

POLITICAL ECONOMY OF DYNAMIC RESOURCE WARS

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Abstract

The political economy of exhaustible resource extraction is analysed in three contexts. First, if an incumbent faces a threat of being removed once and for all by a rival faction, extraction becomes more voracious if the factions do not share rents equally. Second, perennial political conflict cycles are more inefficient if constitutional cohesiveness or the partisan in-office bias is large and political instability is high. Third, resource wars are more intense if constitutional cohesiveness is weak, the incumbent has a partisan in-office bias, reserves of resources are high, the wage is low, governments can be less frequently removed from office, and fighting technology has less decreasing returns to scale. Resource depletion in such wars is more rapacious if there is more government instability, the political system is less cohesive, and the partisan in-office bias is smaller.

Keywords: political conflict; cohesiveness; partisan bias; dynamic resource wars; contests; rapacious depletion; exploitation investment; hold-up problem

JEL codes: D81, H20, Q31, Q38

Revised August 2017

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¹ Also affiliated with St. Petersburg State University, 7/9 Universitetskaya nab., St. Petersburg, 199034 Russia, and with the Vrije Universiteit Amsterdam, CESifo and CEPR. I have benefited from discussions with Julien Daubanes, Niko Jaakkola, Ngo Van Long, Klarizze Puzon, Cees Withagen, Amos Zemel and Aart de Zeeuw. I acknowledge support from a VAM Project of the ENEL Foundation and from the BP funded Oxford Centre for the Analysis of Resource Rich Economies (OxCarre). This paper is an extended and revised version of ‘Resource wars and confiscation risk’, Research Paper 97, OxCarre (2012) and has benefited from the insightful and constructive comments of two anonymous referees and from the helpful comments received at the SURED 2016 conference organised in Banyuls-sur-Mer, France.

1. Introduction

How does the presence of a large stock of exhaustible natural resources and the chance of being removed from office affect government behaviour? How do political instability and constitutional cohesiveness affect rent grabbing and the voracity of resource depletion? How does the threat of war affect the speed of resource extraction and the price of natural resources? How are resource wars affected by constitutional cohesiveness, the ease by which political parties can be removed from office, and fighting technology? How do costly attempts to stay in office ('fighting') affect the probability of staying in office, the rapacity of exhaustible natural resource extraction and efficiency? Our objective is to provide answers to each of these questions by analysing the political economy of natural resource extraction in three different contexts.

First, we analyse the situation where an incumbent faces a threat of being removed once and for all by a rival faction and show how this makes exhaustible resource extraction voracious, especially if the risk of being removed from office is high, a small fraction of resource rents is shared with the rival faction, and the new government hands out a small fraction of rents as cohesiveness payments, and depresses exploitation investment. In contrast, a more cohesive institution implies less voracious depletion, more exploration investment and thus a more efficient outcome.

Second, we analyse perennial political conflict cycles using a model of two-sided regime shifts with exogenous hazard rates. We show that this induces rapacious depletion of the resource, especially if constitutional cohesiveness is weak, the partisan in-office bias is large, and governments change frequently, and we show that political instability lowers the welfare of the incumbent. With constitutional cohesiveness is meant that governments cannot hand out transfers to its own clientele without also giving out transfers to the other citizens. A partisan in-office bias implies that utility in office is weighted more heavily than utility when not in office.

Third, we develop a political economy explanation of dynamic resource wars with the probability of a change of government depending on relative fighting intensities based on a game-theoretic model with two-sided regime shifts and endogenous hazard rates. We show that resource wars are more intense if the constitution is less cohesive, the incumbent has a partisan in-office bias, exhaustible resource reserves are high, the wage is low, governments can be less frequently removed from office, and fighting technology has less decreasing returns to scale. Wars are less intensive if the government has a fighting advantage. Furthermore, extraction of the resource is more rapacious and

less exploration investment takes place, especially if there is more government instability, constitutional cohesiveness is weak, and the partisan in-office bias is smaller.

To get tractable closed-form solutions and have a useful benchmark, we make two bold assumptions: iso-elastic demand for natural resources and zero variable extraction costs. With no risk of being removed from office, monopolistic resource extraction is then efficient and governed by the Hotelling rule (Stiglitz, 1976; Dasgupta and Heal, 1979).² These assumptions thus cut off this known source of inefficiency and help to isolate and highlight the inefficiencies that follow from perennial political cycles and dynamic resource wars in a striking and analytically convenient manner. In addition, we suppose that the incumbent incurs upfront costs of exploitation investment so that the initial stock of natural resource reserves is endogenous (cf., Gaudet and Lasserre, 1988).³

Our model of one-off political risk is related to models of the effects of political uncertainty about nationalization and the speed of natural resource extraction (e.g., Long, 1975; Konrad et al., 1994; Bohn and Deacon, 2000; Laurent-Luchetti and Santaguni, 2012). The empirical evidence in Guriev et al. (2010) suggests that expropriation is more likely in periods when the oil price is high and when there are fewer checks and balances on the government. Evidence from 2,468 oil extraction agreements in 38 resource-rich countries suggests that expropriation occurs regularly, especially if there is asymmetric information on extraction costs and if constraints on the executive (Stroebe and van Benthem, 2013).⁴ Our model of the holdup problem relates to an extensive literature (e.g., Rogerson, 1992; Holmström and Roberts, 1998). Our concept of cohesiveness captures the quality of the constitution and refers to the notion that one cannot give handouts to one faction in society without also giving handouts to other factions (Besley and Persson, 2011a,b,c). Our model of partisan political cycles relies on the incumbent giving a higher weight to utility when in office than when out of office (cf. Aguiar and Amador, 2011). This in-office bias induces an upward partisan bias in the rate of resource extraction, which is akin to the upward debt bias derived in the positive theory of public debt and deficits (e.g., Persson and Svensson, 1989; Alesina and Tabellini, 1990).

² Stiglitz (1976) discusses various reasons why the monopolistic rate of extraction may be distorted. He shows that a rising price elasticity of demand, falling extraction costs and a lower required rate of return for the monopolist due to possibly being able to pool risks than under perfect competition all lead to a more conservationist extraction rate of the monopolist. Kagan et al. (2015) show that if the demand function is of the HARA form (which includes linear, loglinear and semi-loglinear demand functions as special cases) the speed of extraction under a monopoly (and under open-loop oligopoly) is initially too low and later too high.

³ We abstract from uncertainty and irreversible oil exploitation investment (Kellogg, 2014).

⁴ Furthermore, countries that are better able to commit as a result of larger costs associated with reneging, tend to obtain contracts that shift a larger degree of the oil price risk to the international oil company.

Our model of dynamic resource wars makes use of contest functions, familiar from the literature on resource wars in static environments (e.g., Tullock, 1967; Hirshleifer, 1991; Skaperdas, 1996; Konrad, 2009)⁵, and contributes to a recent literature on the two-way link between natural resource extraction and conflict (Acemoglu et al., 2012; van der Ploeg and Rohner, 2012). In contrast to earlier studies on bargaining and war between sovereign states (e.g., Powell, 1993; Skaperdas, 1992; Acemoglu et al., 2012; Caselli et al., 2015)⁶, we focus on conflict over the control of exhaustible natural resources that reside within the boundaries of a state.

Although our paper is theoretical, it is worth pointing out that the cross-country empirical evidence suggests that countries with high natural exports experience more armed conflict especially in sub-Saharan Africa (e.g., Collier and Hoeffler, 2004; Ross, 2004; Fearon, 2005). This type of evidence also suggests that natural resources boost conflict, especially in societies that are ethnically polarised (e.g., Reynal-Quarol, 2002; Montalvo and Reynal-Quarol, 2005) or where ethnic cleavages and the political dominance of one group matters (e.g., Cederman and Girardin, 2007). Giant oil discoveries around the world since 1946 turn out to increase armed conflict especially for countries that had already experienced armed conflict or coups in the previous decade (Lei and Michaels, 2014). Within-country evidence also points in this direction (e.g., Angrist and Kugler, 2008) and establishes that an exogenous increase in the world price of capital-intensive natural resources such as oil leads to more guerrilla and paramilitary attacks (Dube and Vargas, 2013). If elites act inefficiently and repress revolt in order to cling to power (e.g., the blocking of railways and industrialisation by Russian and Austrian empires), then resource booms raise political stakes and makes things worse but they also encourage would-be elites to contest power and fight to take control of resources (Acemoglu and Robinson, 2006). The micro evidence on interstate wars suggests that war is more likely if of two neighbouring countries one has oil and the other one does not or has oil far from the border (Caselli et al., 2015). A recent study uses detailed georeferenced data on mining extraction of 14 minerals with information on conflict events at a spatial resolution of $0.5^\circ \times 0.5^\circ$ for all of Africa between 1977 and 2010, and finds that the historical rise in mineral prices explains up to a quarter of the average level of violence across African countries and that a fighting's group control of a local mining area contributes to escalation from local to global

⁵ Contest success functions have also been used to study the interstate conflicts over natural resources and its effects on trade (Garfinkel et al., 2011).

⁶ Guns versus butter dilemmas and arms races have also been studied in differential game analyses of the Richardson model (e.g., Brito, 1972; Intriligator, 1975; van der Ploeg and de Zeeuw, 1991).

violence (Berman et al., 2017). Mining of minerals and extraction of oil and gas are thus important drivers of conflict.

Most of the empirical literature takes discoveries, reserves and exports of natural resources as exogenous, but evidence on cross-border strips of land suggests that discoveries and drilling are more likely on the side of the border where institutions are better and conflict is less (Cust and Harding, 2015). The fact that known subsoil resource wealth per square kilometre is 23,000 US dollar in sub-Saharan Africa compared with 105,000 US dollar globally (Collier, 2011) suggests that with improved institutions more discoveries will take place in sub-Saharan Africa and indeed this shift in the frontier of natural resource has been documented empirically (Arezki, et al., 2016).

The empirical evidence thus suggests, on the one hand, that natural resources increases armed conflict, and, on the other hand, that a bad quality of institutions (including the threat of expropriation) and conflict curbs discoveries and exploitation activities. However, further empirical work is needed that explicitly takes account of the exhaustible nature of important natural resources, allows for the reverse causality due to conflict affecting the rate of natural resource extraction and exploration investment, and allows for political explanatory variables such as cohesiveness and partisan biases. Our analysis is meant to be a guide to possible testable hypotheses for this purpose.

