g+k)}\right)^2} \frac{Y}{\sqrt{k(g+k)}}. \tag{10}$$

Some algebra shows that the following inequality is a sufficient condition for the denominator to be an increasing function of k:

$$2k > g. \tag{11}$$

Finally, we get:

$$A^* = A^*\left(\overset{+}{Y}, \overset{-}{g}, \overset{-}{k}\right),$$

where the negative sign on k is conditional on (11) holding.

An implication of our results for n^* and A^* under symmetric equilibria is that the number of coalitions forming is always strictly positive, as is the amount they spend on wasteful activities. Finally, we define $\bar{A}$ as the total armed forces under a symmetric equilibrium, $\bar{A} \equiv nA$. From the zero profit condition, it follows that

$$nC = Y \iff n(g + kn)A = Y \iff A = \frac{Y}{n(g+kn)}.$$

Thus, total armed forces $\bar{A}$ are given by:

$$\bar{A} = \frac{Y}{g + kn}.$$

We now consider what happens as $k \to \infty$, which we interpret as the process of development. While it is clear that the path toward development is likely not independent from a country's natural resources, the analysis below should nonetheless provide insights into a cross-section comparison of countries with different levels of the opportunity cost of time k but at the same point in time.

$$\lim_{k\to\infty} n = \lim_{k\to\infty} 1 + \sqrt{1 + \frac{g}{k}} = 2.$$

$$\lim_{k\to\infty} A = \lim_{k\to\infty} \frac{n-1}{n^2} \frac{Y}{g+k} = \frac{1}{4} \lim_{k\to\infty} \frac{Y}{g+k} = 0.$$

$$\lim_{k\to\infty} \bar{A} = \lim_{k\to\infty} nA = 0.$$

We have two rather remarkable results as $k \to \infty$. First, the number of coalitions converges to 2, and many developed countries are polarized around two large political parties.[19] Second, army size goes to zero: as k increases, the number of coalitions drops to 2 and they engage smaller and smaller armies. As a consequence, the total armed forces in the economy also vanish. Total spending across coalitions always equals Y.

Regarding the effects of g,

$$\lim_{g\to\infty} n = \infty$$

$$\lim_{g\to\infty} A = 0.$$

$$\lim_{g\to\infty} \bar{A} = \lim_{g\to\infty} nA = \lim_{g\to\infty} n \left(\frac{n-1}{n^2} \frac{Y}{g+k} \right) = \lim_{g\to\infty} \frac{Y}{g+k} = 0.$$

As the relative price of guns increases, more coalitions form but their size becomes arbitrarily small, and the latter effect dominates on the size of total armed forces, which also goes to zero.

[19] In a related setting but where property rights are endogenous, Hodler [12] finds that natural resources raise a country's *per capita* income when the number of ethnic groups fighting over those resources is below 2, and that they lower *per capita* income otherwise.

Stage 1 The financing of each coalition is made by the engagement of $N_c^* \equiv A^* \left(g + \frac{k}{p^*}\right)/k$ members. Thus, $n^* N_c^*$ individuals choose to join coalitions of size N_c^* in the first stage. The remaining $N - n^* N_c^*$ individuals in the population choose not to become coalition members. In the second stage, a total of $n^* A^*$ wage offers are made and accepted. The remaining $N - n^* (N_c^* + A^*)$ individuals simply work and receive k. The strategy of each individual is optimal given what others are doing at each stage and the backward induction method used to solve for the equilibrium ensures subgame perfection. We note that, although we can characterize equilibria in terms of optimal coalition and army sizes, as well as the number of coalitions, the model is silent concerning the allocation of particular individuals to specific groups. That is, we have multiple equilibria in the sense that one particular person might be a coalition member in one equilibrium and a soldier in another. But up to the identity of the players, the symmetric equilibrium is unique. (We will come back to the identity issue in section 2.4.)

This summarizes the characterization of symmetric subgame-perfect Nash-equilibria of our game.

2.1.3 Asymmetric Coalition Size

Could coalitions of different sizes coexist? If this were to happen, coalitions' profits would also vary by size, which, absent frictions, is not consistent with profit maximizing behavior. We show that, in the current frictionless environment, it is not possible to have coalitions of different sizes.

