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War and Natural Resource Exploitation

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Abstract

Although the relationship between natural resources and civil war has received much attention, little is known about the underlying mechanisms. Controversies and contradictions in the stylized facts persist because resource extraction is treated as exogenous while in reality fighting affects extraction. We study endogenous fighting, armament, and extraction method, speed and investment. Rapacious resource exploitation has economic costs, but can nevertheless be preferred to balanced depletion due to lowered incentives for future rebel attacks. With private exploitation, rebels fight more than the government if they can renege on the contract with the mining company, and hence government turnover is larger in this case. Incentive-compatible license fees paid by private companies and mining investment are lower in unstable countries, and increase with the quality of the government army and office rents. This implies that privatised resource exploitation is more attractive for governments who have incentives to fight hard, i.e., in the presence of large office rents and a strong army. With endogenous weapon investments, the government invests more under balanced than under rapacious or private extraction. If the government can commit before mining licenses are auctioned, it will invest more in weapons under private extraction than under balanced and rapacious nationalized extraction.

JEL-Code: D45, D74, L71, Q34.

Keywords: conflict, natural resources, private resource exploitation, mining investment, license fee.

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1. Introduction

Natural resource abundance and exploitation fuel political unrest if different factions in society try to get control of the resource rents. Put differently, natural resource wealth increases the potential gains of controlling political power. However, the causation between natural resources and conflict also goes the other way. Political instability may push governments to rapacious resource depletion, but can also reduce the incentive of especially private mining companies to explore and extract. Conflict thus influences economic decisions with respect to the method and intensity of natural resource extraction. So far the two directions of causality have been analyzed largely independently. While the literature on conflict and rent seeking has mostly treated natural resource extraction as exogenous and has focused on explaining appropriation efforts and outcomes (e.g., Torvik, 2002; Collier and Hoeffler, 2004; Fearon, 2005; Mehlum et al., 2006; Besley and Persson, 2010), the literature on natural resource economics has investigated the impact of insecure property rights on extraction levels without taking into account the effects of natural resources on fighting decisions (e.g., Tornell and Lane, 1999; van der Ploeg, 2010).

Our objective is to investigate the two-way interaction between natural resource extraction and conflict. We thus present a unified framework with both endogenous armament and fighting decisions and an endogenous choice of method and intensity of extraction. This enables us to derive predictions on the relative and absolute levels of fighting effort, the odds of victory, the method of and investment level in resource extraction, as well as the total amounts and payoffs from extraction received by the government and by international extraction companies. Our results can account for various empirical puzzles.

There are few theoretical papers linking natural resource exploitation and civil war. Most focus on how larger natural resource stocks increase the incentives for rent-seeking and appropriation by increasing the "prize" to be appropriated (Torvik, 2002; Grossman and Mendoza, 2003; Olsson and Fors, 2004; Maxwell and Reuveny, 2005; Hodler, 2006; Morelli and Rohner, 2009). [1] However, all of these articles treat resource extraction as exogenous. Another strand of the theoretical literature emphasizes how there can be over-extraction of natural resources in the presence of uncertainty about property rights (Hotte, 2001, 2005) or about future political outcomes (Robinson et al., 2006). These contributions, however, neither distinguish private versus nationalized extraction methods nor relate to civil conflict.[2]

[1] Fearon (2005) argues that natural resources can foster conflict by weakening state capacity. Acemoglu et al. (2010) link resource extraction to trade and inter-state wars.
[2] Rohner (2006) shows how resources affect fighting, but does not take into account the choice of extraction technologies, non-linear fighting technologies or asymmetries between government and rebels. Gonzales (2005) shows that it can be in the interest of conflicting factions to pick low productivity even if higher productivity was

We build on these strands of the literature and construct what is to our best knowledge the first model that makes fully endogenous both the level of conflict and the mode and intensity of natural resource extraction. Our framework generates several surprising predictions and accounts for various empirical puzzles. In particular, we explain why in some instances in the presence of conflict over-exploitation (i.e., rapacious depletion) takes place while in other instances there is under-exploitation (i.e., under privatized exploitation investment is usually inefficiently low in the presence of conflict). Although rapacious depletion is less desirable from a purely economic standpoint than balanced resource exploitation, it can be preferable once conflict is taken into account, as fighting is higher under balanced depletion. Furthermore, we show why the government has better chances of victory under nationalized than privatized extraction. With private exploitation, rebels fight more than the government if they can renege on the contract with the mining company. As a result, rebels are better off under privatized than under nationalized exploitation. Our results can account for the trend towards nationalized oil companies despite strong empirical evidence that private international oil companies are on average substantially more efficient than national oil companies.[3] The incentive-compatible license fee that has to be paid by the private mining company is higher if the army quality of the government, office rents and future resource revenues are higher. Effectively, there is a hold-up problem for private mining investment which is deterred by the threat of rebels gaining office. With endogenous investment in weapons, there is also a time inconsistency problem for the government, since the government invests more in weapons if it can commit in advance of mining licenses being auctioned. Without commitment there is more investment in weaponry under balanced than under rapacious or private resource extraction.

The remainder of the paper is organized as follows. Section 2 is devoted to a critical survey of the existing empirical literature and puzzles. In section 3 we build the basic model of conflict and resource extraction, whereas in section 4 this framework is extended to allow for endogenous private mining investment. In section 5 government investment in weapons is made endogenous under the various scenarios. Section 6 studies what happens when the government bribes rebels by offering them work. Section 7 concludes and suggests various directions for further research.

available at no cost, in order to be in a better position during distributive conflict. His setting, however, neither features natural resources nor treats issues of depletion speed and private versus nationalized production.

[3] There is substantial empirical evidence that international oil companies are more efficient on a variety of indicators and yield higher returns than nationalized oil companies (Al-Obaidan and Scully, 1991; Victor, 2007; Wolf, 2009; Eller et al., 2010).

2. Stylized empirical facts

We discuss the findings and shortcomings of the existing literature on the impact of natural resources on the onset of civil wars, and examine what our framework suggests about future directions of future empirical research. We then briefly assess the literature studying the effects of conflict on resource extraction and present some new stylized facts.

Table 1: Overview of existing empirical evidence on the impact of natural resources on civil wars

	Resource measure used	*Main findings*	*Control extract. endog. to fight*
Onsets and Incidence			
De Soysa (2002), Fearon and Laitin (2003), Fearon (2005)	Oil exporter dummy, fuel exports / total exports	Both measures increase war onsets	No
Collier and Hoeffler (2004), Collier et al. (2009)	Primary exports / GDP	Increases war onsets (inverted U-shape)	No
Fearon (2005), Brunnschweiler and Bulte (2009)	Primary exports / GDP (with further robustness checks and instrumented)	The effect of primary exports on war onsets seems not very robust	No
Lujala et al. (2005), Lujala (2010)	Diamond deposit, diamond production, and oil production dummies	Secondary diamonds increase onset and incidence (ethnic) war, primary diamonds decrease incidence war, (onshore) oil increases onsets	No
Humphreys (2005)	Oil production, oil reserves, diamond production	Both oil production and diamond production increase war onsets	No
Ross (2006)	Fuel rents and diamond rents per capita	Fuel onshore and offshore and primary diamonds increase war onsets, secondary diamonds increase onsets separatist wars	No
Duration and fatalities			
Fearon (2004), Ross (2006)	Contraband (cocaine, gems, opium etc) dummy	Increases war duration	No
Collier et al. (2004)	Primary exports / GDP	Level not significant. Lower price of commodities exported shortens war	No
Lujala (2009)	Gem, drug and hydrocarbon production dummies	The presence of these measures in conflict zone increases combat deaths	No
Lujala (2010)	Gemstones, oil reserves and production dummies	The presence of these measures in conflict zone increases duration war	No

2.1. The impact of natural resources on civil wars: empirical results

Table 1 summarizes the findings of the existing empirical literature on the impact of natural resources on onset of civil war, pioneered by Collier and Hoeffler (2004)[4], who found that an intermediate (rather than a small or large) ratio of primary commodity exports over GDP increases the risk of civil war. It is controversial how robust this finding is (cf. Fearon, 2005). However, it is widely accepted that some natural resources are more conducive to war than others. In particular, diamonds (Lujala et al., 2005; Humphreys, 2005; Ross, 2006; Lujala, 2010), oil (De Soysa, 2002; Fearon and Laitin, 2003; Ross, 2004, 2006; Fearon, 2005; Humphreys, 2005) and narcotics (Angrist and Kugler, 2008; Lujala, 2009) increase the risk of civil conflict onsets. Further, lootable resources like alluvial gemstones, narcotics and timber also tend to sustain and prolong war effort during conflict (Fearon, 2004; Ross, 2004, 2006; Lujala, 2010). Trade and commodity price shocks have also been found to lead to conflict in some instances (Ross, 2006; Dube and Vargas, 2008; Besley and Persson, 2010; Brückner and Ciccone, 2010).