The outline of the paper is as follows. Section 2 analyses the effects of a one-off change in government on the rate of resource extraction and on exploitation investment when political factions can depart from the cohesiveness requirements prescribed by the constitution. Section 3 extends this to perennial political cycles and ongoing regime shifts. Section 4 extends the theory further to dynamic resource wars. In both these sections factions have to stick to the cohesiveness prescribed by the constitution. Section 5 summarises results and suggests topics for further research.

2. One-Off Chance of a Future Regime Shift: Role of Cohesiveness

Consider two factions. The incumbent faction A faces a one-off chance of being removed from office by the rival faction B at some unknown future date T . The risk of removal from office for the incumbent is $h > 0$. In a society with a fully cohesive constitution it is not possible for the incumbent government to take rents without giving equal rents to the other faction in which case $\tau^A = \tau^B = \tau = 0.5$. But in societies with a poor constitution $0 < \tau^A = \tau^B = \tau < 0.5$ and rents are less

equally shared (cf. Besley and Persson, 2011a,b,c).⁷ In particular, giving one dollar to a client of the incumbent faction implies that $0 < \tau/(1-\tau) < 1$ dollar must be given to members of the rebel faction. We are interested in the effect of constitutional cohesiveness on the rate of oil extraction and exploration investments⁸, but also analyse two departures from the constitution. The first one is when the incumbent adheres to the constitution and shares rents according to $\tau^A = \tau$, but faces a threat of removal from office by a rogue rival faction that offers less than what is stipulated by the constitution, i.e., $\tau^B < \tau^A = \tau$. The second one is where the incumbent is the rogue administration that faces a threat of being replaced by an administration that shares rents more fairly. This corresponds to $\tau^A < \tau^B = \tau$. We will show that both types of departures make oil extraction more voracious and depress exploration investment.

Let the price elasticity of oil demand, ε , be constant and marginal revenue be positive, so $\varepsilon > 1$. Oil extraction costs are zero and factions are risk-neutral. Utility is thus $U(R) = R^{1-1/\varepsilon} / (1-1/\varepsilon)$, where $R > 0$ denotes the rate of oil depletion. Welfare is the area under the demand curve, so that the inverse demand function is given by

$$(1) \quad p = U'(R) = R^{-1/\varepsilon}, \quad \varepsilon > 1.$$

As marginal revenue is always finite and positive, reserves are exhausted asymptotically.

2.1. Resource depletion rates of the new government

Working backwards in time in accordance with the principle of optimality of dynamic programming, faction B once in office maximises its rent net of cohesive payments,

$$(2) \quad \text{Max}_{R, I} \int_T^{\infty} (1 - \tau^B(t)) p(t) R(t) e^{-r(t-T)} dt,$$

subject to the inverse demand function (1) and the oil depletion equations,

$$(3) \quad \dot{S}(t) = -R(t), \forall t \geq T, \quad \int_T^{\infty} R(t) dt \leq S(T),$$

where S denotes the stock of oil reserves and r is the exogenous and constant market interest rate. The optimal policy requires that marginal oil revenue must equal the scarcity rent, λ , which according to the Hotelling rule must rise at a rate equal to the market interest rate, r :

⁷ Our model can be reformulated to capture the risk of expropriation of an international oil company if one sets $\tau^A = 0$ and interprets $1 - \tau^B$ as the confiscation tax and h as this risk.

⁸ From now on, we will refer to oil as shorthand for natural resources.

$$(4) \quad (1 - \tau^B)(1 - 1/\varepsilon)R(t)^{-1/\varepsilon} = \lambda(t), \quad \dot{\lambda}(t)/\lambda(t) = r, \quad t \geq T.$$

It follows from (1) and (4) that under the new regime of faction B the price and oil depletion paths are efficient despite the country being a monopolist on world markets:

$$(5) \quad \dot{p}(t)/p(t) = r > 0, \quad \dot{R}(t)/R(t) = -\varepsilon r < 0, \quad t \geq T,$$

Using (5) in the oil depletion equations (3), we obtain $R(t) = \varepsilon r S(t)$ and thus get

$$(6) \quad \begin{aligned} R(t) &= \varepsilon r e^{-\varepsilon r(t-T)} S(T), \quad S(t) = e^{-\varepsilon r(t-T)} S(T) \leq S(T), \\ p(t) &= e^{r(t-T)} (\varepsilon r S(T))^{-1/\varepsilon}, \quad \forall t > T. \end{aligned}$$

The optimal depletion and price paths follow Hotelling paths and are constrained efficient (conditional on $S(T)$). They do not depend on the cohesiveness transfer rate, τ^B , because this is effectively a lump-sum tax. Substituting (6) in (2), we get B's welfare at time T :

$$(7) \quad V^B(S(T), \tau^B) \equiv \int_T^\infty (1 - \tau^B) R(t)^{1-1/\varepsilon} e^{-r(t-T)} dt = (1 - \tau^B)(\varepsilon r)^{-1/\varepsilon} S(T)^{1-1/\varepsilon}.$$

where $V^B(\cdot)$ denotes B's (undiscounted) value function. The welfare for the incumbent faction at the time after it has lost office consists of constitutional cohesiveness payments only and is given by

$$(8) \quad V^A(S(T), \tau^B) \equiv \tau^B (\varepsilon r)^{-1/\varepsilon} S(T)^{1-1/\varepsilon}, \quad \forall t \geq T.$$

2.2. Resource depletion rates and exploitation investment by the incumbent

Given future expected cohesiveness payments, the incumbent A has to choose initial exploitation investment, I , and the extraction path to maximise its expected welfare not knowing what the date of its expected term of office T is. Given the exponential density function for the realisation of T , i.e., $h \exp(-hT)$, with h the constant hazard rate, the problem for the incumbent is thus,

$$(9) \quad \begin{aligned} \text{Max}_{R, I} E \left[\int_0^\infty (1 - \tau^A) p(t) R(t) e^{-rt} dt + e^{-rT} V^A(S(T), \tau^B) \right] - qI = \\ \left(\int_0^\infty h \exp(-hT) \left(\int_0^T (1 - \tau^A) p(t) R(t) e^{-rs} dt + e^{-rT} V^A(S(T), \tau^B) \right) dT \right), \end{aligned}$$

subject to the inverse oil demand function (1), the oil depletion equations,

$$(10) \quad \dot{S}(t) = -R(t), \quad \forall 0 \leq t \leq T, \quad S(0) = S_0 > 0, \quad \int_0^T R(t) dt \leq S_0 - S(T),$$

and the oil exploitation investment schedule,

$$(11) \quad S_0 = \Omega(I) = \omega_0 I^\omega, \quad \Omega' > 0, \Omega'' < 0, \quad \omega_0 > 0, \quad 0 < \omega < 1,$$

where q is the exogenous price of oil exploitation investment. Concavity of $\Omega(\cdot)$ ensures decreasing returns to exploitation investment. The exponential distribution implies that the cumulative probability that the incumbent is removed from office in the interval ending at time t is

$$(12) \quad \Pr(T \leq t) = 1 - \exp(-ht), \quad \forall t \geq 0, \quad h \geq 0,$$

and that the probability that A is *not* removed from office before time t is $\Pr(T > t) = \exp(-ht)$. The conditional probability that removal from office has not taken place during an interval of duration s is independent of time, i.e., $\Pr(T > s + t | T > s) = \Pr(T > t)$, $\forall s, t \geq 0$. Both the expected duration and the standard deviation of A's term of office equal the inverse of the hazard rate, $1/h$.

The problem defined by (9)-(11) follows Gaudet and Lasserre (1998) and thus assumes that all exploration investments have to be done up front. For simplicity, the possibility of making further exploration investments as time goes along or when a new faction enters office is abstracted from. This may be justified if the incumbent has exhausted all geological possibilities for further discoveries, so that a successor is unable to discover new oil fields.⁹

The HJB equation for the dynamic programming problem of the incumbent A is (see appendix 1)

$$(13) \quad rV(S, \tau^A, \tau^B) = \max_R \left[(1 - \tau^A)U'(R)R - V'(S, \tau^A, \tau^B)R \right] - h \left[V(S, \tau^A, \tau^B) - V^A(S, \tau^B) \right],$$

Where $p = U'(R)$ is the inverse oil demand function, $V(S, \tau^A, \tau^B)$ denotes the value function (excluding its outlay on exploitation investment) for A when it still is in office and $V^A(S, \tau^B)$ is the value function for A when it has lost office. The optimality condition for the rate of oil extraction is

$$(14) \quad (1 - \tau^A)(1 - 1/\varepsilon)p(t) = V'((S(t), \tau^A, \tau^B)) \Rightarrow R(t) = \left(\frac{V'((S(t), \tau^A, \tau^B))}{(1 - \tau^A)(1 - 1/\varepsilon)} \right)^{-\varepsilon}, \quad 0 \leq t \leq T.$$

Upon substitution of (14) into the HJB equation (13), we obtain

⁹ Pindyck (1978) analyses a model of ongoing optimal exploration investments, discoveries and extraction of an exhaustible natural resource which could be adapted for this purpose, but this would lead to extra state and co-state equations and a need to resort to numerical methods without altering the key qualitative political economy insights of our analysis. Arezki et al. (2016) obtain empirical evidence for the hypothesis that discoveries and exploration spending is higher if markets are liberalised and markets are open.

$$(15) \quad rV(S, \tau^A, \tau^B) = \frac{(1 - \tau^A)^\varepsilon}{\varepsilon} \left(\frac{V'(S, \tau^A, \tau^B)}{1 - 1/\varepsilon} \right)^{1-\varepsilon} - h[V(S, \tau^A, \tau^B) - V^A(S, \tau^B)].$$

To solve (15), we use the method of undetermined coefficients. We thus postulate $V(S, \tau^A, \tau^B) = KS^{1-1/\varepsilon}$, substitute it, use (8), verify, and solve for K from the algebraic equation:¹⁰

$$(16) \quad \frac{(1 - \tau^A)^\varepsilon}{\varepsilon} K^{1-\varepsilon} + h\tau^B(\varepsilon r)^{-1/\varepsilon} = (r + h)K.$$

From (14) and (1), we then have the oil price and depletion rate during A's incumbency:

$$(17) \quad p(t) = KS(t)^{-1/\varepsilon} / (1 - \tau^A) \quad \text{and} \quad R(t) = (1 - \tau^A)^\varepsilon K^{-\varepsilon} S(t), 0 \leq t < T.$$

Defining $L \equiv ((1 - \tau^A) / K)^\varepsilon$ and solving for the time paths from (17) and (3), we obtain

$$(18) \quad p(t) = e^{L/\varepsilon} (LS_0)^{-1/\varepsilon}, \quad R(t) = Le^{-L} S_0, \quad S(t) = e^{-Lt} S_0, \quad 0 \leq t < T.$$

Proposition 1: *Once the incumbent has once and for all been removed from office, the oil price rises at the rate r and the oil depletion rate and reserves decline at the rate ε . Before the change of office, the oil depletion rate and reserves decline at the rate $L > \varepsilon$ and the oil price rises at the rate $L/\varepsilon > r$ with the time paths given by (17). A higher probability of being removed from office (higher h), less cohesive rent sharing by the incumbent (smaller τ^A) and the anticipation of less cohesiveness payments once out of office (smaller τ^B) leads to more voracious oil depletion (higher L) and lower welfare of the incumbent (lower K).*

Proof: see appendix 2.