Proposition 1 *There are no coalitions of different size in equilibrium.*

Proof. Suppose, for contradiction, that there are coalitions of different sizes. Let two of the coalitions in this equilibrium have sizes A_i and A_j, let $\bar{A}$ indicate the total number of armed forces in the equilibrium (the sum across all coalitions), and, without loss of generality, let coalition i be larger than coalition j. If both A_i and A_j have the optimal size given $\bar{A}$, then both A_i and A_j have to satisfy the first-order condition (7). Define

$\theta_i \equiv A_i/\bar{A}$ and θ_j similarly, with $\theta_i > \theta_j$. We may now rewrite (7) as:

$$
\begin{aligned}
A_i &= \theta_i \bar{A} = \sqrt{\frac{Y(1-\theta_i)\bar{A}}{g+k}} - (1-\theta_i)\bar{A} \iff \\
\tilde{A} &= \sqrt{\frac{Y(1-\theta_i)\bar{A}}{g+k}} \implies \bar{A} = \frac{Y(1-\theta_i)}{g+k}.
\end{aligned}
$$

Similarly, for A_j,

$$
\begin{aligned}
A_j &= \theta_j \bar{A} = \sqrt{\frac{Y(1-\theta_j)\bar{A}}{g+k}} - (1-\theta_j)\bar{A} \implies \\
\bar{A} &= \frac{Y(1-\theta_j)}{g+k}.
\end{aligned}
$$

From the assumption that coalition i is greater than j, it follows that

$$\frac{Y(1-\theta_j)}{g+k} > \frac{Y(1-\theta_i)}{g+k},$$

and so we get two different solutions for $\tilde{A}$, a contradiction. ■

2.2 Deterrence

We now consider the case where the natural resources have been successfully claimed by a coalition in the past. This coalition moves first by making offers to soldiers and engaging a defending army.[20] Other agents in the economy may then choose whether or not to form coalitions to engage armies to try and gain control of Y.

The coalition in charge of Y is assumed to have the means to pay for an army, should it choose to engage one. For this reason, we do not worry here about whether it should retain more members in order to gather resources to sponsor a large enough army. Further, we assume that its membership has been somehow determined in the previous quest for Y. We thus take as given the number N_{det} of its members.

[20] In Grossman and Kim's [10] fundamental model of property rights, individuals first decide on the amount of defensive weapons they wish to acquire; in a second stage, they decide on the amount of offensive weapons to be used to try to gain control of alien resources. An equilibrium exists where only defensive weapons are acquired: given those, it does not pay to acquire offensive ones. We could reinterpret the timing in the current paper in a similar fashion: given that only the deterrence coalition has wealth, it moves first to set up a defensive army. In the current case, this is enough to deter others from attempting to steal Y. Under the modified contest success function proposed in section 3, this need not always be the case.

Timing This is an extensive game with a finite horizon. In the first stage (labeled zero), the coalition in charge of Y decides on whether or not to make wage offers to noncoalition members and engage an army to secure Y. The remaining individuals in the economy – those not belonging to the first coalition nor to its army – go through stages 1, 2 and 3 of the previous section (i.e. decide whether or not to form coalitions in order to engage armies to try to get control of Y).

Stage 0 By having first-move advantage, the original coalition has the possibility of engaging an army sufficiently large so as to keep other coalitions from entering. Having a smaller size army will result in entry and, consequently, in the profits of all contending coalitions to be driven to zero. Therefore, if expected profits are positive in the scenario of a deterrence army, that will be the unique subgame perfect equilibrium of our game.

In order to find the deterrence army, we consider the objective function of coalition i, considering whether or not to enter after the deterrence army is in place. Let the potential entrant be labeled i. Its objective function is:

$$\max_{A_i} \left\{ \frac{A_i}{A_i + A_{-i}} Y - (g+k) A_i - kA_{-i} \right\}.$$

