Resource Extraction in a Political Economy Framework

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Abstract

We propose a political economy model of resource extraction accounting for the fact that non-renewable resources are often state-owned or state controlled. The 'political elite' extracts a part of the resource and hence turns the resource extraction path suboptimal. We analyze how the politician's rapaciousness and the pace of resource extraction are ultimately determined by the political economy features such as the weight the politician attaches to society's welfare, the politician's discount rate and time horizon. In an endogenous version of the model, the previously exogenous discount rate and social weight result from the politician's probability of losing power.

Keywords: exhaustible resources, oil, dictatorship, political economy, taxation, climate change

JEL Classification: Q31, Q38, Q54

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1 Introduction

In this paper we investigate non-renewable resource extraction in a political economy framework and hence try to account for the institutional framework and political context of resource depletion in some countries. In particular, we consider an economy where the political elite disposes of discretionary decision making power regarding the state-owned resources.

We analyze theoretically and quantitatively whether and how optimal extraction changes if one deviates from the Social Planner optimality framework by including political economy features. We introduce a political leader who optimizes a weighted sum of his own and the society's welfare into a model of resource depletion. The political leader's discount rate differs from the discount rate of the society. Also, his time horizon is finite, whereas the social optimization problem extends to infinity. We analyze how the politician's rapaciousness and the pace of resource extraction depend on these political economy features. We find that the inclusion of political economy features into a model of resource extraction results in a division of the initial resource stock S_0 into a stock depleted for the good of the society, S_0^S, and a stock purely used to benefit the political elite, S_0^P. Whereas a lower social weight decreases the resource stock available to society, the politician's higher discount rate and a shorter time horizon do not imply less available resources for the society. Yet, they do have an adverse effect on the resource extraction paths, and especially on the initial extraction rates: the more the politician discounts the future and the shorter his time horizon, the more extractive he behaves initially, which can raise initial resource extraction over the optimal levels. This might have disastrous consequences for the climate: more emissions today might increase the likelihood that we cross a threshold that triggers a catastrophe. Also the rate of climate change might be speeded up which translates into higher abatement costs when changes occur quickly. Furthermore, higher initial emissions create a higher maximum stock level, and climate costs may be nonlinear in the stock.

In a discrete time setting, we motivate the choice of the form of the political leader's optimization problem. The political elite's higher discount rate results from the probability of losing power. This 'staying in power' or 'reelection' probability is determined by social welfare and, depending on the functional form, induces the politician to also account for the utility of the society. In this setup another aspect of the political economy framework of resource extraction is disclosed: the issue of political commitment and time inconsistency of extraction decisions. We find that the absence of commitment is detrimental to both the amount of resources available for social production and to the resource extraction path.

Our motivation to deviate from the optimality framework of a Social Planner is the fact that a large share of the world's non-renewable resource deposits such as oil and gas are to a certain extent controlled by the respective country's government or exploited by state-owned or state-controlled companies. Prominent examples comprise resources extracted in Venezuela, Russia, the former Soviet Union, Angola, Nigeria, the Arab countries and Iran, for instance. The BP Statistical Review of World Energy estimates that 70 to 80 % or world's oil and about three quarters of world's gas reserves are located in those countries (BP, 2008). The extraction decisions of those politicians hence determine both their societies' welfare and global CO_2 emissions.

Empirical evidence suggests that governments and politicians do not always act as social welfare maximizers. Van der Ploeg (2011) observes the need to "introduce political economy features" in order to explain economic outcomes that do not comply with the efficiency of the Hotelling and Hartwick rules. Another motivation is the debate about the 'resource curse': it describes the stylized fact that resource rich economies tend to exhibit sluggish growth rates. However, we are not striving to add another explication to the already very abundant resource curse literature. Rather, we want to assess the effects of a politician having discretion over a country's natural non-renewable resources on the extent to which the country really benefits from its resource wealth, and the consequences for the resource extraction path and hence global climate change.

Also, analyzing resource extraction in a political economy framework might reveal what actually is the attainable second best for resource-rich countries with a state-owned resource stock and politically controlled resource extraction. Dasgupta (2001) remarks that "intertemporal welfare economics was developed for a society in which the State is not only trustworthy, it also optimizes on behalf of its citizens. Policy prescriptions emerging from the theory are for Utopia, [...]". It does not seem unreasonable that decisions on natural resource depletion taken by politicians (in case the resources are state-owned or the resource management is state-controlled) are not only based on social welfare concerns and that the information available to the decision maker is much more limited than it is generally supposed in the rational agents' framework. Knowledge of the mechanisms and their consequences might help in developing welfare-enhancing policies for resource-rich countries.