Proposition 1 establishes that a more cohesive institution (a higher value of $\tau^A = \tau^B = \tau$) implies less voracious depletion and thus fewer inefficiencies. Furthermore, any departure from the constitution with either the incumbent or the rival faction sharing rents less fairly (τ^A or $\tau^B < \tau$) induces more voracious oil depletion and lower welfare of the incumbent. Note that the incumbent faction has an incentive to share more equally by adhering to the constitutional cohesive payments.

¹⁰ Since $\varepsilon > 1$, the left-hand side of equation (16) falls with K and asymptotically tends to a non-negative value. The right-hand side increases linearly in K , so equation (16) yields a unique, positive solution for K .

For example, if the new rogue government B does not share any rents at all with A, $\tau^B = 0$, then $V^A(S, 0) = 0$ and (15) implies that the incumbent A raises its discount rate, r , with the hazard of being removed from office, h . Indeed, (16) gives $K = (1 - \tau^A)[\varepsilon(r + h)]^{-\varepsilon}$ and $L = \varepsilon(r + h) > \varepsilon r$, so the speed of oil extraction is boosted by the hazard of being removed from office. In general, oil extraction of the incumbent will be less voracious if it gets cohesiveness payments when removed from office from the new government B. In particular, if both factions share their oil rents equally with the rival faction, $\tau^A = \tau^B = 0.5$, equation (16) gives $K = 0.5(\varepsilon r)^{-1/\varepsilon}$ and $L = \varepsilon r$, so that the rate of extraction is efficient and there are no political distortions whatsoever.

If there is no political risk, $h = 0$, equation (16) gives $K = (1 - \tau^A)(\varepsilon r)^{-1/\varepsilon}$ and $L = \varepsilon r$, so the rate of extraction is efficient. If A's tenure is infinitesimally small, $h \rightarrow \infty$, (16) gives $K = \tau^B(\varepsilon r)^{-1/\varepsilon}$ and $L = ((1 - \tau^A) / \tau^B)^\varepsilon \varepsilon r > \varepsilon r$, so the rate of extraction is too fast and more so if the incumbent A and the rebel faction B share little of the oil rents.

2.4. Time paths of oil depletion before and after the change of government

Since oil depletion of the incumbent A is excessively fast ($L > \varepsilon r$), initially the path for the oil depletion rate is above the efficient path and the oil price path is below the Hotelling path. If the realised date of the change of government is far enough in the future, the oil depletion rate before the switch can fall below and the oil price path can rise above the efficient path (see appendix 3). Just before the change in government we have $R(T-) = Le^{-LT} S_0$ and $p(T-) = e^{LT/\varepsilon} (LS_0)^{-1/\varepsilon}$. Using $S(T) = e^{-LT} S_0$, we get

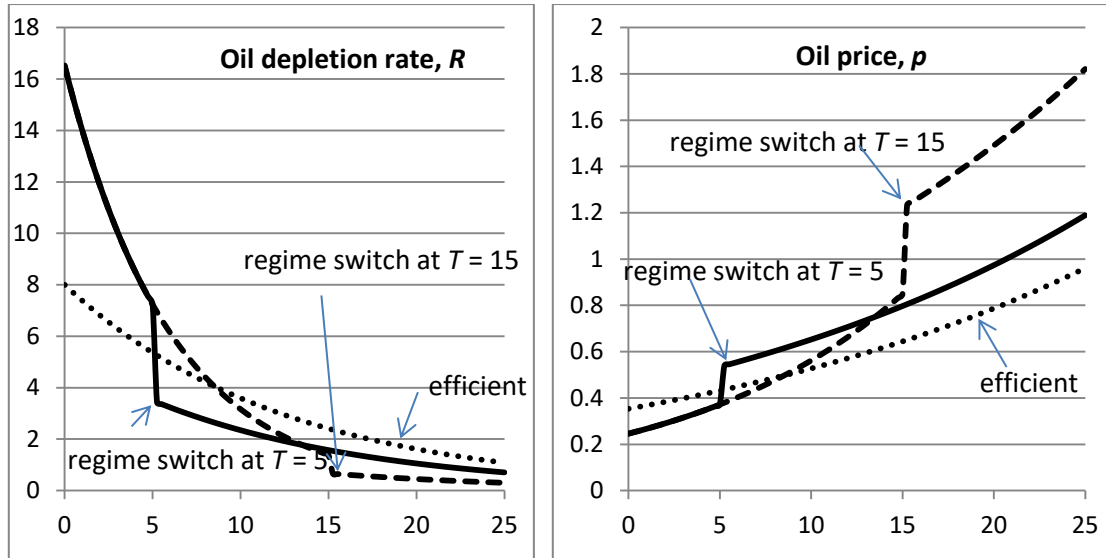
$$(19) \quad R(T+) = \varepsilon r e^{-LT} S_0 < R(T-) = Le^{-LT} S_0, \quad p(T+) = e^{LT/\varepsilon} (\varepsilon r S_0)^{-1/\varepsilon} > p(T-) = e^{LT/\varepsilon} (LS_0)^{-1/\varepsilon}.$$

Once A is removed from office, the oil depletion rate jumps down and the price jumps up by a *discrete* amount. From then on depletion and reserves follow Hotelling paths, but they are constrained inefficient as they start out from fewer oil reserves than without political risk. Oil prices rise at the interest rate, but start from a higher level than without political uncertainty as the voracious extraction during A's incumbency has made oil more scarce when B enters office.

To illustrate, consider the situation where the incumbent does not share rents at all, but the rival faction does promise a more cohesive politics. Figure 1 reports the results from simulating the

model with $\varepsilon = 2$, $r = 0.04$, $S_0 = 100$, $h = 0.1$, $\tau^A = 0$ and $\tau^B = 0.4$. The expected political take-over thus occurs at time 10. Equation (16) gives $K = 2.46$ so $L = 0.165$. The crossing time is 8.5 (from equation (A4) in appendix 3). The reserves to production ratios before and after the regime switch are 6.1 and 12.5, respectively. The dotted lines indicate the efficient outcomes, which prevail if there is no political uncertainty ($h = 0$). The solid lines indicate the inefficient outcomes that result if the realised change of government occurs after 5 units of time. Since $T = 5 < 8.5$, oil depletion rates are always higher and oil prices are always lower than the efficient ones without political uncertainty. The dashed lines correspond to a later change of government with $T = 15 > 8.5$, so the oil depletion and price paths cross the efficient paths before the incumbent leaves office. The simulations confirm that political uncertainty boosts oil depletion rates and depresses oil prices in the period before the change of government. After that, oil depletion jumps down and oil prices jump up and then continue at their less aggressive Hotelling rates.

Figure 1: Time paths of oil extraction and price under the risk of being removed from office



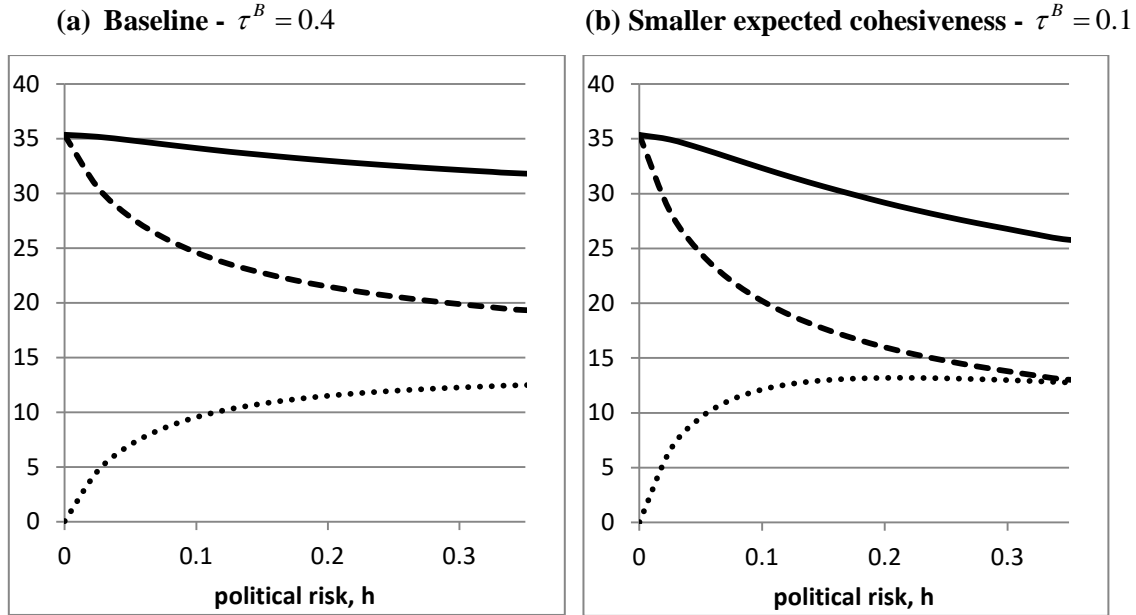
2.5. Social welfare

Social welfare, W , is defined as the sum of the expected welfare of A, i.e., $V(0)$, and of B:

$$\begin{aligned}
 (20) \quad W &= \int_0^\infty \left[(LS_0)^{1-1/\varepsilon} \left(\frac{1 - e^{-(r+L(1-1/\varepsilon))T}}{r + L(1-1/\varepsilon)} \right) + (\varepsilon r)^{-1/\varepsilon} S(T)^{1-1/\varepsilon} e^{-rT} \right] h e^{-hT} dT \\
 &= \left(\frac{h(\varepsilon r)^{-1/\varepsilon} + L^{1-1/\varepsilon}}{r + h + (1-1/\varepsilon)L} \right) S_0^{1-1/\varepsilon}.
 \end{aligned}$$