Graphically, profits are the difference between two schedules. The first, $p_i Y$, measures expected revenues, has origin at $A_i = 0$, is strictly increasing and strictly concave. The second, the straight line $(g+k) A_i + kA_{-i}$, has intercept kA_{-i} and a constant slope of $(g+k)$. Optimality requires A_i^* to be such that the slope of $p_i Y$ equal $g+k$. Although necessary, this is not a sufficient condition for coalitions to form. In fact, if the cost schedule is everywhere above the benefits – more likely if A_{-i} is very large – coalition i will have negative expected profits and should not operate. Coalition i will behave optimally *and* have zero profits provided the cost schedule is tangent to the benefit function and A_i is given by that single intersection point. If there is a level of A_{-i} that accomplishes this, that level will be enough to keep coalition i out: since the best it could do would be to form to have zero profits, it might as well stay out. More generally, this also shows that, if A_{-i} is low enough for additional coalitions to enter, these entrants will need to attain a certain minimum scale in order to be profitable, given by the (lowest) intersection of the $p_i Y$ schedule and the cost line $(g+k) A_i + kA_{-i}$.

For clarity, let us consider also what would happen if A_{-i} exceeded the level previously defined, that exactly leaves any entering coalition with zero profits. Higher A_{-i} raises the intercept of the cost schedule and moves it parallelly upward. Further, higher A_{-i} reduces p_i and thus causes the benefit schedule to move downward, still with intercept at the origin. Thus, the benefit and cost schedules would not longer be tangent, the cost schedule would be everywhere above the benefit schedule and coalition i would have negative profits if it chose to enter. Therefore, selecting A_{-i} so that coalition i's cost and benefit schedules are tangent is the best that a dictator wanting to implement deterrence can do.

Let A_{det} be the smallest army size that will implement deterrence. Then, A_i^* is given by the first-order condition of coalition i and, at the same, by imposing its profits to be zero. This is true when

$$A_i = \sqrt{\frac{Y}{g+k} A_{\text{det}}} - A_{\text{det}}$$

and

$$\frac{A_i}{A_i + A_{\text{det}}} Y - (g+k) A_i - k A_{\text{det}} \quad = \quad 0$$

both hold. Solving for A_{det} we get:

$$A_{\text{det}} = \frac{gY + 2kY - 2\sqrt{Y^2 k^2 \left(1 + \frac{g}{k}\right)}}{g^2}. \tag{12}$$

We may compute A_{det} alternatively as follows. Recall that the condition for deterrence is that a potential entrant, once setting A_i to its optimal size, has expected utility of exactly zero. For this reason, the coalition does not form. Note also that, in the first-order condition for army size, the armed forces of other coalitions show as a sum and the individual parcels do not have any effect beyond that sum. Thus, the deterrence army size will equal the total armed forces of $(n-1)$ coalitions in the symmetric equilibrium. At this level, the n^{th} coalition is indifferent between forming or not because its profits would be zero in both cases. The fact that the deterrence coalition is able to stave off a competing army whose size would have equaled that of a single coalition in the symmetric equilibrium is of course beneficial for those sponsoring the deterrence army: the deterrence coalition has strictly positive profits. Therefore:

$$A_{\text{det}} = \frac{n-1}{n}\bar{A} = \frac{n-1}{n}\frac{Y}{g+nk} = \frac{\sqrt{1+\frac{g}{k}}}{1+\sqrt{1+\frac{g}{k}}}\frac{Y}{g+\left(1+\sqrt{1+\frac{g}{k}}\right)k}.$$

We have then:

$$A_{\text{det}} < \bar{A}.$$

Regarding the effect of development and the price of guns on deterrence, we have:

$$\lim_{k\to\infty} A_{\text{det}} = 0$$

$$\lim_{g\to\infty} A_{\text{det}} = \lim_{g\to\infty} \frac{1}{\frac{1}{\sqrt{1+\frac{g}{k}}}+1}\frac{Y}{g+\left(1+\sqrt{1+\frac{g}{k}}\right)k} = 0.$$

Thus, the property that development (large k) is inconsistent with an inefficient use of resources is common across equilibria of the game, be it under the conflict of multiple armies or under the deterrence solution. A higher gun price also leads to a reduction in the army size of the deterrence army.

Stage 0 In the deterrence equilibrium, the coalition in control of Y formed by N_{det} members makes A_{det} wage offers of k; these offers are accepted. At stage 1, the remaining $N - N_{\text{det}} - A_{\text{det}}$ individuals choose not to form any additional coalitions. No wage offers are made in stage 2 and there is no fighting in stage 3, with the original coalition retaining control of Y. Here, the identity of the members of the original coalition is taken as given; the deterrence equilibrium is unique up to the identity of the soldiers engaged by that coalition.