2.2. Measurement problems and endogenity

One important controversy in this empirical literature has been the issue of how to measure natural resource abundance. The first generation of papers focused on measures of resource wealth as expressed in terms of GDP or of total exports. Collier and Hoeffler (2004), for example, use primary exports / GDP as explanatory variable, while De Soysa (2002), Fearon and Laitin (2003) and Fearon (2005) focus on limited or continuous independent variables that relate oil exports to total exports. As has been pointed out, for example, by Ross (2006) or Brunnschweiler and Bulte (2009) these measures suffer from endogeneity bias. If conflict onsets are preceded by low-level political instability and this unrest is most harmful to complex industrial sectors, the structure of the economy can change and a country can become more resource dependent. Thus, reversed causality is a real concern, as a positive correlation between natural resources and civil war is not only consistent with resources fuelling war, but also with civil war making a country more resource dependent. To counter this criticism, most recent studies use resource measures that are independent of GDP or of total exports. Fearon (2004), Lujala et al. (2005), and Lujala (2009, 2010) use dummy variables for diamond, gems, oil deposits and production and narcotics production, while Humphreys (2005) and Ross (2006) use measures of the total value or rents from fuel and diamond production or reserves. These measures are, however, also not fully satisfactory, because the absolute value of resource rents may also be related to the size of the non-resource economy. Extracting a

[4] Recently, this was extended with more recent data and additional independent variables (Collier et al., 2009).

given small amount of oil or gas has a different meaning for a poor country like Sudan than for a rich country like Switzerland.

One important shortcoming that all of these studies share is that none of them takes into account that both the quantities of natural resources extracted and their profitability is endogenous with respect to the fighting efforts of the various war factions. Natural resource extraction may be more intensive if the government needs to fund a big army and purchase better weapons to fight off rebel coups. Governments may also join forces with multinationals who offer them more efficient modes of natural resource extraction. Furthermore, if mining companies pay a license fee upfront, this provides the funds to stage a better military force. During periods of peace the government is less likely to invest in defense. The theory we put forward attempts, for the first time, to give a simultaneous explanation of both the intensity of war and the intensity and method of natural resource extraction. Empirical estimates that treat natural resource extraction as exogenous and impose a linear relationship between resources and conflict could suffer from biased coefficients and misguiding significance levels that may lead to wrong conclusions.

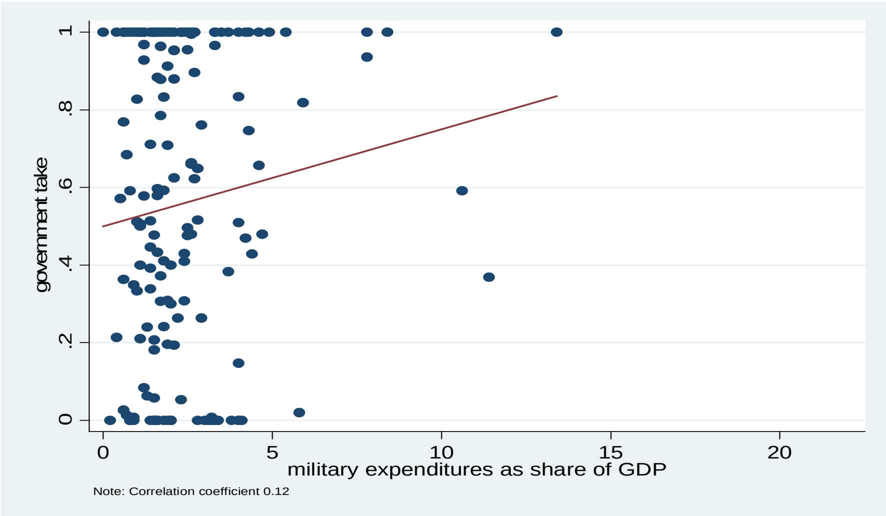
2.3. The impact of political instability on natural resource extraction

There is also a small empirical literature on how political instability affects resource extraction. The results indicate that the presence of conflict leads to distortions; both over- and under-exploitation are observed in reality. According to Deacon (1999) and Bohn and Deacon (2000), insecure property rights lead to excessive deforestation. In contrast, for other natural resources that need more investment and a more sophisticated extraction technology (e.g., minerals), ownership risk can result in inefficiently low investment and extraction. Bohn and Deacon (2000) find that oil drilling is reduced in more risky countries. Deacon and Mueller (2006: 136) summarize the findings of this empirical literature as follows: “In simple situations, insecure tenure for resource stocks leads to premature and excessive depletion. When resource extraction is capital intensive, however, insecure ownership can raise extraction costs and diminish or eliminate the incentive to deplete resource stock.” This empirical literature takes political instability and property rights protection as exogenous. Our model suggests, however, that ignoring the bi-directional causality links between natural resources and conflict can bias estimates.

2.4. Other stylized facts

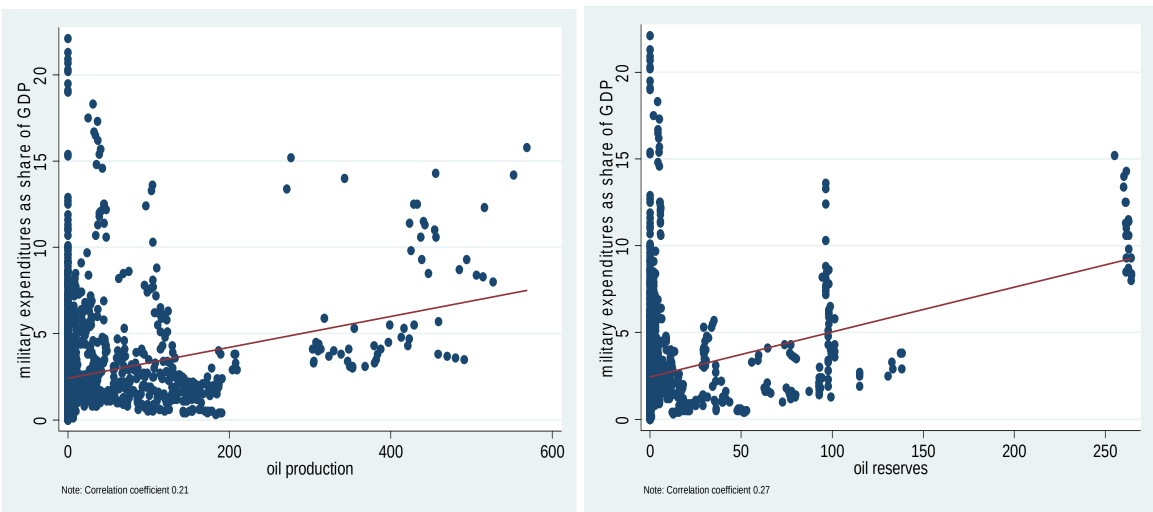
We also offer some stylized suggestive correlations, which are in line with the predictions of our theory. For a description of the data, see appendix A. These stylized facts reflect correlation rather than causality, and are simply meant to motivate part of our analytical results. Figure 1 suggests a positive correlation between the license fee paid by foreign mining companies to the host government and military expenditures as percentage of GDP.[5] This is consistent with the idea that countries with more secure regimes can extract greater license fees from foreign mining companies.

Figure 1: Licence fees and military expenditures



The two panels of figure 2 indicate a positive correlation between oil production or oil reserves and military expenditures. This is in line with our prediction that resource-rich countries have greater incentives to build a large army.

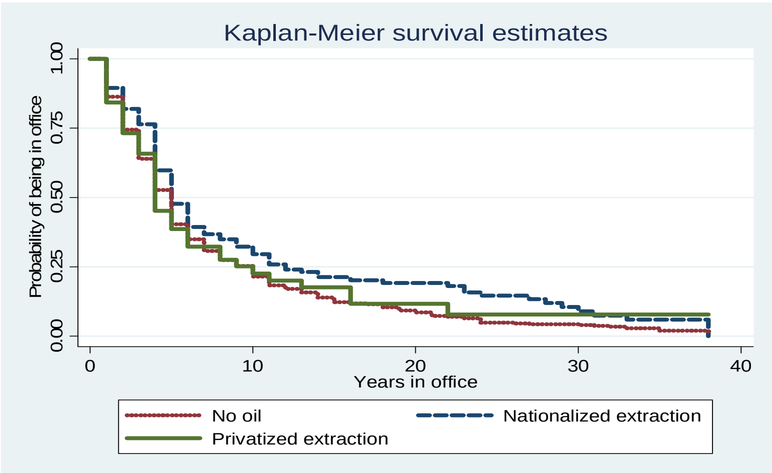
Figure 2: Oil production, oil reserves and military expenditures



[5] Some extreme outliers have been removed in figures 1 and 2, but the correlation coefficients are based on the sample including outliers. Without outliers they would be slightly higher.

We also find in the data that military expenditures seem to be higher in non-democratic and corrupt countries, which is in line with our analysis. Finally, figure 3 suggests that governments tend to have better chances of staying in office for longer when a country produces oil, and a fortiori when the petroleum resources are extracted by a nationalized company (cf., Smith, 2004, who finds that oil increases regime duration, but does not distinguish between private and public oil extraction).

Figure 3: Regime duration and oil extraction



3. Modelling Resource Conflict and Private versus Public Resource Exploitation

We consider a two-period, resource-rich economy with a government G whose term of office at the end of the first period is contested by rebels R.[6] We assume, for simplicity, that both the rate of interest and the time preference of the government equal zero. If the government exploits the natural resources itself, it can either extract them quickly leading to revenue $N_G - \rho$ in period 1 and zero in period 2 or can extract them in a balanced manner leading to revenue $N_G/2$ each period. Balanced exploitation would be optimal under the Hotelling rule if extraction costs are zero (and the interest rate is zero). Quick depletion is inefficient from the Hotelling point of view and thus yields $\rho > 0$ less natural resource revenues in total.

[6] We abstract from multiple rebel factions. We also abstract from the possibility of repression where war is prevented by deterring rebels with government armies. This would yield no war for low, repression for intermediate, and war for high values of natural resource revenues, and requires a degree of representative or consensual political institutions – proxied by having to also pay something to rival groups whenever transfers are made to the own group – as well as asymmetry in the effects of the armed forces being raised on the re-election probability (Besley and Persson, 2010). If political institutions are to some extent consensual, we find that the nationalized outcome with rapacious depletion is unaffected but the one with balanced depletion leads to less fighting of both factions.