The highest social welfare is attained if there no political risk, $h = 0$, i.e., $W = (\varepsilon r)^{-1/\varepsilon} S_0^{1-1/\varepsilon}$. Figure 2 shows for the numerical example of section 2.4 how social welfare (solid lines) and welfare of the incumbent (dashed lines) fall with the degree of political uncertainty (h). The rival faction's welfare (dotted lines) rises due to the increased chance of gaining office but at a decreasing rate due to the inefficiencies of rapacious resource extraction caused by political uncertainty. Panel (a) shows outcomes for the baseline level of cohesiveness of the future government, i.e., $\tau^B = 0.4$, and panel (b) for a lower expected cohesiveness, $\tau^B = 0.1$. Although smaller expected cohesiveness induces a small shift in welfare from the incumbent to the rival faction, the main effect is a curbing of the incumbent's welfare and social welfare due to the increased rapacity of resource extraction.

Figure 2: Welfare versus political risk, h



Key: Solid lines indicate joint social welfare, dashed lines the incumbent's welfare and dotted lines welfare of the rival faction. B's cohesiveness is 0.4 in panel (a) and only 0.1 in panel (b).

2.6. Exploitation investment and the hold-up problem

Substituting equation (11) into the incumbent's value function, we get $V(\Omega(I)) = K\Omega(I)^{1-1/\varepsilon}$. The optimal outlay on exploitation investment follow from setting its marginal value to its cost:¹¹

¹¹ The signs of the partial derivatives in the second part of (21) follow from total differentiation of the first part: $q[\Omega'(I)/\varepsilon\Omega(I)] - \Omega''(I)/\Omega'(I)]dI = -dq + (q/K)(K_h dh + K_{\tau^A} d\tau^A + K_{\tau^B} d\tau^B)$.

$$(21) \quad (1 - 1/\varepsilon)K\Omega(I)^{-1/\varepsilon}\Omega'(I) = q \quad \Rightarrow \quad I = I(h, \tau^A, \tau^B, q), \quad I_h, I_{\tau^A}, I_q < 0, I_{\tau^B} > 0.$$

Hence, a bigger political risk, an obligation to share a bigger fraction of rent, and less expected cohesive payments once out of office (i.e., higher value of h , τ^A and τ^B) depress welfare and make it is less attractive to undertake exploitation investment so that the discovered stock of oil reserves is less. This hold-up problem exacerbates the inefficiencies highlighted in proposition 1 and figures 1 and 2. To the extent that the probability of a change in government increases with the promised cohesiveness by the rival faction, some of the beneficial effects of higher cohesiveness are offset.

2.7. Incentives to depart from the constitution

Our analysis assumes that factions A and B must award the *exogenous* fraction τ^A and τ^B of the rents to B and A, respectively, when in office. This is a strong assumption, especially for faction B who will be in power for ever once it gets into office. On the one hand sharing less means B can keep more for itself, but on the other hand it boosts conflict and depresses welfare. The dotted lines in Figure 2 suggest B's welfare improves if it shares less with A (especially for moderate values of political risk h), because the simple model of this section does not allow B to be kicked out again once in office. But this boost to welfare may be attenuated or turn into a welfare fall once one allows for the adverse consequences on exploration investment discussed in section 2.6. Similarly, the incumbent A might want to choose what it gives to B optimally also. The trade-off is that A wants to give less to capture more of the rents for itself but on the other hand this causes additional inefficiencies induced by the extra fighting and more rapacious depletion of oil reserves that this causes. The fact that B stays in office forever once it is in implies that it has an incentive to deviate from the constitution by giving less to faction A, but this is less likely in a situation where it may be removed from office again at a later date. This is why section 3 allows for ongoing political cycles and section 4 for ongoing political revolt and regime shifts, albeit that we concentrate in these sections at the effect of the constitution (changes in $\tau^A = \tau^B = \tau$) rather than at departures from it.

3. Ongoing Political Resource Conflict Cycles

We now allow for perennial ongoing switches in political regime. We suppose here that the constitution dictates the same cohesiveness for both factions, so that $\tau^A = \tau^B \equiv \tau$, and suppose that the probability of being removed from office, h , is the same whatever faction is in government. Since we focus at symmetric (asymptotic) Nash equilibrium outcomes, there is no need to

distinguish the value functions for the two factions separately. We thus denote the in-office value function by $V(S)$ and the out-of-office value function by $V^*(S)$. In contrast to section 2, we follow Aquiar and Amador (2011) and introduce a multiplicative partisan in-office bias, $\beta \geq 1$, to reflect that the incumbent enjoys utility more in office than in opposition, who show that this captures well the partisan political economy biases analysed in the seminal contributions by Persson and Svensson (1989) and by Alesina and Tabellini (1990). An additive partisan in-office bias would not deliver this type of political economy distortion. Note that a value of $\beta > 1$ is *not* meant to reflect a more efficient use of income once in power. In fact, the natural resource curse literature suggests, if anything, a less efficient use in which case $\beta < 1$ might be more appropriate (e.g., Sachs and Warner, 2001; van der Ploeg, 2011; Frankel, 2012). However, to focus on our political distortions, we abstract from this. The HJB equation for when in office is thus (see appendix 1):

$$(22) \quad \text{Max}_R [\beta(1-\tau)U'(R)R - V'(S)R] - h[V(S) - V^*(S)] = rV(S).$$

The value of being out of office is the present value of expected cohesiveness payments received when out of office plus the expected net rents upon gaining office, so that the HJB equation is

$$(23) \quad rV^*(S) = \tau U'(R)R - V^{*'}(S)R + h[V(S) - V^*(S)].$$

From the HJB equation (22) the marginal revenue corrected for in-office bias must equal the shadow value of oil, $\beta(1-1/\varepsilon)(1-\tau)U'(R) = V'(S)$. We obtain the following proposition.

Proposition 2: *With perennial ongoing political cycles, exhaustible resource depletion is rapacious and faster than predicted by the competitive Hotelling rule ($L > \varepsilon r$), especially if constitutional cohesiveness is weak (low τ), the partisan in-office bias is large (high β), and there are frequent changes of government (high h). Political instability curbs value to the go of the incumbent.*

Proof: See appendix 2.

Political uncertainty and less cohesive constitutions in a situation with ongoing political conflict (i.e., perennial two-sided regime shift) lead to more voracious extraction of the exhaustible resource. Furthermore, a partisan in-office bias also makes resource extraction more voracious.

4. Dynamic resource wars: strategic, two-way regime shifts

We extend the two-sided regime shift model of perennial political turnover of section 3 to allow for endogenous hazard rates. The hazard rates depend on fighting and are strategically determined. This more general framework allows us to analyse the dynamic interactions between exhaustible resource extraction and wars and to understand the political determinants of resource extraction and political turnover. We analyse the two-way interaction between exhaustible resource extraction and conflict when there is uncertainty about who controls natural resources. By diverting labour from productive activities, the incumbent engages in a costly fight to increase their grip on office and the proceeds of oil whilst the incumbent engages in a fight to improve the chances of removing the incumbent from office and gain control of oil. We thus develop an infinite-horizon game-theoretic analysis of ongoing exhaustible resource wars with repeated switches of government regime.¹²

4.1. The model

We denote by an asterisk outcomes for the factions if they are out of office. If A is the incumbent, factions A and B fight f^A and f^{B*} units of time, respectively and thus have $N - f^A$ and $N - f^{B*}$ units of time left for work with N the exogenous labour supply of each faction. If B is the incumbent, factions A and B fight, respectively, f^{A*} and f^B units of time and work $N - f^{A*}$ and $N - f^B$ units of time. The opportunity cost of fighting is the exogenous wage W . The hazard rates of faction A being replaced by B and of faction B by A depend on relative fighting efforts and are:

$$(24) \quad h^A = \frac{2H(f^{B*})^\phi}{(f^A)^\phi + (f^{B*})^\phi}, \quad h^B = \frac{2H(f^{A*})^\phi}{(f^{A*})^\phi + (f^B)^\phi}, \quad H > 0, \quad 0 < \phi \leq 1.$$

Equations (24) imply that by fighting more intensively each faction improves its chances of entering office and gaining control of oil reserves. Further, a rebel faction that does not fight, never gains office (i.e., $h^A = 0$). If both the incumbent and the rebel faction fight with the same intensity, the hazard of being removed from office is $h^A = h^B = H$. If the incumbent does not make any effort to fend off rebels, its hazard of being removed from office is twice as high, i.e., $h^A = 2H$, and B once in office will stay in forever, $h^B = 0$. By fighting much more than the rebel faction, it can increase its grip on office by curbing the hazard of being removed from office. Our hazard rates functions are akin to the contest success functions used in the static conflict literature (e.g., Tullock, 1967; Hirshleifer, 1991; Skaperdas, 1996; Konrad, 2009), which finds that conflict increases in the stakes

¹² This contrasts with the much simpler two-period analysis of van der Ploeg and Rohner (2012).

and decisiveness of conflict technology. This literature also finds that less productive groups fight harder and have a higher winning chance than richer groups. Our model also yields these results if we let the wage differ for the two factions.