2.3 The Cost of Inefficiency

What is the resource cost of inefficient activities? In the case with multiple armies, from the zero-profit/free-entry condition for coalitions it follows that:

$$\begin{aligned} pY - C_i &= 0 \iff \\ \frac{Y}{n} &= C_i \iff nC_i = Y. \end{aligned}$$

Thus, the cost of inefficiency equals Y under the symmetric equilibrium case, the income to be appropriated at the outset.

As discussed earlier, the deterrence army is smaller than the total armed forces of the symmetric equilibrium. In addition, this coalition has the lowest wage bill per soldier, since its soldiers will retain control of resources with probability 1. So, the deterrence solution is more efficient than the symmetric equilibrium case. The deterrence solution's inefficiency cost is $A_{\text{det}}(g+k)$, where $A_{\text{det}}(g+k) < Y$.

2.4 Discussion

The analysis shows that there will always be inefficient military activities going on – either in the form of multiple coalitions fighting each other or in the deterrence form – provided k is finite and Y is positive.

The model predicts that, in equilibria with more than one coalition, coalition size should be identical. Should this not be the case, frictions outside the model must be operating. One likely candidate is financial frictions and/or coordination costs. In fact, we could have framed the coalition's problem as that of a firm maximizing its expected profits and issuing shares to get the resources for financing its operations. The shareholders in our economy are the coalition members who bring in their income to finance the coalition's army. The model assumes that the capital structure of the coalition does not affect its operations and thus, as many shares as required to attain optimal army size will be issued.

Of course financial constraints are likely to be an important consideration for these coalitions. Even if it were feasible to gather as many coalition members as needed to pay for C_i^*, the coordination costs of this endeavour would likely get out of hand: issues of trust, of credible repayment and internal coordination would likely loom large even under small coalition sizes. This suggest that, from an operational point of view, it is less costly to have the smallest possible coalition. It follows that the wealthy have a comparative advantage at setting up the coalition since they are more likely to be able to operate with fewer additional financiers and to have fewer coordination problems. In fact, coalitions may not even be able to form if they would require too large a number of financiers just to attain a profitable size (recall that, for small A_i and large A_{-i}, coalition i is making negative profits).

Differential access to finance thus provides an immediate source of heterogeneity in coalition and army sizes. More importantly, it narrows the identity possibilities for coalition members to the set of wealthy people: under binding financial constraints, the poor will not be able to participate in coalitions.

Should resource control have been achieved by an existing coalition, the deterrence analysis suggests that this coalition should be able to retain this control indefinitely. If that is not the case, then frictions other than access to finance must be lurking in our problem: after all, it is not reasonable to expect the coalition in control of the large pool of resources Y to be financially constrained. If control over Y is not stable, there must be something about the nature of the resources – geographic conditions such as accessibility, for example – that makes it impossible for control to be maintained with probability one. Another possibility is coordination problems at the level of the armed forces engaged. If these costs become large for army sizes below those that would deter entry by other coalitions, then deterrence will no longer be an equilibrium in our model.

The current setup rules out these possibilities through the choice of the contest success function. With $p(A_i, A_{-i})$ given by the ratio of one's armed forces to the total armed forces in the economy, it is always in the interest of an existing coalition to engage an army large enough to deter entry and, by doing so, that coalition is able to successfully retain control of Y. In the next section, we consider an alternative contest success function that places an upper bound on the probability of success in the fight over Y.

3 An Alternative Contest Success Function

Here, we propose a modified contest success function $\tilde{p}(A_i, A_{-i})$. This modified csf is such that, although increasing one's armed forces raises the probability of control of Y, it does so at a slower rate than before, as follows. Let:

$$\tilde{p}(A_i, A_{-i}) = \frac{A_i}{\theta A_i + A_{-i}},$$

with $\theta > 1$. Parameter $\theta > 1$ captures the difficulty of handling large groups of people, and is thus is a measure of the contentiousness or lack of cohesion of one's armed forces. Common ethnicity of financiers and soldiers would be reflected in a lower θ: coalition members would get more out of their army if they recruited within their own ethnicity.[21] Note that coalition i's armed forces still disrupt the probability that other coalitions will grab Y (A_i shows in the denominator of $\tilde{p}_j$ with a coefficient of unity, less than θ). But while they hurt others in their attempts to get Y (after all, these are groups of armed soldiers lacking perfect coordination), their lack of coordination is also partially hurtful to coalition i itself.[22]