Instead of nationalized resource exploitation, the government can also delegate this to a more efficient private company M. This private mining company invests I in the first period in order to obtain natural resource revenues N_P in period two. For this privilege, it has to pay the government a license fee L. The private sector is assumed to be competitive. We further assume that $N_P - I > N_G > N_G - \rho$ holds, i.e., that private extraction is more efficient than balanced nationalized extraction and a fortiori than rapacious nationalized extraction. One way of interpreting this setup is that the government has access to alluvial natural resource deposits without having to invest in advanced mining technology whereas the private mining company has the knowledge and financial resources at its disposal to invest in exploitation technology to reach less easily accessible natural resource deposits. We treat the investment level I of the private mining company as given, but section 4 shows that our results carry over if I is endogenous.

The probability p of the government holding on to office and not being removed by the rebels increases with the fighting effort by the government group f_G and the quality of its army α but decreases with the fighting effort by the rebels f_R. More precisely, we have the familiar ratio-form contest success function $p = \alpha f_G/(\alpha f_G + f_R)$. The quality of the rebel army is normalized to one, but the government can use some of the resource revenues or license fee to buy weapons at a cost $C(\alpha)$, $C(1)=0$, $C'>0$, $C''\geq 0$ to boost the quality of its army to $\alpha > 1$. Note that roman capital letters followed by parentheses designate functions. In this section we take levels of α and $C(\alpha)$ as given. We discuss optimal investment in weapon stocks under various non-cooperative outcomes in section 5, which does not affect the results of this section.

Total time available to both the government and rebel factions for either work or fighting is normalized to unity. The time that the government and rebel groups do not fight (i.e., $1-f_G$ and $1-f_R$, respectively), they work and earn an exogenous wage W. For simplicity, we do not include wage W for period two, as this would be the same for all outcomes and therefore plays no role in the analysis. We could also allow for a psychic and casualty cost of war (e.g., $f_G D$ and $f_R D$, respectively), but analytically this is equivalent to increasing the wage with this cost of war (i.e., using $W+D$ rather than W as the wage)[7]. The group in power gets office rents B in each period (e.g., from bribes, status, ego). One can think of B being larger in countries that are autocratic and/or have high corruption levels. We assume that both governments and rebels are risk neutral, but it is straightforward to allow for risk aversion. In the following, we indicate the non-cooperative outcomes with conflict under rapacious nationalized extraction, balanced (Hotelling) national extraction and private exploitation by the superscripts Q, H and P, respectively. The cooperative outcome with peace will, in addition, be denoted by the superscript C.

[7] We abstract from the possibility that conflict adversely affects health and productivity of workers, destroys infrastructure, and thus lowers the wage (i.e., we ignore that W may depend negatively on f_G+f_R).

We assume the following timing: (1) the extraction method (*Q*, *H* or *P*) is selected, (2) license fees are paid and investment costs are incurred (if *P* is selected), (3) both factions decide on fighting levels, (4) the winner is announced, and (5) if the government stays in power the mining contract is honoured, while if the rebels enter office they expropriate the mining company.

Notice that all players solve the game by backward induction and take past costs and benefits as sunk. Further, note that the assumption that the license fee is paid up-front in the case of private exploitation eases exposition, but does not affect the results. As shown in appendix B, our results also hold if the license fee is partly or fully paid at the end of the period. A key assumption that we make is that the government honours mining contracts, i.e., it does not expropriate the private mining company in the second period, while rebels after victory do not respect past contracts and proceed to expropriations.[8] Although this simplifies the exposition, we do not need to make this contrast so sharply, as our results also go through if the government is somewhat more likely than rebels to honour mining contracts. Indeed, there is abundant evidence that this is the case; e.g. Le (2004) finds that unconstitutional government change harms private investment, and Guriev et al. (2009) and Albertus and Menaldo (2010) show that expropriations and nationalizations occur more often after regime change.[9]

Another key assumption that we make is that governments cannot credibly pre-commit ex-ante to how hard they will fight rebels in the future. The government thus faces a time inconsistency problem, because it would like to be able to credibly promise high future fighting efforts in order to obtain a larger license fee, but has incentives to renege on this later on. This assumption is in line with the large empirical literature showing that governments are generally unable to commit to future fighting efforts (cf., Walter, 2009, for a survey). However, it is interesting to see how this time inconsistency problem affects the results. Therefore we also discuss throughout the paper how results would change if pre-commitment to fighting efforts was possible (the case of private extraction with feasible pre-commitment to fighting efforts is labeled *PP*).

[8] Note that if the government would also never honour mining contracts, no private enterprise would ever want to do the initial investment and private extraction would not occur (which is not the case in reality).

[9] Examples of expropriation after coups and rebel victories include, among many others, Russia after the Bolshevik victory in 1917, Spain's Franco government after victory in the civil war in 1939, Cuba under Fidel Castro after 1959, Peru under Alvarado's Revolutionary Government after 1968, Libya under Gaddafi after 1969, Portugal's National Salvation Junta after 1974, and Iran after the 1978 revolution.

3.1. Benchmark: Peace and the cooperative outcome

The cooperative outcome avoids war, so has no fighting about office rents or resource revenues. Hence, the government does not invest in weapons, $\alpha = 1$. Further, $f_G^i = f_R^i = 0$, $i = CQ, CH, CP$. As a result, the payoff to rebels before compensation always equals the wage, $\Pi_R^i = W$, $i = CQ, CH, CP.$ The competitive license fee under privatized extraction will equal expected resource revenues minus the necessary investment outlay, $L = N_P - I$. Due to the inefficiency losses of too quick depletion (i.e., $\rho > 0$), it never pays for the government to deplete resources rapaciously under nationalized exploitation. The government would thus follow the Hotelling rule. However, private exploitation is more efficient than nationalized extraction and is thus preferred to balanced and a fortiori to rapacious nationalized extraction. Given that the government faction in each of the three regimes gets office rents B in each period and can work undisturbed earning wage income W, we thus have the following ranking of government payoffs under the peace outcome:

(1) $$\Pi_G^C = \Pi_G^{CP} = 2B + W + N_P - I > \Pi_G^{CH} = 2B + W + N_G > \Pi_G^{CQ} = 2B + W + N_G - \rho.$$

Hence, privatized extraction is the preferred mode under cooperation. We will thus denote the preferred cooperative outcome with the superscript C instead of CP. Since there is no fighting, the cooperative outcome can only be sustained if the rebels receive side payments from the government (and implicitly from the private mining company). The magnitude of these side payments can be determined from the Nash bargaining solution, where the outcome depends on the fallback positions for both the government and the rebels. This cooperative outcome is only feasible if the government credibly commits to pay the transfers and rebels credibly commit to renounce violence. Below we shall discuss situations where this credible commitment to maintaining peace is not possible and non-cooperative outcomes occur.

3.2. Fighting under balanced nationalized exploitation

Payoffs to the government and rebel factions are, respectively, given by

(2) $$\Pi_G^H = B + \frac{N_G}{2} - \mathrm{C}(\alpha) + \left(\frac{\alpha f_G^H}{\alpha f_G^H + f_R^H}\right)\left(B + \frac{N_G}{2}\right) + (1 - f_G^H)W \quad \text{and}$$
$$\Pi_R^H = \left(\frac{f_R^H}{\alpha f_G^H + f_R^H}\right)\left(B + \frac{N_G}{2}\right) + (1 - f_R^H)W,$$

where superscript *H* denotes balanced (Hotelling) extraction. The first two terms in the expressions for the government faction payoff indicate office rent plus resource revenues in period one, the third term indicates the cost of procuring weapons to the government, the fourth term indicates the expected office rent plus resource revenue in period 2, and the final term is the wage income earned during the time that the government faction is not fighting. The pay-off to the rebels is similar but without the first three terms. The non-cooperative Nash equilibrium in fighting efforts is then given by:[10]

$$f_G^H = f_R^H = \frac{\alpha}{(1+\alpha)^2}\frac{B+\frac{N_G}{2}}{W}. \tag{3}$$

where we suppose for the time being that investment in weapons α is exogenous (see section 5). Hence, government and rebels fight more if office rents *B* are high, resource revenues in the second period are high and return on work *W* is low. Both government and rebels are deterred from fighting if the government has access to superior weapons ($\partial\left[\alpha/(1+\alpha)^2\right]/\partial\alpha = -(\alpha-1)/(1+\alpha)^3 < 0$ provided $\alpha > 1$). This is a general result for these standard ratio-form contest success functions: higher asymmetry between fighting technologies of the conflict parties decreases total fighting efforts in equilibrium.

3.3. Fighting under rapacious nationalized exploitation

Under rapacious nationalized exploitation the government exploits its natural resources all in one go, which is inefficient from the Hotelling point of view but has the advantage that the rebels cannot appropriate the natural resources. The payoffs to the government and rebel factions are thus given by

$$\begin{aligned}\Pi_G^Q &= B + N_G - \rho - \mathrm{C}(\alpha) + \left(\frac{\alpha f_G^Q}{\alpha f_G^Q + f_R^Q}\right)B + (1-f_G^Q)W \quad \text{and} \\ \Pi_R^Q &= \left(\frac{f_R^Q}{\alpha f_G^Q + f_R^Q}\right)B + (1-f_R^Q)W,\end{aligned} \tag{2′}$$

respectively, where superscript *Q* denotes the outcome under rapacious nationalized extraction. The difference with (2) is that the government now mines all the resources in period one with an efficiency

[10] We suppose groups perfectly monitor each others' military strength. In a classic dynamic guns-versus-butter dilemma, not being able to monitor each others' military strength leads to a bigger build-up of armaments and lower social welfare (van der Ploeg and de Zeeuw, 1990).

loss ρ and has no resource revenue in period two; neither has the rebel faction if they gain office. The non-cooperative Nash equilibrium in fighting efforts under quick depletion yields the symmetric outcome

$$(3') \qquad f_G^Q = f_R^Q = \frac{\alpha}{(1+\alpha)^2}\frac{B}{W} < f_G^H = f_R^H .$$

Under quick depletion there is less fighting by both government and rebels, since each of them is only concerned with office rents as there are no resource revenues in the second period.