Four key parameters characterise outcomes. The first one is H and stands for how fast elections take place or for *core political instability*. The second parameter is the *cohesiveness* of the constitution, $0 < \tau \leq 0.5$, and indicates the share of oil rents the incumbent gives to the rebel faction (as in sections 2 and 3). The third parameter is the *partisan in-office bias*, $\beta \geq 1$, and indicates the extra weight given by the incumbent to net rents when in office (as in section 3). The fourth parameter is ϕ and indicates *fighting technology*, which is subject to non-increasing returns to scale ($\phi \leq 1$). A high ϕ implies that the effect of incumbent fighting on the chance of being removed from office and for rebels fighting on their chance of gaining office is high.

The incumbent fights to improve its chance of staying in office and chooses the optimal rate of oil extraction. The contender fights to try to get into office and control oil. We use (24) to write A's HJB equations for the non-cooperative subgame-perfect Nash equilibrium outcome as follows:

$$(25) \quad \text{Max}_{f^A, R^A} \left\{ \beta(1-\tau)U'(R^A)R^A - V_S^A(S)R^A + W(N - f^A) - h^A [V^A(S) - V^{A*}(S)] \right\} = rV^A(S),$$

$$(26) \quad \text{Max}_{f^{A*}} \left\{ \tau U'(R^B)R^B - V_S^{A*}(S)R^B + W(N - f^{A*}) + h^B [V^A(S) - V^{A*}(S)] \right\} = rV^{A*}(S),$$

where h^A and h^B depend on relative fighting efforts and are given by (24). There are two similar HJB equations for B in $V^B(S)$ and $V^{B*}(S)$. Equation (25) states that the incumbent's maximum oil rents (net of any share of oil revenue transferred to the rival faction and net of the shadow cost of oil) *plus* income from productive activities *minus* the expected loss in value terms of losing office must equal the return from investing oil proceeds at the market rate of interest. Equation (26) states that the contender's cohesiveness transfers *plus* wage income *plus* the expected gain of entering office must equal the market rate of return. Asymptotically, the effect of which faction started in office withers away and the in- and out-office value functions for the two factions converge. We will use this and thus concentrate on the asymptotic subgame-perfect Nash equilibrium outcome.

4.2. Non-cooperative outcomes for fighting intensities and resource extraction

The Nash non-cooperative outcome supposes that, if faction A is in office, it takes as given rebel fighting efforts, f^{B*} , when choosing its optimal fighting efforts, f^A , and oil depletion rate, R^A . If

A is the rebel faction, it takes fighting efforts of the incumbent, f^B , as given when deciding on its fighting efforts, f^{A*} . Faction A's marginal expected gain from, respectively, fighting in and out of office is set to its opportunity cost of fighting (the wage):

$$(27) \quad \left(\frac{2\phi H (f^A)^{\phi-1} (f^{B*})^\phi}{[(f^A)^\phi + (f^{B*})^\phi]^2} \right) [V^A(S) - V^{A*}(S)] = \left(\frac{2\phi H (f^{A*})^{\phi-1} (f^B)^\phi}{[(f^{A*})^\phi + (f^B)^\phi]^2} \right) [V^A(S) - V^{A*}(S)] = W$$

and similarly for faction B.¹³ Equations (27) yield two reaction functions for when faction A is in and out of office indicating that A will fight more if B fights more (both if A is in and out of office). Provided the intersection with the complementary reaction functions for faction B exists¹⁴, it gives the non-cooperative symmetric Markov-perfect Nash equilibrium. Since the cohesiveness parameter, fighting technology and the wage are the same for both factions and the hazard rates are given by symmetric contest functions, the non-cooperative Nash equilibrium outcome is symmetric. We thus get from (27) and its counterpart for B the following Nash equilibrium fighting intensities:

$$(28) \quad f^A = f^{A*} = f^B = f^{B*} = \frac{\phi H}{2W} [V(S) - V^*(S)].$$

We see from (28) that fighting increases if the expected gain from staying or getting into office is high relative to the opportunity cost of fighting (W). Further, fighting is more intense if fighting technology has less decreasing returns to scale (higher ϕ) and it is easier to remove the incumbent from office (higher H). The striking result that (asymptotically) fighting efforts are the same for both factions and independent of whether the faction is in or out of office is a result of the specific functional form of the hazard rates (24). Note that there is no direct effect of cohesiveness or partisan bias on fighting efforts, only via the value functions. Substituting (28) into (24), we establish that in equilibrium $h^A = h^B = H$. In fact, the result that fighting efforts are the same for both factions and irrespective of whether they are in or out of office and identical hazard rates for regime shifts survives even if the incumbent has a fighting advantage (see appendix 4). The only

¹³ The second-order optimality condition for f^A requires that $d \left((f^A)^{\phi-1} [(f^A)^\phi + (f^{B*})^\phi]^{-2} \right) / df^A =$
 $\left[-(1+\phi)(f^A)^{2\phi-2} + (\phi-1)(f^A)^{\phi-2} (f^{B*})^\phi \right] [(f^A)^\phi + (f^{B*})^\phi]^{-3} < 0$, and similarly for the other three second-order conditions. At the symmetric equilibrium (see equation (28) below), the right-hand side boils down to $-f^{-2-\phi} / 4 < 0$ so the second-order optimality conditions indeed hold.

¹⁴ It is not immediately clear that the parabolas corresponding to these reaction functions cross, but due to the symmetric nature of our problem it can be verified that the equilibrium indeed exists. In asymmetric problems existence may not be guaranteed under certain parameter values in which case Acemoglu and Jensen (2013) offer an existence theorem.

difference is that fighting then decreases as the incumbent's fighting advantage works as a deterrence, and as a result inefficiency losses are less.

The HJB equations for when in and out of office become, respectively:

$$(25') \quad \text{Max}_{R^A} \left\{ \beta(1-\tau)U'(R)R - V'(S)R + WN - (1+0.5\phi)H[V(S) - V^*(S)] \right\} = rV(S),$$

$$(26') \quad \tau U'(R)R - V^{*'}(S)R + WN + (1-0.5\phi)H[V(S) - V^*(S)] = rV^*(S).$$

The incumbent sets marginal oil revenue (net of cohesiveness payments to the rival faction but including the partisan in-office bias) to the marginal social cost of oil:

$$(29) \quad \beta(1-\tau)(1-1/\varepsilon)p = V'(S).$$

Equation (29) implies that the oil price is low and the rate of oil depletion high if oil is abundant (high S and low $V'(S)$), cohesiveness of the political system is weak (low τ), and the partisan bias is big (large β). To solve the simultaneous HJB equations (25') and (26') together with (29), we conjecture that the asymptotic value functions are given by $V^A(S) = V^B(S) = KS^{1-1/\varepsilon} + WN/r$ and $V^{A*}(S) = V^{B*}(S) = K^*S^{1-1/\varepsilon} + WN/r$ with K and K^* constants to be determined. Using these conjectured value functions, we find from (29) the optimal oil price and oil depletion rates:

$$(30) \quad p = \frac{K}{\beta(1-\tau)} S^{-1/\varepsilon}, \quad R = LS, \quad L \equiv [\beta(1-\tau)]^\varepsilon K^{-\varepsilon}.$$

Substituting (30) into equations (25') and (26') and equating coefficients on $S^{1-1/\varepsilon}$, we get:

$$(31) \quad \frac{1}{\varepsilon} [\beta(1-\tau)]^\varepsilon K^{1-\varepsilon} - (1+0.5\phi)H(K - K^*) = rK,$$

$$(32) \quad \tau [\beta(1-\tau)]^{\varepsilon-1} K^{1-\varepsilon} - (1-1/\varepsilon) [\beta(1-\tau)]^\varepsilon K^{-\varepsilon} K^* + (1-0.5\phi)H(K - K^*) = rK^*.$$

These two nonlinear algebraic equations can be solved for K and K^* , which can then be substituted into (32) to get oil prices and depletion rates and (from equation (28)) fighting efforts:

$$(33) \quad f = f^* = \frac{\phi H}{2W} (K - K^*) S^{1-1/\varepsilon}.$$

4.3. Characterising the non-cooperative Nash equilibrium

To characterise the non-cooperative Nash outcomes, we first consider three special cases.

First, if the constitution demands full cohesiveness in the sense that all resource rents are shared equally between parties independent of whether they are in office or not ($\tau=0.5$) and there is no partisan in-office bias ($\beta = 1$), it is easy to establish from equations (31)-(32) that the solution is $K = K^* = 0.5(\varepsilon r)^{-1/\varepsilon}$, $L = \varepsilon r$ and thus $R = \varepsilon r S$ and from (33) $f = 0$, regardless of the fighting effectiveness ϕ . Hence, a perfectly cohesive constitution without a partisan in-office bias is efficient and ensures that there is no armed conflict.

Second, if it is not possible to remove factions from political office, i.e., the hazard rate H is zero, there is no point in fighting, (31) solves for $K = \beta(1-\tau)(\varepsilon r)^{-1/\varepsilon}$ (whilst K^* is irrelevant) and (30) gives $p = (\varepsilon r S)^{-1/\varepsilon}$ and $R = \varepsilon r S$. Hence, if factions cannot be removed from office, the outcome is also efficient irrespective of the degree of constitutional cohesion, τ , or the partisan in-office bias, β .

Third, if there is a partisan in-office bias ($\beta > 1$), zero cohesiveness ($\tau=0$), and fighting effectiveness is quadratic in effort ($\phi = 2$), one can establish from equations (31) and (32) that $K = \beta[\varepsilon(r + 2H)]^{-1/\varepsilon}$, $K^* = 0$, $L = \varepsilon(r + 2H) < \varepsilon r$ and $f = f^* = \beta[\varepsilon(r + 2H)]^{-1/\varepsilon} H S^{1-1/\varepsilon} / W$. We thus establish that for this case that more core political instability (higher H) leads to a more voracious speed of resource extraction. It can also be shown that this increases fighting intensities (higher f). Interestingly, a bigger partisan in-office bias (higher β) does not affect the speed of resource extraction for this case. It does, however, boost fighting and conflict. The fighting induces efficiency losses over and above the losses from rapacious resource depletion.

The next proposition generalises the insights of proposition 2 to allow for dynamic resource wars.