Contest success function $\tilde{p}(\cdot)$ places an upper bound of $1/\theta < 1$ on the probability of getting control of Y, regardless of the amount of armed forces engaged. That is, the most cohesive and organized army facing no opposition from other coalitions gets control of Y with probability $1/\theta$. It is effectively as if, in an n-player contest, there were an additional player – chance – that retains probability $(\theta - 1)/\theta$ over Y. This could be the probability that one's own army engages in an insurrection and quits securing Y, for example.[23]

Next, we examine the implications of using csf $\tilde{p}(\cdot)$ for the main results derived above.

3.1 Unclaimed Natural Resources

Optimal coalition size in the unique symmetric equilibrium will be given by (compare with (7)):

$$\tilde{A}_i^* = \frac{1}{\theta}\left(\sqrt{\frac{A_{-j}Y}{(g+k\theta)}} - A_{-j}\right). \tag{13}$$

[21] This effect of ethnicity is different from that in Esteban and Ray [6]. There, the poor benefit from the financial strength of the rich belonging to the same ethnic group to secure a fraction of governmental budget targeted toward an ethnic agenda. They lack such support if they form allegiances with other poor (necessarily of a different ethnicity), and thus class conflict is less appealing. This explains the salience of ethnic conflict in that paper. Here, it is because recruiting within one's own ethnic group raises army efficiency that coalition members become more likely to recruit among their own ethnicity.

[22] One option to model the cohesiveness/coordination issues with armies would have been to assume

$$\tilde{p}(A_i, A_{-i}) = \frac{A_i}{\theta_1 A_i + \theta_2 A_{-i}},$$

with $\theta_1, \theta_2 > 1$, $\theta_1 > \theta_2 > 1$. In this case, other coalition's armed forces are more disruptive to coalition i than previously assumed, with the pcf $p(\cdot)$, but this lack of cohesiveness or coordination is more hurtful when coming from coalition i's own soldiers as expressed in the fact that θ_1 exceeds θ_2. For simplicity, we chose to normalize θ_2 to unity.

[23] The analysis in Sakperdas [21] shows that $\tilde{p}(\cdot)$ does not satisfy the independence of irrelevant alternatives.

In a symmetric equilibrium (again the only type we have when Y is a new discovery) with $\tilde{n}$ identical coalitions whose armed forces are all identical to $\tilde{A}$, the probability of success is:

$$\tilde{p} = \frac{\tilde{A}}{\theta\tilde{A} + (\tilde{n}-1)\tilde{A}} = \frac{1}{\tilde{n} + (\theta - 1)} < \frac{1}{\tilde{n}}. \tag{14}$$

This is not surprising given the upper bound of $1/\theta$ that $\tilde{p}$ places on the individual probability of success. Imposing symmetry in (13), we get (compare with (8)):

$$\tilde{A}^* = \frac{(\tilde{n}-1)}{(\theta + (\tilde{n}-1))^2} \frac{Y}{g + k\theta}. \tag{15}$$

For constant $\tilde{n}$, and since $\theta > 1$, it follows that individual coalitions have fewer soldiers under $\tilde{p}(\cdot)$ than they did under csf $p(\cdot)$.

The equilibrium value of $\tilde{n}$, found by imposing that expected profits of coalitions be zero, is now (compare with (9)):

$$\tilde{n}^* = 1 + \sqrt{\theta^2 + \frac{g\theta}{k}}. \tag{16}$$

As before, $\tilde{n}^*$ exceeds 2 for all values of g and k. Interestingly, $\tilde{n}^*$ exceeds n^* as long as $\theta > 1$. The probability of success in a symmetric equilibrium, $\tilde{p}$, is thus lower than the corresponding probability under csf $p(\cdot)$ (see (14)). It can further be shown that $\tilde{A}^*$ is a decreasing function of $\tilde{n}^*$, when $\tilde{n}^*$ equals its equilibrium expression (16). Since $\tilde{n}^* > n^*$, we now have smaller coalitions fighting over Y but a larger number of them. The former force dominates in terms of the total resources spent fighting. From the zero-profit condition, we get

$$\tilde{p}Y - C = 0 \iff \frac{Y}{\tilde{n} + (\theta - 1)} = C \iff Y = (\tilde{n} + (\theta - 1))\, C < \tilde{n}C.$$

This shows that, under $\tilde{p}(\cdot)$, military spending does not exhaust all the rents to be appropriated.