Proposition 1: Government and rebels fight more vigorously if office rents are high, anticipated resource revenues are high and the return on working is low. Both are deterred from fighting if the government has access to superior weapons. Fighting intensity is largest if fighting strengths are symmetric. With rapacious extraction both government and rebels fight less intensively than with balanced extraction.

Proof: Follows from equations (3) and (3′).

Intuitively, rapacious depletion is less bellicose since factions are only concerned with office rents as there are no natural resource revenues left in the future. Hence, balanced extraction is efficient from a Hotelling point of view, but not from a political point of view as it induces more fighting and less productive activities. Proposition 1 is supported by empirical evidence showing that countries which are more corrupt and less democratic (i.e., with high *B*) and poor (i.e., low *W*) experience higher fighting efforts and are more likely to experience civil war (e.g., Reynal-Querol, 2002; Fearon and Laitin, 2003; Collier and Hoeffler, 2004; Cederman and Girardin, 2007; Collier and Rohner, 2008; Collier et al., 2009).

3.4. Fighting and incentive compatible license fee under private exploitation

We suppose that if the government concludes a contract with the mining company, this contract is binding and enforceable. However, if the government is removed from office, the rebels do not feel bound to the contract. Hence, they grab all natural resource revenue and the mining company receives nothing.[11] We shall start with the main timing and commitment scenario outlined above (denoted by the superscript *P*), where governments cannot credibly commit to future fighting levels. The timing sequence is such that first mining licenses are auctioned, then the decision of how much to work or fight is made by both the government and rebel factions, then the winner is announced and the natural resources are mined. The mining company solves the game backwards, i.e., it anticipates that the government will take the license

[11] An alternative is that Nash bargaining takes place between the rebels and the mining company. Our main qualitative insights also hold for this alternative assumption.

fee as sunk and given when selecting the fighting effort. The government receives in period one office rent, license fee and wage income earned during the time that the government faction is not fighting and, if it stays in office, it receives in period two the expected office rents. If the rebels win they renege on the contract with the mining company and thus receive in period two the expected value of office rents plus resource revenue. The payoffs to the government and rebels can be written as:

(2″)
$$\Pi_G^P = B + L - \mathrm{C}(\alpha) + \left(\frac{\alpha f_G^P}{\alpha f_G^P + f_R^P} \right) B + (1 - f_G^P) W \quad \text{and}$$
$$\Pi_R^P = \left(\frac{f_R^P}{\alpha f_G^P + f_R^P} \right) \left(B + N_P \right) + (1 - f_R^P) W,$$

where the superscript *P* refers to the private extraction. The resulting non-cooperative Nash equilibrium in fighting efforts is given by the asymmetric outcome:

(3″)
$$f_G^P = \frac{\alpha B^2}{[(1+\alpha)B + N_P]^2} \frac{B + N_P}{W} < f_R^P = \frac{\alpha B (B + N_P)}{[(1+\alpha)B + N_P]^2} \frac{B + N_P}{W}.$$

The rebels fight more and work less than the government faction, since they do not feel bound by the contract with the mining company and aim to grab all resource revenues in the second period. Hence, the chances of the government staying in office, *p*, are lower under private than nationalized extraction:

(4)
$$p^P = \frac{\alpha B}{(1+\alpha)B + N_P} < p^H = p^Q = \frac{\alpha}{1+\alpha}.$$

Furthermore, higher projected resource revenues induces rebels to fight more ($\partial f_R^P / \partial N_P > 0$) but the government to fight less ($\partial f_G^P / \partial N_P < 0$ if $N_P > (\alpha - 1) B$ which holds if $\alpha = 1$). The government faction thus fights less while rebels fight more under private than under nationalized extraction.

The following participation constraint needs to hold, which says that expected natural resource revenues must at least cover the initial investment outlay plus the license fee:

(5)
$$\left(\frac{\alpha f_G^P}{\alpha f_G^P + f_R^P} \right) N_P \geq I + L.$$

Given our assumption of perfect competition among mining companies, the above incentive compatibility constraint holds with equality.[12] In equilibrium the mining company thus pays the following license fee:

$$L^P = \left[\frac{\alpha B}{(1+\alpha)B + N_P} \right] N_P - I. \tag{6}$$

The license fee is higher if the weapon technology of the government is better (higher α), since then the property rights of the government and thus of the mining company are better protected. Further, the license fee increases in office rents B and expected future resource revenues N_P [13] and is reduced by the necessary exploitation investment outlays.

Now consider an alternative, less realistic scenario where the government can pre-commit itself to future fighting levels before the mining licenses are auctioned. This scenario is denoted by the superscripts *PP*. In this case the factions commit to fighting levels first, then the licenses are auctioned, fighting occurs, and after that the winner is selected and resources are mined. In this case, the government maximizes its pay-off given in (2″) subject to the participation constraint (5). The resulting Nash equilibrium for the fighting efforts is:

$$f_G^{PP} = f_R^{PP} = \frac{\alpha}{(1+\alpha)^2} \frac{B + N_P}{W} > f_G^H = f_R^H > f_G^Q = f_R^Q \quad \text{as} \quad N_P > N_G / 2. \tag{3‴}$$

We see that total fighting by government and rebel factions is higher if the government can pre-commit itself to militarily defend mining rights in the privatized extraction regime:[14]

[12] Licenses can be allocated via a competitive auction (cf., Boadway and Keen, 2010, for an excellent survey on the taxation of natural resources). In general, a balance must be struck between efficient allocation of oil rights and high revenues for the government. A simultaneous first-price sealed-bid auction may suffice when competition is weak and values are additive; with more complex value structures dynamic auctions with package bids such as the clock-proxy auction are preferable (Cramton, 2007).

[13] This follows from $\partial L / \partial B = \alpha N_P{}^2 / [(1+\alpha)B + N_P]^2 > 0$, $\partial L / \partial N_P = \alpha(1+\alpha)B^2 / \left[(1+\alpha)B + N_P\right]^2 > 0$. Note that $\partial^2 L / \partial^2 B < 0$ and $\partial^2 L / \partial^2 N_P < 0$.

[14] It can be easily seen that $f_G^{PP} + f_R^{PP} > f_G^P + f_R^P$ requires $2/(1+\alpha)^2 > B(2B + N_P)/[(1+\alpha)B + N_P]^2$. The left-hand side equals the right-hand side if $N_P = 0$. Moreover, the left-hand side is independent of N_P, while the right-hand side is decreasing in N_P. Hence, for positive N_P the left-hand side is larger than the right-hand side.

$$f_G^{PP} + f_R^{PP} > f_G^{H} + f_R^{H} > f_G^{Q} + f_R^{Q} \text{ and}$$

(3′′′′)
$$f_G^{PP} + f_R^{PP} = \frac{2\alpha}{(1+\alpha)^2}\frac{B+N_P}{W} > f_G^{P} + f_R^{P} = \frac{\alpha B(B+N_P)(2B+N_P)}{[(1+\alpha)B+N_P]^2 W}.$$

Further, being able to pre-commit to fighting efforts also raises its chances of staying in office as $p^{PP} = p^{H} = p^{Q} > p^{P}$. As a result, the fee obtained from the mining company will be higher if the government is able to pre-commit itself:

(6′)
$$L^{PP} = \left[\frac{\alpha}{1+\alpha}\right]N_P - I > L^{P} = \left[\frac{\alpha B}{(1+\alpha)B+N_P}\right]N_P - I.$$

As is evident from equations (3″) and (3′″), without commitment the government does not have incentives to fight as much, as it has already pocketed the license fee from the mining company. Hence, not being able to commit to fighting induces an inefficient outcome.

Proposition 2: With extraction delegated to a private mining company and the government unable to commit to fighting ahead of the auction of mineral rights, the rebels fight more and work less than the government. Accordingly, chances of the government retaining office are lower under private than nationalized extraction. The mining company pays a higher license fee if the government has superior weapons and office rents are large. However, if the government can pre-commit to fighting ahead, there will be more fighting, a bigger license fee, and a bigger probability of staying in office.

Proof: Follows from equations (3″), (3′″), (3″″), (4), (6) and (6′).

In the core scenario where governments cannot commit to fighting effort, the rebels fight harder as they are not bound by the contract with the mining company and aim to grab all future resource revenues. This makes them more likely to gain office. All factors that favour the military prospects of the government (i.e., powerful weapons and large office rents) result in better property rights protection and lead to a higher licence fee. Anecdotal evidence suggests that international oil companies tend to offer “bad” exploitation deals to politically instable countries, and that at least in some instances these companies have engaged in direct military support of the government, for example by furnishing military equipment and weaponry (cf., the cases of oil companies in Colombia, of Total in Burma or of Elf in Chad, Republic of Congo and Angola) (Swanson, 2002; Humphreys, 2005). Our predictions are also backed up by systematic evidence from firm-level data indicating that governments in countries with higher democratic accountability, lower political risk and higher bureaucratic ability receive a larger share of natural resource rents while multinationals receive less (McMillan and Waxman, 2007).