Proposition 3: *Dynamic resource wars are more intense if exhaustible resource reserves are high and workers are paid poorly. Depletion of resource reserves is less rapid if the constitution is more cohesive and a greater share of resource revenue is shared with rebels (bigger τ). This is also the case if government stability is higher (lower H) and fighting technology displays decreasing returns (lower ϕ) in which case welfare for the incumbent rises. A partisan in-office bias ($\beta > 1$) leads to more rapacious resource depletion, especially if the constitution prescribes more cohesiveness and more of resource rents have to be shared.*

Proof: See appendix 2.

4.4. Numerical illustrations

Figure 3 plots the effects of the constitutional cohesiveness share given to rebels, τ , on oil depletion rates and fighting intensities and figure 4 plots the values to go with baseline parameters set to $\varepsilon = 2$, $r = 0.04$, $S_0 = 100$, $H = 0.1$, $N = 0.2$ and $W = 8$. In line with proposition 3 we see that more cohesiveness leads to less rapacious oil depletion. It also leads to less armed conflict. Figure 4 indicates that the more oil rents are shared, i.e., the more cohesive the political system, the higher the value to the rebels and the higher joint value to go, but the incumbent's value to go first decreases slightly and then increases slightly with constitutional cohesiveness.

Figure 3: Oil depletion rates and fighting intensities ($f = f^*$) vs. constitutional cohesiveness (τ)

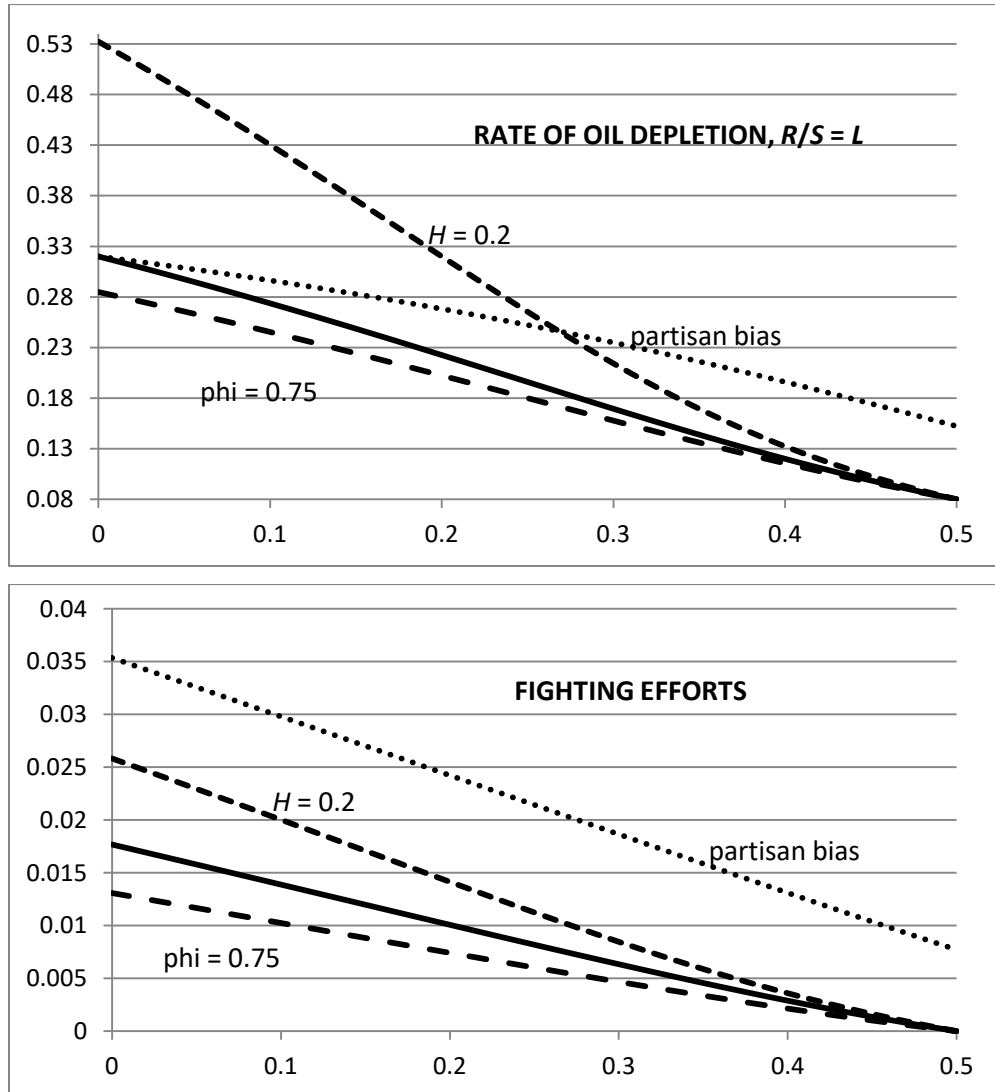
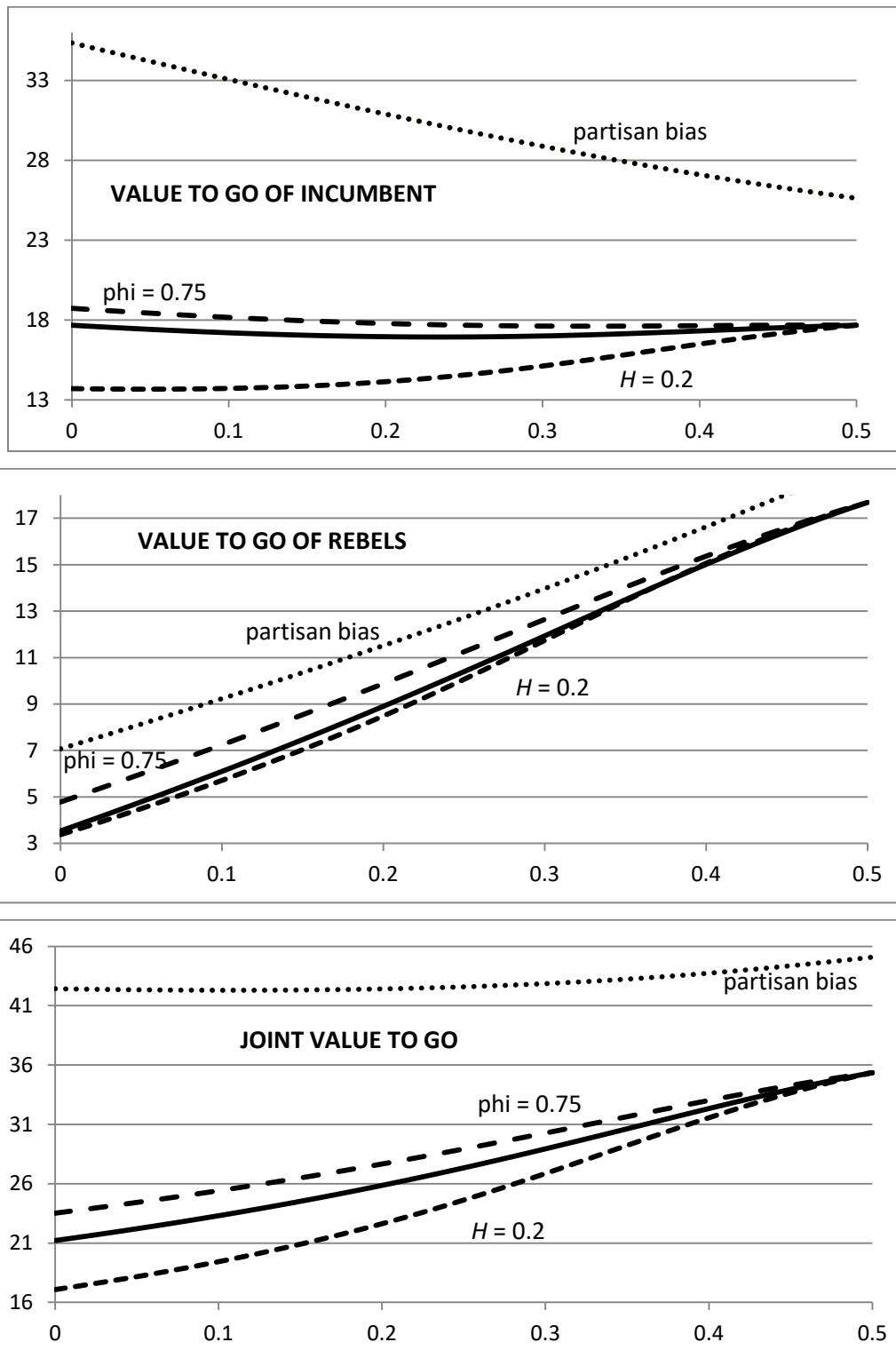


Figure 4: Values to go vs. constitutional cohesiveness (τ)

The short-dashed lines in figure 3 show that more political instability ($H = 0.2 > 0.1$) induces more rapacious oil depletion in line with proposition 3 and more intensive fighting, especially if the political system is less cohesive. Effectively, if the possibility of being removed from office is more imminent, the ruling faction is fearful of losing control of the oil stake and the rebels find it more attractive to fight. Figure 4 shows that the inefficiencies caused by conflict and rapacious depletion resulting from more political instability depress value to go for the incumbent and the rebel factions, especially if constitutional cohesiveness is weak. Hence, oil-rich countries with few elections and where the incumbent is hard to remove from office have less conflict than oil-rich countries with regular, hotly contested elections.

The long-dashed lines in figure 3 show that decreasing returns in fighting technology ($\phi = 0.75 < 1$) curb rapacious depletion in line with proposition 3 and leads to less intense resource wars, especially if the constitution prescribes less cohesiveness. As a result, figure 4 indicates that payoffs to the ruling and rebel faction increase, more so if the political system is less cohesive. Worse fighting technology can thus make factions better off in countries that are rich in oil.