Inserting (16) into (15), we get (compare with (10)):

$$\tilde{A}^* = \frac{\sqrt{\theta^2 + \frac{g\theta}{k}}}{\left(\theta + \sqrt{\theta^2 + \frac{g\theta}{k}}\right)^2} \frac{Y}{g + k\theta}. \tag{17}$$

3.2 Deterrence

We saw earlier that, when an existing coalition had control over Y, its optimal strategy was to take advantage of the first-mover advantage and to build a large enough army so as to completely eliminate the incentives of potential entrants to form armies. Here, we show that this is no longer necessarily optimal. Because of the high nonlinearity of the problem, we proceed by providing examples (*i.e.* parameter values) under which the former deterrence solution yields negative expected profits and where the optimal deterrence army does not fully deter entry.

The problem of the coalition in control of Y is to maximize its expected profits by choice of an army size $\tilde{A}_{\text{det}}$. Should $\tilde{A}_{\text{det}}$ not fully deter entry, then, and once $\tilde{A}_{\text{det}}$ has been put in place, the remainder entrants are playing a game similar to the "unclaimed natural resources" case. That is, taking $\tilde{A}_{\text{det}}$ as given, proposition 1 applies and the new entrants will be identical in size.

Should there be entry, let $\tilde{n}_{\text{det}}$ denote the number of new entrants once $\tilde{A}_{\text{det}}$ has been put in place, $\tilde{n}_{\text{det}} \geq 1$. Let $\tilde{A}_{\text{det},i}$ denote the individual quantity of coalition i if there is entry once $\tilde{A}_{\text{det}}$ has been set to defend Y, $i = 1, 2, \ldots, \tilde{n}_{\text{det}}$. Then, the problem of the original coalition is to:

$$\max_{\tilde{A}_{\text{det}}} \tilde{p}_{\text{det}} Y - \left(g + \frac{k}{p_{\text{det}}} \right) A_{\text{det}},$$

where

$$p_{\text{det}} = \frac{A_{\text{det}}}{\theta A_{\text{det}} + \tilde{n}_{\text{det}} A_{\text{det},i}}$$

is the probability of winning for the original coalition, and where $A_{\text{det},i}$ solves

$$\tilde{A}_{\text{det},i} = \frac{1}{\theta} \left(\sqrt{\frac{A_{-i} Y}{(g + k\theta)}} - A_{-i} \right),$$

with

$$A_{-i} = (\tilde{n}_{\text{det}} - 1) A_{\text{det},i} + A_{\text{det}}.$$

Finally, $\tilde{n}_{\text{det}}$ solves implicitly the zero-profit condition for entrant coalition i:

$$\tilde{p}_{\text{det},i} Y - \left(g + \frac{k}{\tilde{p}_{\text{det},i}} \right) A_{\text{det},i} = 0,$$

given A_{det} and $A_{\text{det},i}$, and where

$$\tilde{p}_{\text{det},i} = \frac{A_{\text{det},i}}{\theta A_{\text{det},i} + (n-1) A_{\text{det},i} + A_{\text{det}}}.$$

The nonlinearity of the problem is self-evident. Since the point of the current exercise is to show that csf $\tilde{p}(\cdot)$ can lead to the instability of the deterrence solution by allowing entry, which was previously not optimal under $p(\cdot)$, we proceed by providing a numerical example where that is the case.