3.5 Comparing the payoffs under nationalized and privatized extraction

For nationalized extraction, the substitution of fighting efforts (3) and (3′) into, respectively, payoff functions (2) and (2′) yields the following non-cooperative Nash equilibrium payoffs for the government:

(7) $$\Pi_G^H = B + \frac{N_G}{2} - \mathrm{C}(\alpha) + W + \frac{\alpha^2}{(1+\alpha)^2}\left(B + \frac{N_G}{2}\right)$$

(7′) $$\Pi_G^Q = B + N_G - \rho - \mathrm{C}(\alpha) + W + \frac{\alpha^2}{(1+\alpha)^2} B .$$

The government prefers balanced to rapacious exploitation if and only if the efficiency loss ρ of rapacious extraction is above the threshold $\rho^* \equiv \frac{1+2\alpha}{2(1+\alpha)^2} N_G$. The relative attractiveness of rapacious exploitation thus increases in the total resource rents N_G and decreases in the government's fighting strength α and the efficiency cost of rapacious resource depletion ρ. Further, note that rebels always prefer the government to postpone depletion in a balanced Hotelling manner as this offers them more scope to appropriate natural resource revenues.

Substituting (3″) and (6) into (2″) yields the government payoff under private resource extraction in case it cannot pre-commit to fighting and protecting the rights of the mining company:

(7″) $$\Pi_G^P = B - \mathrm{C}(\alpha) - I + W + \frac{\alpha B(B+N_P)(\alpha B + N_P)}{[(1+\alpha)B + N_P]^2} .$$

The government thus prefers private extraction *P* if the following condition holds:

(8) $$\frac{\alpha B(B+N_P)(\alpha B + N_P)}{\left[(1+\alpha)B + N_P\right]^2} - I > \mathrm{Max}\left\{ N_G - \rho + \frac{\alpha^2}{(1+\alpha)^2} B, \frac{N_G}{2} + \frac{\alpha^2}{(1+\alpha)^2}\left(B + \frac{N_G}{2}\right)\right\} .$$

This is the case if N_G and *I* are relatively small and ρ is large. Further, private extraction (*P*) is preferred by the government if its weapon strength α is very large and office rents *B* are large.[15] In contrast, the government prefers balanced nationalized extraction if $\rho > \rho^*$ and the following condition holds:

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[15] As $\alpha \to \infty$ equation (8) becomes $B + N_P - I > \mathrm{Max}\left\{N_G - \rho + B, N_G + B\right\}$, which always holds. We also have $\partial\left(\frac{\alpha B(B+N_P)(\alpha B + N_P)}{[(1+\alpha)B + N_P]^2} - \frac{\alpha^2}{(1+\alpha)^2} B \right) / \partial B > 0 \cdot$

(9) $$\frac{\alpha B(B+N_P)(\alpha B+N_P)}{[(1+\alpha)B+N_P]^2}-I<\frac{N_G}{2}+\frac{\alpha^2}{(1+\alpha)^2}\left(B+\frac{N_G}{2}\right).$$

Rapacious nationalized extraction is preferred if $\rho<\rho^*$ and the following condition holds:

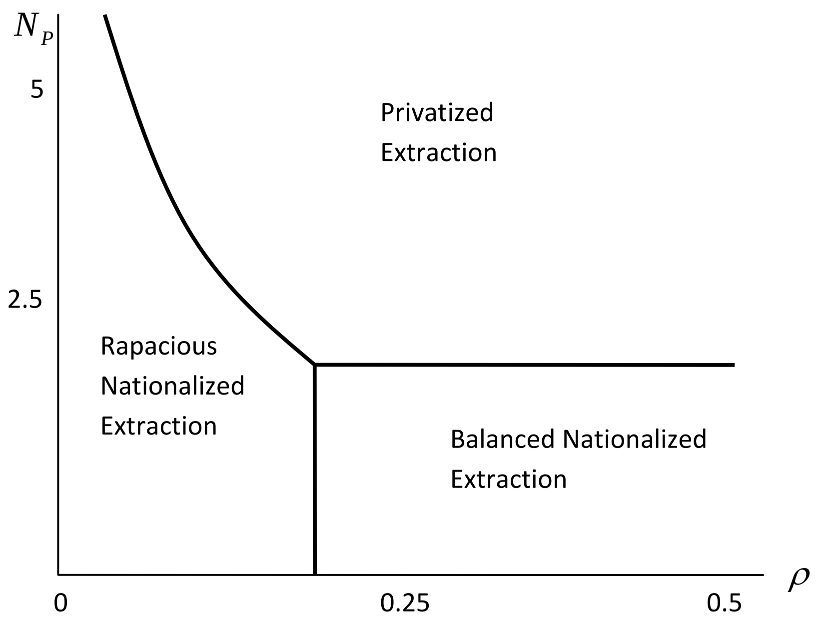
(10) $$\frac{\alpha B(B+N_P)(\alpha B+N_P)}{[(1+\alpha)B+N_P]^2}-I<N_G-\rho+\frac{\alpha^2}{(1+\alpha)^2}B.$$

The various regimes are displayed graphically in figure 4 for various parameter combinations[16]. Panel (a) does this for combinations of ρ and N_P. Privatized extraction dominates for high returns to privatized production N_P and large efficiency losses of rapacious depletion ρ. Rapacious depletion is selected for low levels of N_P and ρ, while Hotelling extraction is chosen for low N_P and high ρ.

Panel (b) displays the same three zones for the same parameter values (and now $N_P=2$), but this time in the space ρ and α. Privatized exploitation takes place for high levels of α, while we predict rapacious extraction for low α and low ρ. For low α and high ρ balanced depletion takes place. Finally, panel (c) indicates that privatized dominates nationalized extraction for high values of *B*.

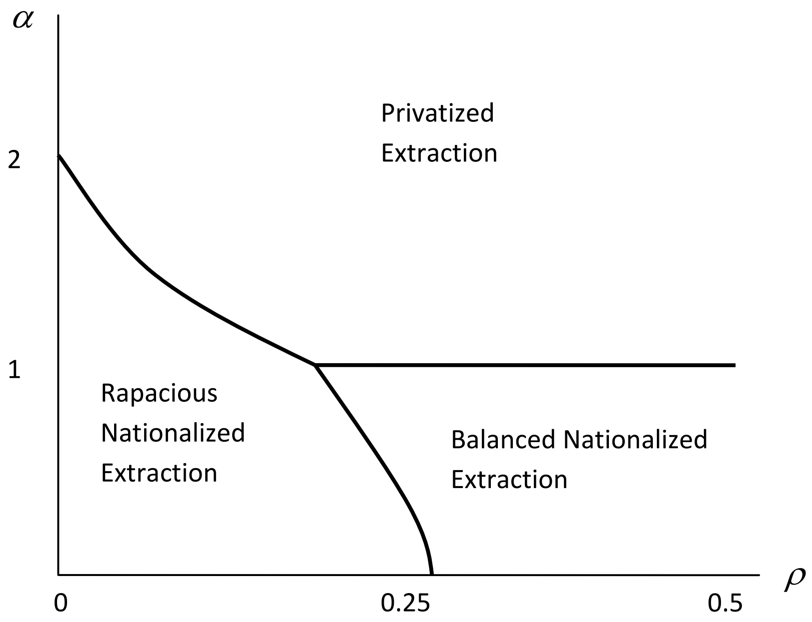
Figure 4: Extraction regimes

(a) Efficiency of privatized extraction N_P and cost of rapacious depletion ρ

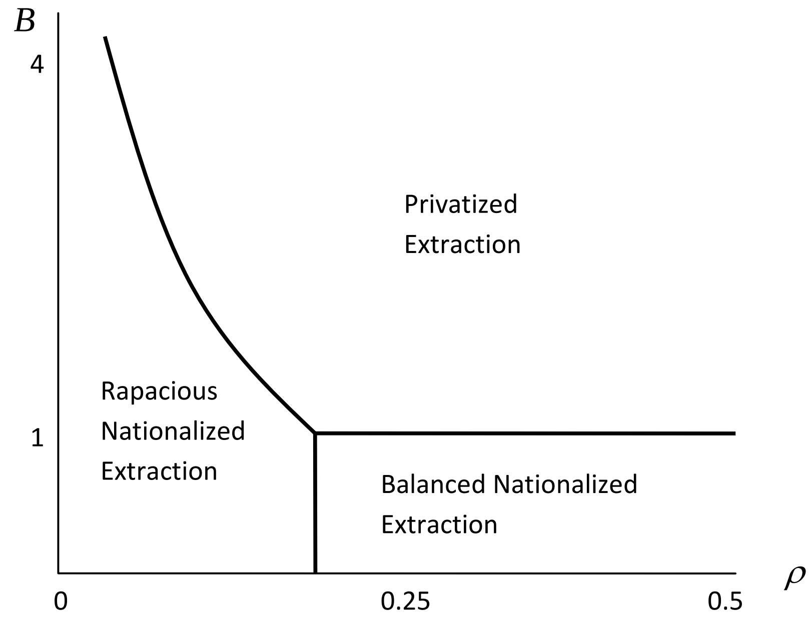


[16] For figure 4 we have used the parameter values B=1, N_G=0.5, α =1, and I=0.