The dotted line in the top panel of figure 3 confirms proposition 3 in that a partisan in-office bias ($\beta = 2 > 1$) induces more rapacious resource depletion especially in countries with more cohesive constitutions. Another way of putting this is that the adverse effect of a partisan in-office bias on the rate of resource depletion can be offset with a more cohesive constitution. The dotted line in the bottom panel indicates that a partisan in-office bias induces for any given degree of cohesiveness more conflict as incumbents want to cling to office. Figure 4 indicates that a partisan in-office bias increases value to go for rebels. The increase in the incumbent's value to go tapers off strongly as constitutional cohesiveness is increased. This is why joint value to go rises only slightly as the degree of constitutional cohesiveness increases.

Although τ is a proxy for the quality of the constitution and not a choice variable, it is of interest to ask what incentives does a ruling faction have to depart from the constitution implying that it and any other government after it shares more of revenues with its rival faction or, put differently, can get away less with giving handouts to its own clientele without giving the same handouts also to the rest of the population (i.e., lowering τ). On the one hand improving the constitution in this fashion implies that the governing faction captures less of the oil rents but on the other hand there will be less fighting and thus less efficiency losses. Figure 4 suggests that the value to go of the incumbent typically declines with τ but that the joint value to go rises with τ . So improving the constitution

(implying more sharing) is good for society but not for the incumbent. However, with more political instability (i.e., $H = 0.2 > 0.1$) the value to go of the incumbent rises with improving constitutional cohesiveness too and thus the incumbent has an interest in constitutional reform.

Table 1: Sensitivity of speed of oil extraction and fighting efforts

	V	V^*	$V + V^*$	$L = R/S$	f
Benchmark: $\tau = 0.25, \beta = \phi = 1, H = 0.1$	16.94	10.40	27.34	0.196	0.082
Double the initial oil stock: $S(0) = 200$	23.96	14.71	38.67	0.196	0.116
Half the wage: $W = 4$	16.94	10.40	27.34	0.196	0.163
Halving the interest rate: $r = 0.02$	20.59	14.23	34.82	0.133	0.079

Finally, table 1 confirms that conflict is more intense, despite the speed of depleting oil reserves being unaffected, if the stake (oil reserves, S) is high and the opportunity cost of fighting (the wage, W) is low. A higher oil stake increases payoff to both ruling and the rebel factions. A lower wage leaves payoffs from oil unaffected. Fighting is less intense if rebels are more patient (lower r of 0.02 instead of 0.04) in which case oil depletion is less rapid and payoffs to both the ruling and the rebel faction (as does human capital) increase.

4.5. Effects on oil exploitation investment and initial reserves

Analogously to (21), we find that $I = I(K(\beta, \tau, \phi, H))$, $I_\phi, I_H < 0$, so more political stability and decreasing returns to fighting technology leads to more oil exploitation investment and higher initial oil reserves. This boosts welfare further than indicated in figure 4. Similarly, a partisan in-office bias increases the value to go for the incumbent and thus boosts oil exploitation and initial reserves, and more so if the political system is not very cohesive. Cohesiveness itself has a non-monotonic effect on value to go for the incumbent as shown in figure 4 and thus has a non-monotonic effect on oil exploitation and initial reserves.

5. Conclusion

Our analysis of ongoing political cycles in economies with exhaustible resource rents and exogenous hazards of being removed from political office extends a more standard model of a one-off irreversible regime shift to a model of ongoing reversible regime shifts.¹⁵ We have shown that

¹⁵ Both models build on the theory of confiscation risk facing a resource-owning monopolist, which is akin to the effects of an uncertain time at which an oil cartel is broken up and whether this leads the cartel to

political uncertainty then induces rapacious depletion of exhaustible resources and holds back exploration investment, especially if constitutional cohesiveness is weak, the partisan in-office bias is large and governments are frequently removed from office. Our dynamic model of exhaustible resource wars extends this model of ongoing political cycles to one where the hazard rates are no longer exogenous but depend on fighting efforts of the different factions in society.

Empirical research surveyed in the introduction suggests that fighting is more prevalent in societies with large reserves of natural resources and a low opportunity cost of fighting (a low wage), especially if institutions are bad and societies are fractionalised. Our analysis of two-way political regime shifts, exhaustible resource extraction and wars suggests a number of challenges for empirical research. Empirical research must get to grip with the two-way link between exhaustible resource extraction and conflict. In other words, natural resources cannot be treated as an exogenous variable when seeking to explain conflict. Exploration investment, the stock of resources and the speed of exhaustible resource extraction depend on conflict and thus suitable care must be taken to avoid endogeneity bias. Our analysis suggests three main additional testable implications for further empirical research. First, fighting is more intense, exploration investment is held back and exhaustible resource extraction is more rapacious if constitutional cohesiveness is weak in the sense that the ruling faction can get away with giving a bigger transfer to its own clientele than to other citizens.¹⁶ Second, these testable implications also hold if partisan in-office biases are strong. Third, exhaustible resource wars are more intense if there is not much change-over of governments, although the rate of depletion of reserves is then less rapid.

Various extensions are of interest. One could allow for more general demand and cost functions. For example, if the demand elasticity increases (decreases) as oil demand falls, the monopolistic rate of oil depletion will be too slow (rapid)¹⁷ and it is of interest to examine whether this increases fighting about control of resources. Also, if oil depletion becomes more expensive as less accessible fields are explored, the speed of oil depletion will be more conservative and it of interest to see how

overproduce (Benchechrone et al., 2006) and the interplay between political risk and foreign investment (Cherian and Perotti, 2001). It is also related to the literature on the role of wealth distribution and wealth accumulation when regimes switch between bad and good property rights (e.g., Tornell, 1997; Leonard and Long, 2012), albeit that this literature is concerned with deterministic instead of stochastic regime shifts.

¹⁶ This contrasts with the central case of inelastic oil demand discussed in Acemoglu et al. (2012), where oil extraction is too slow and incentives for war are mitigated.

¹⁷ Linear demand has increasing price elasticity and more conservative depletion (Stiglitz, 1976). This also occurs with semi-loglinear demand. But power utility with subsistence need for oil, $R = \bar{R} + p^{-\hat{\varepsilon}}$ with $\bar{R} > 0$ and $\varepsilon = \hat{\varepsilon} / (1 + \bar{R}p^{\hat{\varepsilon}}) < \varepsilon$ has a falling price elasticity and too rapid oil depletion.

this affects outbreak of conflict. One could also allow for more general hazard functions. For example, the probability of being removed from office might rise as untapped reserves fall which increases the incentive to take oil less quickly out of the ground and might increase conflict. Also, more general contest functions may allow for regimes of suppressed conflict (Besley and Persson, 2011a). One could also allow for general equilibrium. If resource production is capital (labour) intensive, higher (lower) resource prices boost the return on capital and lower the wage and thus intensify war and conflict (Dal Bo and Dal Bo, 2011; Dube and Vargas, 2013). It is also important to allow for the potential effect of conflict on exchange rates and the potential erosion of the value of resource exports. Finally, societies with a cohesive constitution build up states in the face of military conflict to finance armies whilst less cohesive societies do not and thus drop out of conflict (e.g., Gennaioli and Voth, 2015) and it is of interest to study how the building of state capacity and conflict are affected by the presence of a large stock of natural resources.

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Appendix 1: Derivation of HJB equations with hazard of a regime switch

Derivation of the HJB equation (13) in section 2

Since the probability of a regime shift in an infinitesimally small time period Δt is $h\Delta t$, the Principle of Optimality from the perspective of time zero can be written as follows:

$$(A1) \quad e^{-rt}V(S(t)) = \max_{R^B} \left[\int_t^{t+\Delta t} e^{-rs} (1 - \tau^A) U'(R(s)) R(s) ds + (1 - h\Delta t) e^{-r(t+\Delta t)} V(S(t + \Delta t)) + h\Delta t e^{-r(t+\Delta t)} V^A(S(t + \Delta t)) \right].$$

Multiplying both sides by e^{rt} , rearranging and dividing by Δt , we rewrite (A1) as:

$$(A2) \quad \max_{R^B} \left[\frac{\int_t^{t+\Delta t} e^{-r(s-t)} (1 - \tau^A) U'(R(s)) R(s) ds}{\Delta t} - h e^{-r\Delta t} V(S(t + \Delta t)) + h e^{-r\Delta t} V^A(S(t + \Delta t)) + \frac{(e^{-r\Delta t} - 1)V(S(t + \Delta t))}{\Delta t} + \frac{V(S(t + \Delta t)) - V(S(t))}{\Delta t} \right] = 0.$$

Evaluating the integral in (A2) for infinitesimally small Δt and taking the limit as $\Delta t \rightarrow 0$ whilst

using l'Hôpital's Rule for $\lim_{\Delta t \rightarrow 0} \frac{\exp(-r\Delta t) - 1}{\Delta t} = -r$, and taking terms that do not depend on $R(t)$

outside the square brackets, we get:

$$(A3) \quad \text{Max}_{R^B} \left[(1 - \tau^A) U'(R(t)) R(t) + \dot{V}(S(t)) \right] - hV(S(t)) + hV^A(S(t)) - rV(S(t)) = 0.$$

Substituting $\dot{V} = V'(S)\dot{S}$ and using equation (3), rearranging and dropping the time index,

$$(13) \quad rV(S) = \text{Max}_R \left[(1 - \tau^A) U'(R) R - V'(S) R \right] - h \left[V(S) - V^A(S) \right].$$

This corresponds to the HJB equation (13).

Derivation of the HJB equations (22) and (23) in section 3

For the model of perennial ongoing political conflict of section 3, the probability of a regime shift in an infinitesimally small time period Δt is still $h\Delta t$ as the hazard rate h is still exogenous in this section. A similar procedure can thus be used to derive the HJB equations (22) and (23).

Derivation of the HJB equations (25) and (26) in section 4

The derivation of the HJB equations (25) and (26) for the model of dynamic resource wars discussed in section 4 is more subtle, since now the hazard rate depends on fighting intensities. The derivation of these HJB equations requires that the hazard functions are continuous. We assume that these continuity assumptions hold when deriving (25) and (26). The equilibrium we obtain satisfies these assumptions, because the equilibrium outcomes derived in section 4 all involve hazard rates that are continuous functions of the stock of in situ oil. This is due to optimal fighting efforts (see equation (28)) and thus the hazard functions being continuous functions of the stocks S and S^* . In fact, the equilibrium hazard rates due to the symmetry result in equation (28) are constant and independent of S and S^* . Hence, imposing the continuity assumptions up front can be justified. Nevertheless, one cannot rule out the possibility that other equilibrium outcomes might exist that involve piece-wise continuous controls and hazard rates, but we abstract from these.