Proposition 2 *There are parameter values under which it is optimal for the original coalition to allow entry.*

Proof. Under $g = k = 1$ and $Y = 100$, expected profits of the original coalition are negative when $\tilde{A}_{\text{det}}$ is set to $(\tilde{n}_{\text{det}} - 1)\tilde{A}_{\text{det},i}$. Maximal and positive profits are attained for positive A_{det} strictly below $(\tilde{n}_{\text{det}} - 1)\tilde{A}_{\text{det},i}$. ■

Figure 1 shows how the expected profits of the old optimal deterrence strategy (setting $\tilde{A}_{\text{det}} = (\tilde{n} - 1)\tilde{A}$) for values of θ above unity. Expected profits are computed using the formerly optimal deterrence quantity and assuming no entry. Thus, $\tilde{p}$ equals the upper bound $1/\theta$.[24]

For $\theta = 1$, we are back in the problem of the previous section and the coalition in charge of Y makes positive expected profits by preventing entry. As θ increases, however, profits monotonically decline. For θ around 3.6, they become negative.

Picture 2 shows the original coalition's expected profits as a function of its output, taking into account how entrants will react to it. For the parameter values considered in proposition 2 and $\theta = 3.8$, the army size that would deter entry equals 5.83 units but is associated with negative profits. Instead, the profit maximizing army size is roughly 2.3, less then half of the former value. The army size of entrant coalitions is 1.37, and there will be 5.27 of them. As expected, the coalition in charge of Y has the largest army and strictly positive profits.

[24]Technically, potential entrants would be making exactly zero profits and thus still enter. Entry deterrence would occur for sure for $\tilde{A}_{\text{det}} = (\tilde{n} - 1)\tilde{A} + \varepsilon$, for positive but arbitrarily small ε.

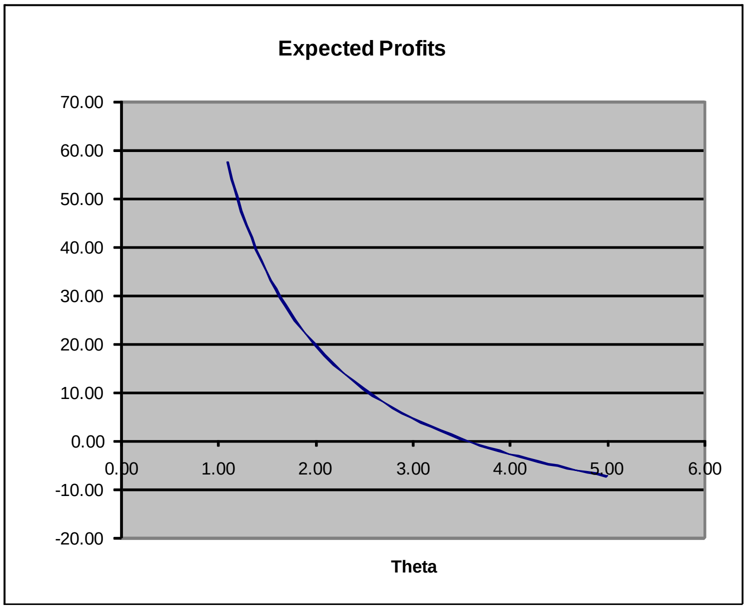

Figure 1: Expected Profits of Original Coalition Under Old Deterrence Strategy

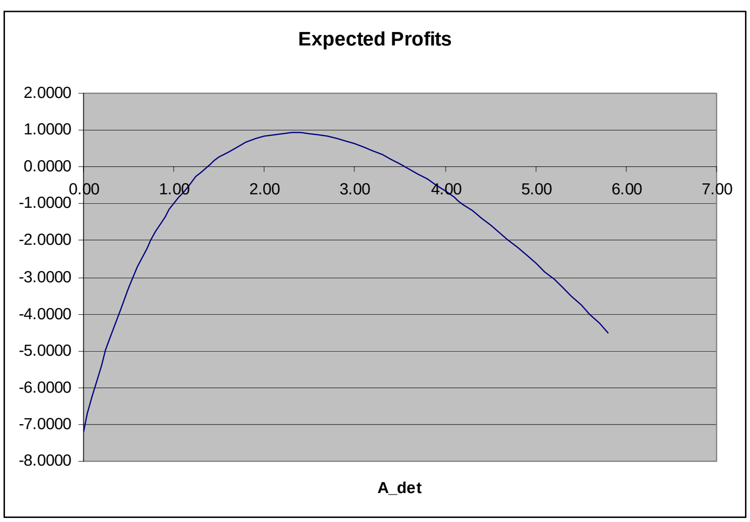

Figure 2: Expected Profits of Original Coalition as a Function of Ouput

4 Overview

The analysis so far has shown that, provided Y is positive and k finite, there is always inefficient use of resources in the economy. If access to finance is limited, as one would expect to be the case in the real world, then the model restricts the identity of coalition members to the group of wealthy people in the economy. If control of Y is unstable, this indicates lower productivity of the army technology in gaining control over Y than previously used.