(b) Weapon technology of government *α* and cost of rapacious depletion *ρ*



(c) Office rents *B* and cost of rapacious depletion *ρ*



Under the alternative assumption that pre-commitment to fighting levels is feasible, we have:

(7‴) $$\Pi_G^{PP} = B - \mathrm{C}(\alpha) - I + W + \frac{\alpha^2}{(1+\alpha)^2}\left(B + N_P\right),$$

where $\Pi_G^{PP} > \Pi_G^H \Leftrightarrow \frac{\alpha^2}{(1+\alpha)^2}\left(N_P - \frac{N_G}{2}\right) > \frac{N_G}{2} + I$ and $\Pi_G^{PP} > \Pi_G^Q \Leftrightarrow \frac{\alpha^2}{(1+\alpha)^2} N_P > N_G - \rho + I$.

As before, Π_G^{PP} becomes more attractive for large N_P, α and ρ, and low N_G.

Proposition 3: If credible commitment to peace and side payments are feasible, cooperation sustains peace with extraction delegated to a more efficient private mining company and rebels receiving a share of natural resource rents. Without credible commitment and side payments, fighting occurs. The government then prefers rapacious to balanced depletion if the efficiency cost of rapacious depletion ρ is small. In the absence of the government being able to pre-commit to fighting effort ahead of the auctioning of mineral rights, privatized exploitation is preferred by the government if resource rents N_G and investment cost I are small relative to N_P and the efficiency loss of rapacious depletion ρ is large, the government can rely on a powerful army (high α), and office rents B are large.

Proof: Follows from equations (1), (8) and the condition $\rho > \rho^*$.

The first part of this proposition relating to the cooperative outcome is in line with the empirical evidence that shows that the resource curse can be turned into a blessing in countries with good institutions (Mehlum et al., 2006). Indeed, social tensions and distributive conflict are less salient if consensual political institutions and power-sharing are in place (Reynal-Querol, 2002; Cederman and Girardin, 2007). There is also empirical evidence which suggests that democracies opt less frequently for (nationalized) rapacious depletion (Li and Reuveny, 2006) and that nationalization of oil companies is more likely to occur if the quality of institutions is low (Guriev, et al., 2009).

The rest of proposition 3 focuses on situations where the cooperative outcome does not occur. In this case, higher office rents make it more likely that a government selects more efficient privatized resource extraction, so we expect office rents and natural resource output to be positively correlated. Since corruption increases the office rents of being in power, this corroborates evidence that suggests that natural resources production is associated with more corruption (Isham et al., 2005). More precisely, Bhattacharyya and Hodler (2010) find that the positive correlation between oil and corruption only holds for undemocratic countries (i.e., when it is harder to achieve the cooperative outcome in our setting). However, while the prevailing literature focuses on natural resources destroying good governance in rentier states, we argue that there also exists another channel with the opposite direction of causality. Undemocratic and corrupt regimes find it easier to commit to putting down rebels as the stakes of keeping office are very high. These incentives for high levels of government fighting lead to a better protection of property rights for private companies, which encourages investment and extraction.

For completeness, we characterize the Nash equilibrium of our basic model in the following proposition:

Proposition 4: If credible commitment to peace and side payments are feasible, there is a cooperative outcome with private extraction (*P*) and no fighting. If credible commitment or side payments are not feasible, there is a non-cooperative outcome of the following form.

- For parameter values satisfying equation (8), private extraction (*P*) takes place and fighting efforts f_G^P, f_R^P are given by equation (3″).

- For parameter values satisfying equation (9) and $\rho > \rho^*$, balanced nationalized extraction (*H*) takes place and fighting efforts f_G^H, f_R^H are given by equation (3).

- For parameter values satisfying equation (10) and $\rho < \rho^*$, rapacious nationalized extraction (*Q*) takes place and fighting efforts f_G^Q, f_R^Q are given by equation (3′).

This fully characterizes the Nash equilibrium for all parameter values.

Proof: Follows from equations (3), (3′), (3″), (8), (9) and (10).

4. Endogenous Private Mining Investments

Now consider endogenous private mining investments. As before, we first consider the case where pre-commitment to future fighting efforts is infeasible (denoted by superscript *P*). The mining company invests *I* in the first period to obtain natural resource revenues $N_P = \mathrm{N}(I),\ \mathrm{N}' > 0,\ \mathrm{N}'' \leq 0$ in the second period by extracting more than only alluvial natural resource deposits. The timing is such that the government first sets the license fee and the mining company then selects the investment level, and after that fighting efforts are selected. We proceed by backward induction. The mining company decides on its optimal exploitation investment after the cost of the license fee has been sunk. Given the license fee and anticipated fighting efforts of government and rebel armies, the mining company thus maximizes profits

$\Pi_M^P = \left(\dfrac{\alpha f_G^P}{\alpha f_G^P + f_R^P} \right) \mathrm{N}(I) - I - L$ where the subscript M refers to the mining company. Hence, expected marginal revenue from natural resources must equal the marginal cost of exploitation investment:

$$\text{(11)} \qquad \left(\frac{\alpha f_G^P}{\alpha f_G^P + f_R^P} \right) \mathrm{N}'(I) = 1 \quad \Rightarrow \quad I^P = \mathrm{I}\left(\overset{+}{\alpha f_G^P / f_R^P} \right) \text{ and } N_P^P = \mathrm{N}^*\left(\overset{+}{\alpha f_G^P / f_R^P} \right),$$

where $\mathrm{I}' = -\mathrm{N}' / \left\{ (\alpha f_G^P / f_R^P) \left[1 + \alpha f_G^P / f_R^P \right] \mathrm{N}'' \right\} > 0$ and $\mathrm{N}^{*\prime} = \mathrm{N}'\mathrm{I}' > 0$ follows from total differentiation of the first part of (11). Hence, if the government makes a relatively large fighting effort (large ratio f_G^P / f_R^P) and has a superior weapon technology (high α), the property rights on natural resource rents are better protected and the mining company's natural resources are less likely to be appropriated by the rebels. As a result, the mining company invests more and is thus able to extract more natural resources. The relative fighting efforts (3″) are used to rewrite (11) and to solve simultaneously for equilibrium mining investment and resource output:

$$\text{(11}'\text{)} \qquad I^P = \mathrm{I}\left(\frac{\alpha B}{B + N_P} \right) \text{ and } N_P^P = \mathrm{N}^*\left(\frac{\alpha B}{B + N_P} \right) \quad \Rightarrow \quad I^P = \mathrm{I}^*\left(\overset{+}{B}, \overset{+}{\alpha} \right) \text{ and } N_P^P = \mathrm{N}^{**}\left(\overset{+}{B}, \overset{+}{\alpha} \right).$$

Higher office rents and a higher quality of the government army make it more likely that the government stays in power, so that the contract with the mining company will not be revoked by the rebels. Consequently, exploitation investment and natural resource output will be higher. Armed with (11′), we use (6) to obtain the incentive-compatible license fee that is paid by the mining company:[17]

$$\text{(6}'\text{)} \qquad L^P = \left[\frac{\alpha B}{(1+\alpha)B + \mathrm{N}^{**}(B,\alpha)} \right] \mathrm{N}^{**}(B,\alpha) - \mathrm{I}^*(B,\alpha) \equiv \mathrm{L}(\overset{+/-}{B}, \overset{+/-}{\alpha}).$$

Equation (6′) captures (net) expected resource revenues received by the government. On the one hand, license revenues are higher if the quality of government weapons α and office rents B are higher on

[17] Total differentiation of (6′) yields $\mathrm{d}L^P = \underbrace{\alpha \left[(1+\alpha)B^2 \mathrm{N}_B^{**} + N_P{}^2 \right] \{ [(1+\alpha)B + N_P]^{-2}}_{+} \mathrm{d}B \underbrace{-\mathrm{I}_B^*}_{-} \mathrm{d}B$ $\underbrace{+B\left[\alpha(1+\alpha)B\mathrm{N}_\alpha^{**} + N_P(B + N_P) \right] [(1+\alpha)B + N_P]^{-2}}_{+} \mathrm{d}\alpha \underbrace{-\mathrm{I}_\alpha^* \mathrm{d}\alpha}_{-}$, which gives the partial derivatives of L(.).

account of the higher probability of the government holding on to office[18] and the higher level of mining investment and consequent higher level of natural resource revenues. On the other hand, these effects are offset somewhat by higher exploitation investments which are also higher if office rents are higher and the government army is better.

If the government can credibly pre-commit to future fighting effort, the mining company maximizes $\Pi_M^{PP} = \left(\dfrac{\alpha f_G^P}{\alpha f_G^P + f_R^P} \right) \mathrm{N}(I) - I^{PP} - L^{PP}$, so the first order condition is $\left(\dfrac{\alpha}{\alpha + 1} \right) \mathrm{N}'(I^{PP}) = 1$. Since the mining company can now be sure its mineral rights are better protected, mining investment and revenue are higher than before, $I^{PP} = \mathrm{I}\left(\overset{+}{\alpha} \right) > I^P$ and $N_P^P = \mathrm{N}^*\left(\overset{+}{\alpha} \right) > N_P^{PP}$ from (3″) and (11), and the license fee is higher as well:[19]

$$(6'') \qquad L^{PP} = \left[\frac{\alpha}{\alpha + 1} \right] \mathrm{N}^*(\alpha) - \mathrm{I}(\alpha) > L^P.$$

Proposition 5: Mining investments and resulting natural resource production are greater if property rights are better protected, which occurs if the government enjoys substantial office rents and has superior weapons (and, of course, if the government can pre-commit to future fighting efforts). In that case, the government is likely to have a bigger chance of holding on to office. This together with the higher level of resource revenues boosts the license fee paid by the mining company. These effects are offset somewhat by the higher cost of mining investment.

Proof: Follows from equations (11′), (6′) and (6″).