Appendix 2: Proofs

Proposition 1: From (16) $K = (1 - \tau^A)(\varepsilon r)^{-1/\varepsilon}$ and $L = \varepsilon r$ if $h = 0$ and $K = \tau^B(\varepsilon r)^{-1/\varepsilon} < (\varepsilon r)^{-1/\varepsilon}$

and $L = \left(\frac{1 - \tau^A}{\tau^B} \right)^\varepsilon \varepsilon r \geq \varepsilon r$ if $h \rightarrow \infty$ provided $\tau^A + \tau^B < 1$. Totally differentiating (16) gives

$$(16') \quad dK = \frac{-(L - \varepsilon r)(K / \varepsilon h)dh - (\tau^A / K)^{\varepsilon-1} d\tau^A + h(\varepsilon r)^{-1/\varepsilon} d\tau^B}{r + h + (1 - 1/\varepsilon)L} \Rightarrow K = K(h, \tau^A, \tau^B),$$

with $K_h < 0, K_{\tau^A} < 0$ and $K_{\tau^B} > 0$. We can show $L = L(h, \tau^A, \tau^B)$ with $L_h > 0, L_{\tau^A} < 0$ and $L_{\tau^B} < 0$.

The ratio of oil reserves to production, S/R , before the political take-over, $1/L$, is smaller than afterwards, $1/\varepsilon r$. \square

Proposition 2: Substituting this and the conjectured value functions, $V(S) = KS^{1-1/\varepsilon}$ and $V^*(S) = K^*S^{1-1/\varepsilon}$, and oil demand $R = LS$ with $L \equiv [\beta(1-\tau)]^\varepsilon K^{-\varepsilon}$ into (22) and (23) and equating coefficients on $S^{1-1/\varepsilon}$ gives two equations that can be solved for K or L and K^* :

$$(22') \quad \frac{1}{\varepsilon} [\beta(1-\tau)]^\varepsilon K^{1-\varepsilon} - H(K - K^*) = rK,$$

$$(23') \quad \tau [\beta(1-\tau)]^{\varepsilon-1} K^{1-\varepsilon} - (1-1/\varepsilon) [\beta(1-\tau)]^\varepsilon K^{-\varepsilon} K^* + H(K - K^*) = rK^*.$$

Using this we get $K^* = \left[\frac{\varepsilon \left(\frac{\tau}{\beta(1-\tau)} \right) L + \varepsilon H}{\varepsilon(r+H) + (\varepsilon-1)L} \right] K$. Putting this in (22') gives

$$(A4) \quad (\varepsilon-1)L^2 + \Xi L - \varepsilon^2 r(r+2H) = 0, \quad \Xi \equiv \varepsilon[2(r+H) - \varepsilon r] - \varepsilon^2 H \left(\frac{\beta(1-\tau) - \tau}{\beta(1-\tau)} \right).$$

Picking the positive solution to equation (A4) gives the equilibrium speed of oil extraction,

$$(A5) \quad \frac{R}{S} = L = \frac{\sqrt{\Xi^2 + 4(\varepsilon-1)\varepsilon^2 r(r+2H)} - \Xi}{2(\varepsilon-1)} > 0,$$

upon which and K, K^* and values to go follow. Total differentiation of (A4) yields:

$$(A4') \quad [2(\varepsilon-1)L + \Xi]dL = 2\varepsilon^2 rdH + \varepsilon^2 H \left(\frac{\tau}{\beta^2(1-\tau)} \right) L d\beta - \varepsilon^2 H \left(\frac{(1+\beta)(\beta-1)\tau + \beta}{\beta(1-\tau)} \right) L d\tau.$$

Since $2(\varepsilon-1)L + \Xi > 0$, we deduce $\partial L / \partial \beta > 0, \partial L / \partial \tau < 0$ and $\partial L / \partial H > 0$. The effect of β on L is zero if $\tau = 0$ and increases in τ . It follows from (A4') that $\partial K / \partial H < 0$. The effect of τ on K is non-monotonous. \square

Proposition 3: Using $R / S = [\beta(1 - \tau)]^\varepsilon K^{-\varepsilon} \equiv L$, we use (32) to obtain

$$(32') \quad K^* = \left[\frac{\varepsilon \left(\frac{\tau}{\beta(1 - \tau)} \right) L + \varepsilon(1 - 0.5\phi)H}{\varepsilon[r + (1 - 0.5\phi)H] + (\varepsilon - 1)L} \right] K.$$

We can use (32') to rewrite (31) as a quadratic equation in L :

$$(31') \quad (\varepsilon - 1)L^2 + \Xi L - \varepsilon^2 r(r + 2H) = 0, \quad \Xi \equiv \varepsilon[2(r + H) - \varepsilon r] - \varepsilon^2(1 + 0.5\phi)H \left(\frac{\beta(1 - \tau) - \tau}{\beta(1 - \tau)} \right).$$

Picking the positive solution to equation (31') gives the equilibrium speed of oil extraction,

$$(A6) \quad \frac{R}{S} = L = \frac{\sqrt{\Xi^2 + 4(\varepsilon - 1)\varepsilon^2 r(r + 2H)} - \Xi}{2(\varepsilon - 1)} > 0,$$

and thus K . Subsequently, one gets K^* from (32'), fighting efforts from (33) and values to go for each of the factions. Total differentiation of (31') yields:

$$(A7) \quad \begin{aligned} [2(\varepsilon - 1)L + \Xi]dL &= \varepsilon^2 \left[2r + 0.5\phi \left(\frac{\beta(1 - \tau) - \tau}{\beta(1 - \tau)} \right) L \right] dH + 0.5H \varepsilon^2 \left(\frac{\beta(1 - \tau) - \tau}{\beta(1 - \tau)} \right) d\phi \\ &+ \varepsilon^2(1 + 0.5\phi)H \left(\frac{\tau}{\beta^2(1 - \tau)} \right) L d\beta - \varepsilon^2(1 + 0.5\phi)H \left(\frac{(1 + \beta)(\beta - 1)\tau + \beta}{\beta(1 - \tau)} \right) L d\tau. \end{aligned}$$

At the solution to the quadratic equation (31') the derivative of the quadratic slopes upwards, so that $2(\varepsilon - 1)L + \Xi > 0$ and thus from (A7) we deduce $\partial L / \partial \beta > 0$, $\partial L / \partial \tau < 0$, $\partial L / \partial \phi > 0$ and $\partial L / \partial H > 0$. The effect of β on L is zero if $\tau = 0$ and increases in τ . It follows from the definition of L that $\partial K / \partial \phi < 0$ and $\partial K / \partial H < 0$. The effect of τ on K is non-monotonous. \square

Appendix 3: Time at which incumbent's oil depletion rate falls below efficient rate

The oil depletion rate before the switch of government is below the efficient rate for all $t > T^*$, where T^* follows from $Le^{-LT^*} = \varepsilon r e^{-\varepsilon r T^*}$:

$$(A8) \quad T^* = \frac{\ln(L(h, \tau^A, \tau^A) / \varepsilon r)}{L(h, \tau^A, \tau^A) - \varepsilon r} \equiv T^*(h, \tau^A, \tau^A) > 0.$$

Consider $\partial T^* / \partial L = [L - \varepsilon r - L \ln(L / \varepsilon r)] / [L(L - \varepsilon r)^2]$. The denominator is positive and the derivative of the numerator is $-\ln(L / \varepsilon r) < 0$. Hence, as the numerator approaches zero as L approaches εr , we have $\partial T^* / \partial L < 0$. Hence, $T_h^* < 0$, $T_{\tau^A}^* < 0$ and $T_{\tau^B}^* > 0$. A higher probability of being removed from office thus brings forward the date (provided A is still in office) that the oil depletion rate falls below efficient extraction rate and that the oil price moves above the efficient path of oil prices.

Appendix 4: Asymmetric hazard functions and fighting advantage for the incumbent

Let $\gamma > 1$ denote the fighting advantage of the incumbent over the rebel faction. In that case, the hazard rates of faction A being replaced by B and of faction B by A and are given by:

$$(24') \quad h^A = \frac{2H(f^{B*})^\phi}{(\gamma f^A)^\phi + (f^{B*})^\phi}, \quad h^B = \frac{2H(f^{A*})^\phi}{(f^{A*})^\phi + (\gamma f^B)^\phi}, \quad H > 0, \quad 0 < \phi \leq 1, \quad \gamma > 1.$$

Setting faction A's marginal expected gain from, respectively, fighting in and out of office to its opportunity cost of fighting gives:

$$(27') \quad \left(\frac{2\phi H \gamma (\gamma f^A)^{\phi-1} (f^{B*})^\phi}{[(\gamma f^A)^\phi + (f^{B*})^\phi]^2} \right) [V^A(S) - V^{A*}(S)] = \left(\frac{2\phi H (f^{A*})^{\phi-1} (\gamma f^B)^\phi}{[(f^{A*})^\phi + (\gamma f^B)^\phi]^2} \right) [V^A(S) - V^{A*}(S)] = W$$

and similarly for faction B. Since $f^A = f^B$ and $f^{A*} = f^{B*}$, the first equality of (27') gives $f^A = f^{A*}$ and $f^B = f^{B*}$. The second equality of (27') thus gives fighting efforts:

$$(28') \quad f^A = f^{A*} = f^B = f^{B*} = \frac{\phi H}{2W} \left(\frac{4\gamma^\phi}{(1+\gamma^\phi)^2} \right) [V(S) - V^*(S)].$$

Note that this boils down to (28) if $\gamma = 1$. Since $\partial \left(\frac{\gamma^\phi}{(1+\gamma^\phi)^2} \right) / \partial \gamma = -\frac{(\gamma^\phi - 1)}{(1+\gamma^\phi)^3} \phi \gamma^{\phi-1} < 0$ for $\gamma > 1$,

one can establish from (28') that fighting decreases if the incumbent has a fighting advantage.