Is there a way of avoiding the inefficient use of resources – either through conflict or through deterrence? The reason for the conflict is the existence of Y and the fact that k is small. One issue we seek to examine in future research is the dynamic relationship of k with conflict. It is likely, however, that one consequence of conflict would be the worsening of the country's infrastructure and thus a reduction in future k. Lower k, in turn, lowers the cost of conflict, raises army size across equilibria and the number of coalitions fighting in the symmetric case. From this point of view, conflict today makes conflict more likely tomorrow. Dynamic considerations *per se* do not appear to help achieve an efficient outcome.

One solution would be for the countries that buy the natural resources to earmark the income from its sales for development purposes, for example, or to require that goods be certified not to have originated from a conflict area, the latter option resembling the Kimberley accords for diamonds. But the new question that arises here is of course whether this international agreement is individually rational from the point of view of outsiders, be they rich individuals who could finance the control of Y and reap its benefits, or be they rich governments of neighboring countries. If outside countries are rich enough (in the sense of enjoying a very large k themselves and thus of having no interest in getting hold of Y), they may be willing to enforce this agreement. Informally, enforcement of this agreement would seem to depend on the existence of a sufficiently large group of rich countries that could credibly commit not only not to finance the capture of Y for their own exclusive use but also to putting in place mechanisms (international courts with adequately high punishments) that would be persuasive enough to other tempted countries and/or individuals. Removing a tyrant is not a solution: the 'nature' of the problem will give rise to a continuation of conflict or deterrence.

The analysis shows that, absent financial frictions and as k goes to infinity, the size of competing armies goes to zero but expenditures on wasteful activities do not. Whereas under csf $p(\cdot)$ military expenditures always equal Y, under csf $\tilde{p}(\cdot)$ they equal the fraction $1/(\tilde{n}+(\theta-1))$ of Y. The latter increases as k goes to infinity and converges to $1/(2\theta)$. Thus, the model predicts that, in a contemporaneous comparison across countries, developed countries (those with higher k) should be virtually conflict free while still having a significant amount of wasteful expenditures, whereas developing countries (with low k) should be plagued by conflict or else have sizable deterrence-type armed forces seeking to retain control of Y. Testing these implications is part of our ongoing research agenda.

Other frictions such as output destruction costs come to mind and could easily be incorporated into the analysis without qualitatively modifying the results. By reducing the benefits of controlling Y, they would reduce the equilibrium number of coalitions contending for the resources or, alternatively, reduce the size of the deterrence army. But unless those costs were very unrealistically sizeable, they would not change the analysis. The resource problem, with its potential for everlasting and derisive conflict, has often been considered along ethnicity issues. In Hodler [12], for example, there is an exogenous number of groups fighting over the economy's natural resources, and these groups correspond to ethnic and/or linguistic factions within society. Here, we preferred to let the force of economic power speak first, thus deliberately avoiding any strictly ethnic motivation for getting hold of Y. Ethnic issues are not completely absent from the analysis inasmuch as they may affect the cohesion of armed forces and thus lower the parameter θ in the modified csf $\tilde{p}(\cdot)$.

5 Conclusion

This paper proposed a fundamental approach to political economy outcomes. It started at a more general level than the existing literature by allowing for endogenous group formation. It further examined the implications of considering solely the forces of economic power, disregarding any other conventional "institutions" (such as whether or not there is a democratic government, for example). We believe that, by doing so, we are effectively providing endogenous bound for economically sustainable institutions. The approach was applied to the natural resource curse. We see the generality of this approach as an important tool in the understanding of political economy outcomes and in the identification of the elements in the nature of a country that render inefficient outcomes unavoidable.

We seek to extend our analysis of the natural resource curse to incorporate dynamics. We also aim to explore the enormous variety of constellations of inefficient institution outcomes from the vantage point of the method proposed here in the hope of finding their determinants and potential solutions.

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