This is in line with empirical evidence indicating that in politically unstable countries the levels of resource depletion is often suboptimal (Bohn and Deacon, 2000).

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[18] Note that from (4) and (11′), we have $p^P = \alpha B / [(1+\alpha)B + \mathrm{N}^{**}(\alpha, B)] \equiv p^*(\overset{+}{B}, \overset{+}{\alpha})$. Also, note that $\partial p^P / \partial B > 0$ and $\partial p^P / \partial \alpha > 0$, as long as N_B^{**} and N_α^{**} are not too large.

[19] Using (3″) and $N > 0$, we see that all three terms in (6′) are less than the corresponding ones in (6″). Since it is easy to establish that $\mathrm{N}^*\left(\alpha \overset{+}{f_G^P} / f_R^P \right) - \mathrm{I}\left(\alpha \overset{+}{f_G^P} / f_R^P \right)$ increases in $\alpha f_G^P / f_R^P$ as $\mathrm{N}^{*\prime} - \mathrm{I}' = (f_R^P / f_G^P)\mathrm{I}' > 0$ from the first-order condition for optimal mining investment.

5. Government Investment in Weapons

What happens if government investment in weapons α is made endogenous? For expositional ease we focus here first on the simpler case where the government can pre-commit to fighting efforts (PP), before considering the more realistic case of no commitment. The timing is as follows: first, the extraction method is selected, then simultaneous pre-commitment to fighting efforts and weapon investment occurs, after that the license fee is paid, and then fighting takes place and the winner is announced. Rebels do not invest in weapons and simply fight by fielding soldiers. To keep matters simple, we also suppose that exploration investments *I* are exogenous as in sections 2 and 3. Using the expression for the incentive-compatible license fee (6) in the pay-off expressions (2″), the government and rebel pay-offs under private extraction with pre-commitment to investment in weapons and fighting efforts are $\Pi_G^{PP} = B - \mathrm{C}(\alpha^{PP}) + \left(\dfrac{\alpha^{PP} f_G^{PP}}{\alpha^{PP} f_G^{PP} + f_R^{PP}} \right)(B + N_P) - I + (1 - f_G^{PP})W$ and Π_R^{PP} as before. The investment in weaponry that maximizes the government payoff in the various outcomes is set so that the marginal cost of weapons equals the marginal change in the probability of staying in office times the stake of staying in office:

$$\text{(12)} \qquad \mathrm{C}'(\alpha^H) = \left(\frac{\partial p^H}{\partial \alpha^H} \right)\left(B + \frac{N_G}{2} \right), \quad \mathrm{C}'(\alpha^Q) = \left(\frac{\partial p^Q}{\partial \alpha^Q} \right) B \quad \text{and} \quad \mathrm{C}'(\alpha^{PP}) = \left(\frac{\partial p^{PP}}{\partial \alpha^{PP}} \right)(B + N_P),$$

where $\partial p^i / \partial \alpha^i = f_G^i f_R^i / (\alpha^i f_G^i + f_R^i)^2 > 0, \quad i = H, Q, PP.$ Notice that in each outcome the stake of staying in office corresponds to the office rents plus the revenue from oil extraction. A Nash equilibrium in fighting efforts yields (3) and (3′) for the nationalized outcomes with balanced and rapacious depletion. As shown in (3′′′), with private extraction and pre-commitment to investment in weapons and fighting efforts, the armies that are being fielded by the government and the rebels are the same, and bigger than under nationalized extraction due to the larger oil revenues that can be expected under private oil extraction:

$$\text{(3′′′)} \qquad f_G^{PP} = f_R^{PP} = \frac{\alpha^{PP}}{(1 + \alpha^{PP})^2} \left(\frac{B + N_P}{W} \right) > f_G^H = f_R^H > f_G^Q = f_R^Q.$$

We thus obtain the following first-order conditions for the optimal investment in weapon stocks:

$$\text{(12′)} \quad \mathrm{C}'(\alpha^H)(1 + \alpha^H)^2 = B + \frac{N_G}{2}, \quad \mathrm{C}'(\alpha^Q)(1 + \alpha^Q)^2 = B \text{ and } \mathrm{C}'(\alpha^{PP})(1 + \alpha^{PP})^2 = B + N_P.$$

The third expression of (12′) gives investment in weapons in the private extraction outcome with pre-commitment as an increasing function of natural resource revenues as a fraction of office rents and an increasing function of office rents themselves; hence, $\alpha^{PP} = \mathrm{A}(B + \overset{+}{N_P})$. Together with the first two expressions of (12′), this gives the following ranking:

(13) $$\alpha^{PP} = \mathrm{A}(B + \overset{+}{N_P}) > \alpha^{H} = \mathrm{A}(B + \overset{+}{N_G} / 2) > \alpha^{Q} = \mathrm{A}(\overset{+}{B}).$$

We thus see that the government invests more in weaponry under balanced than under rapacious depletion, since the stake to be fought over is larger as it includes future resource revenues as well as office rents. As a result, its grip on office is stronger ($p^H > p^Q$). We also see that investment in weaponry under private extraction with full pre-commitment is larger than under balanced (and a fortiori rapacious) nationalized extraction and thus that the grip on office is stronger yet again ($p^{PP} > p^H > p^Q$). The reason is that the government realizes that its probability of re-election is an increasing function of resource revenues as well as investment in weaponry. Note that investment in weapons is generally higher if fewer soldiers are being fielded by the incumbent and the rebel army is larger.[20] It follows that it is attractive for the government to invest more in weapons.

Consider now the situation that the government cannot pre-commit to promises to invest in weaponry or to deliver these investments and to fighting efforts before licenses are auctioned in the private extraction outcome (indicated by the superscript *P*). The license fee is then a bygone at the moment decisions are made about fighting efforts and weapon investments so the stake is *B* and not *B* + *L*. The factions thus solve the game backwards with the main difference being that the armies that are being fielded are given by expression (3″) and thus the incumbent's probability of holding to office is given by (4). It follows that the first-order condition for the optimal investment in weapons under private extraction with no commitment is given by $\mathrm{C}'(\alpha^P)(1 + \alpha^P + N_P / B)^2 = B + N_P$. We can use the implicit function theorem to obtain the optimal level of investment in weaponry for this case:

(13′) $$\alpha^{P} = \mathrm{A}^*(B + \overset{+}{N_P}, \overset{-}{N_P / B}) < \alpha^{PP} = \mathrm{A}^*(B + \overset{+}{N_P}, 0) = \mathrm{A}(B + \overset{+}{N_P}).$$

[20] Note $\partial^2 p / \partial\alpha\partial f_G = f_R(f_R - \alpha f_G)/(\alpha f_G + f_R)^3$ being negative (positive) depending on whether f_R is less than (or exceeds) αf_G. Similarly, $\partial^2 p / \partial\alpha\partial f_R > 0$ if $\alpha f_G > f_R$. In the symmetric case, we have $\partial^2 p / \partial\alpha\partial f_G < 0$ and $\partial^2 p / \partial\alpha\partial f_R > 0$ provided that $\alpha > 1$.

It is clear from the signs of the partial derivatives that the government invests less in weaponry if it cannot commit itself to investing in weaponry and fighting efforts, and thus to safeguarding property rights on natural resources. Not being able to commit to investment in weaponry and fighting efforts means that the government obtains a lower license fee than if it can commit. In fact, the incumbent faces a time inconsistency problem: it wants to convince the mining company that it will invest a lot in weapons to stave off rebellion and make mining attractive, but once the license fee has been received it has an incentive to renege. Without commitment, investment in weaponry is too low and both the government and the mining company are worse off as a result.

A more realistic timing assumption is that the government can commit to invest in weaponry before the mining license is auctioned, but cannot commit to fighting efforts before the license fee is paid and mining investments are undertaken. We will denote this outcome with the superscript *PW*. The armies that are being fielded are thus again given by (3″) and the chances of holding to office by (4), but optimal investment in weapons now follows from $C'(\alpha^{PW})(1+\alpha^{PW}+N_P/B)^2 = (B+N_P)^2/B > B+N_P$. It thus follows that investment in armaments will be higher if the government can commit to invest before the mining license is auctioned,

$$\alpha^{PW} > \alpha^{P}, \tag{13″}$$

because then it obtains a higher fee and offers better protection to the mining company.

Proposition 6: Investment in weaponry is lower if the government cannot credibly commit itself to investment in weapons and fighting efforts before the mining license is allocated. If commitment is feasible, the government invests more in weapons under private extraction and thus increases its chances of staying in office and enjoys a higher license fee. It then invests more in weaponry than under balanced and a fortiori under rapacious nationalized extraction. If the government undertakes weapon investments before auctioning the mineral license and cannot commit to fighting efforts, it invests more in armaments to better protect future mineral rights and obtain a higher license fee.

Proof: Follows from (13), (13′) and (13″).

Empirically, oil increases the risk of conflict in non-corrupt countries, but in corrupt countries it has a less detrimental effect on stability (Fjelde, 2009). This and the positive relation between corruption and military spending found by Gupta et al. (2001) are consistent with our mechanism that high office rents can induce large army investments by the government, which reduce the effects of resources on conflict.

6. Bribing rebels

One possibility for the government to avoid rebel coups is to offer rebels attractive jobs.[21] For example, if the government offers a wage subsidy S^i to rebels only, the government payoff is reduced by $(1-f_R^i)S^i$ and rebel wages are increased by the same amount. With exogenous natural resource revenues, it follows that in the non-cooperative Nash equilibrium $f_R^i / f_G^i = W/(W+S^i) < 1, i = H, Q,$ and thus that fighting efforts under balanced depletion are given by

$$(14)\qquad f_G^H = \frac{\alpha(S^H+W)}{(W+\alpha(S^H+W))^2}\left(B+\frac{N_G}{2}\right) > f_R^H = \frac{\alpha W}{(W+\alpha(S^H+W))^2}\left(B+\frac{N_G}{2}\right) \text{ if } S^H > 0$$

and under rapacious depletion are given by

$$(14')\qquad f_G^Q = \frac{\alpha(S^Q+W)}{(W+\alpha(S^Q+W))^2}B > f_R^Q = \frac{\alpha W}{(W+\alpha(S^Q+W))^2}B \text{ if } S^Q > 0.$$

Hence, rebels now fight in both outcomes less than the government if bribes incite them to work rather than fight. Note that equations (14) and (14′) reduce to (3) and (3′) if there is no bribe. The qualitative insight of proposition 1, i.e., for a given bribe fighting is less under rapacious than balanced depletion, is unchanged. Differentiating both sides of (14) and (14′) with respect to the wage subsidy, we see that a wage subsidy reduces fighting by both government and rebels ($\partial f_G^i / \partial S^i < 0, \partial f_R^i / \partial S^i < 0, i = H, Q$), but rebels' fighting effort declines relatively more. The probability of the government staying in office under both balanced and rapacious depletion is higher if it introduces a wage subsidy for rebels:

$$(15)\qquad p^i = \frac{\alpha(S^i+W)}{W+\alpha(S^i+W)} \text{ with } \partial p^i / \partial S^i = \frac{\alpha W}{(W+\alpha(S^H+W))^2} > 0, \quad i = H, Q.$$

The optimal wage subsidy for rebels sets the marginal benefit arising from a higher probability of staying in office ($\partial p^i / \partial S^i$ times the stake of B under rapacious depletion, respectively $B + N_G/2$ under balanced depletion) equal to number of existing rebels plus the additional rebels who put down their arms that have to be subsidized to work $(1 - f_R^i - S^i(\partial f_R^i / \partial S^i) > 1 - f_R^i)$. This optimality condition can be rewritten as

$$(16)\qquad S^H = \sqrt[3]{\frac{2(1+\alpha)W^2(B+N_G/2)}{\alpha^2}} - \frac{W(1+\alpha)}{\alpha}$$

[21] For wars between two rational and completely informed players it can be shown that, without binding contracts, war can be avoided if the "rich" player transfers parts of its money to the "poor" player (Beviá and Corchón, 2010).

for the case of balanced depletion and

(16′) $$S^Q = \sqrt[3]{\frac{2(1+\alpha)W^2 B}{\alpha^2}} - \frac{W(1+\alpha)}{\alpha}$$

for the case of rapacious depletion, where the signs of the partial derivatives are found from total differentiation of (16) and (16′). It thus follows that the higher stake under balanced depletion warrants a bigger wage subsidy to incite rebels to fight less than under rapacious depletion. The government incurs both the cost of fielding a bigger army and the cost of bribing rebels. Still, as the government's grip on office and on natural resources has tightened, it may become more attractive for the government to switch from rapacious to balanced depletion.

Proposition 7: It is optimal for the government to pay rebels to work and put down their arms. The wage subsidy should be higher the bigger the office rents. It should also be higher under balanced than rapacious depletion, especially if resource revenues are bigger. As a result, rebels fight less, the government fields a bigger army, and the government's grip on office becomes stronger.

Proof: See equations (14), (14′), (16) and (16′).

The implications of bribes under private extraction can be conducted in a similar fashion.

7. Conclusions

We presented a framework that makes both conflict behaviour and resource extraction endogenous, which helps to make sense of the controversies and contradictions in the stylized facts. Thus, with a small number of exogenous parameters related to extraction technology and office rents, we derive a multitude of predictions on conflict variables such as the equilibrium fighting efforts and armament, variables related to resource depletion like extraction method, extraction speed, investment levels and licence fees, and political outcomes like regime durability.

We have analyzed endogenous armament, fighting, and choice of type of resource investment and extraction. Rapacious resource exploitation has economic costs, but we have shown that it can nevertheless be optimal due to lowered incentives for future rebel attacks. We have shown that private extraction is more attractive if the threat from rebels is not too large (i.e., with large office rents and a strong army), because fragile governments can only gain modest license fees. With private exploitation, rebels fight more than the government if they can renege on the contract with the mining company and if the government cannot pre-commit to future fighting efforts. It thus follows that government turnover must be higher under private extraction. We have also shown that both license fees and private mining investment are larger if property rights are better protected, i.e., if government rents and army size are large.

Furthermore, we have shown that governments invest more in the quality of their armies under balanced than under rapacious extraction. If the government can commit to weapon investments in case of private extraction, it can overcome the time inconsistency problem and will invest more in weapons, and will therefore increase its grip on office and receive a bigger fee from the mining company. In that case, investment in weaponry exceeds that under balanced and a fortiori under rapacious nationalized extraction. We have also shown that it is optimal for the government to bribe rebels to encourage them to work and put their arms down and that this wage subsidy is higher under balanced than rapacious depletion, especially if resource revenues are substantial. As a result, rebels fight less intensively, the government fields a bigger army, and the government's grip on office is stronger.

Some of these predictions can be tested with the help of the existing empirical evidence. For example, some of our results with respect to the determinants of fighting or with respect to factors favouring under-investment can provide mechanisms to explain existing empirical results. In contrast, other propositions require new empirical efforts. For example the expected effects of domestic political institutions and military capacity on the ownership structure and depletion speed of extraction companies, as well as on the share of rents captured by the government, is still empirical terra incognita. Similarly, our prediction of a "conditional resource curse", making the conflict-inducing impact of natural resources depend on extraction method and speed as well as on military asymmetry, needs further empirical investigation. Moreover, our findings on the impact of speed and method of extraction on government turnover and army size suggest new topics for empirical testing.

Our analysis can be extended in the following directions. First, if the government has cash constraints and cannot use future resource revenue as collateral, private mining companies have an incentive to help finance an army to fight off rebel coups. This biases the mode of exploration towards balanced nationalized or privatized extraction as this yields more funds upfront. However, looting and "booty futures" can also finance a stronger rebel army which can set off or prolong conflict (Ross, 2004). Second, mining companies may not have an interest to disclose private information about in-situ reserves, necessary investment outlays, or costs of extraction to the government in which case the design of incentive-compatible contracts under moral hazard with risk sharing is called for (e.g., Bolton and Dewatripont, 2005; Radon, 2007; Cramton, 2007). Third, with capital-intensive mining (say, oil or gas) a higher price of resources pushes up the relative return on capital and pushes down the wage which boosts conflict (Dal Bó and Dal Bó, 2010). With balanced rather than rapacious depletion, fighting intensities increase more as not only the wage falls but also the revenues from natural resources and thus the stake rise. On the other hand, a higher price of labour-intensive resources (e.g., coffee, rice or bananas) pushes up wages and reduces the return on capital, so fighting becomes less intense and work more attractive.

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Appendix A: Description of data used in section 2

Government Take: Percent of mining and petrol rents received by the government. Computations based on the data for US firms operating abroad. From the Bureau of Economic Analysis (2009).

Military Expenditures as Share of GDP: From SIPRI (2009).

Oil Production: In million tonnes. From British Petroleum (2009).

Oil Reserves: Proved reserves in thousand million barrels. From British Petroleum (2009).

State Ownership: Dummy for state ownership of oil extraction (S1 and S2). From Jones Luong and Weinthal (2010), where their coding is explained in detail.

Years in Office: Years in office of the chief executive. From Beck et al. (2001, updated April 2008).

Appendix B: Alternative timing

Here we consider what happens if the license fee is negotiated before fighting takes place, but only part q of the licence fee is paid up front and the remainder is paid *after* resource extraction. So, when the government loses power, it does not receive the part (1–q) of the license fee. We denote this outcome with the superscript *PA*. The payoffs to the government and rebels are now given by:

(A1)
$$\Pi_G^{PA} = B + qL - \mathrm{C}(\alpha) + \left(\frac{\alpha f_G^{PA}}{\alpha f_G^{PA} + f_R^{PA}}\right)(B + (1-q)L) + (1 - f_G^{PA})W \quad \text{and}$$
$$\Pi_R^{PA} = \left(\frac{f_R^{PA}}{\alpha f_G^{PA} + f_R^{PA}}\right)\left(B + N_P\right) + (1 - f_R^{PA})W.$$

The mining company's participation constraint requires:

(A2)
$$\left(\frac{\alpha f_G^{PA}}{\alpha f_G^{PA} + f_R^{PA}}\right)(N_P - (1-q)L) \geq qL + I.$$

With perfect competition among international mining firms, this holds with equality. The equilibrium fighting effort levels are as follows:

(A3)
$$f_G^{PA} = \frac{\alpha(B+N_P)(B+L(1-q))^2}{[(1+\alpha)B + N_P + \alpha L(1-q)]^2 W} < f_R^{PA} = \frac{\alpha(B+N_P)^2(B+L(1-q))}{[(1+\alpha)B + N_P + \alpha L(1-q)]^2 W}.$$

Note that $N_P > L$ always holds given $I > 0$ and the mining firm's participation constraint. It follows that $f_G^{PA} < f_R^{PA}$ for all levels of q (even for $q=0$). This implies that,

(A4)
$$p^{PA} = \frac{\alpha(B+L(1-q))}{\alpha(B+L(1-q)) + B + N_P} < p^H = p^Q = \frac{\alpha}{1+\alpha}.$$

While all expressions become more tedious, all qualitative results go through in this extended setting.