Another aspect is related to the relevance of resource depletion and usage for the environment. Abstracting from the fact that exhaustible resources will not exist any more after extraction and thus the environment *per se* is changed, the consumption of resources, especially oil and gas, has consequences for climate change. A higher speed of resource depletion on global level might worsen the impact of resource usage on the climate (Ramanathan, 1980). Also Withagen (2012) acknowledges the role of the resource market structure (such as the cartel-versus-fringe model in his case) for the climate due to the strong relationship between climate change and CO_2 emissions as a consequence of burning fossil fuel. The same reasoning can be applied to the political economy features influencing the rate of resource extraction in our model.

The theoretical framework at hand can be related to the literature on the resource curse where political leadership, or generally, the quality of institutions are used as one explanatory factor for the bad economic performance and low economic growth in resource rich countries.[1] Whereas some studies seem to confirm the role of resource rich countries' political economy on their economic performance (Sachs & Warner, 1995, 2001; Gylfason, 2001), the theoretical literature still offers a variety of possible mechanisms. Tornell & Lane (1999), for instance, find a "voracity effect" when powerful groups interact via a fiscal process which results in a disproportionately high increase in fiscal redistribution. Mehlum *et al.* (2006) note that the quality of institutions determines the scope of rent seeking. Deacon (2003) shows theoretically and empirically that public good provision varies systematically with the quality and form of government. He concludes that public good provision is larger in more inclusive regimes such as democracies than in autocracies. Bulte & Damania (2008) model the government explicitly as an active player with own objectives and constraints whose behavior, additional to the rent seeking of private agents, gives a possible explanation for the resource curse. Similarly, Leite & Weidmann (1999) highlight the role of corruption in the presence of resource abundance and its effects on growth in a general equilibrium framework.

In contrast to these more decentralized mechanisms, Robinson *et al.* (2006) develop a simple two period probabilistic voting model and try to assess the political incentives that are generated by resource endowments. They find that politicians tend to over-extract natural resources. In their model, the overall impact of resource booms on the economy depends on institutions as they determine to which extent political incentives are mapped into policy outcomes. Another attempt to place models of resource depletion in a political economy framework is made by van der Ploeg (2011b) who derives political counterparts of the Hotelling and the Hartwick rules in a fractionalized economy. There, each societal fraction owns a part of the national resource stock; yet, ownership rights on the stock are not secure as the resource fields are interconnected and seepage occurs. This induces a dynamic common-pool problem which results in prices and resource depletion increasing faster than suggested by the Hotelling rule. In another paper, van der Ploeg (2012) analyzes how a possible regime switch affects the resource depletion of a monopolistic private owner. He assumes that two types of government are possible: a benevolent and a grabbing populist government. The higher initial oil depletion rates are driven by the higher risk of confiscation in case a regime switch occurs. A higher regime switching probability induces higher resource depletion in both regimes.

[1] Frankel (2010) and van der Ploeg (2011a) survey a variety of hypotheses and papers on the resource curse.

We expose the basic intuition for our framework in Section 2.1. In Section 2.2 we introduce the model and analyze how resource extraction depends on the political economy parameters. Section 2.3 compares the resource extraction paths in a political economy framework with the outcome in a decentralized economy where politicians try to raise revenue by levying profit taxes on the resource extraction sector. In Section 3 we endogenize the weight the political leader attaches to societal welfare by modelling the impact of resource extraction and resource use on the political leader's hazard of staying in power in a discrete time setting. Furthermore, we provide a motivation for the political leader's higher discount rate and delineate the discrepancy in the commitment and no-commitment solutions. Section 4 concludes.

2 A Political Economy Model of Resource Extraction

2.1 Assumptions and Intuition

Our main assumption is that the political leader or the political elite of a country disposes of discretionary decision making power regarding the natural non-renewable resources in the country. We can think of it in two ways: the government is the direct recipient of *all* the resources extracted by state-owned companies and decides on the resource share that it directly accroaches and the share which the society can use for productive purposes. Alternatively, the government allocates a share of the stock for social use by disseminating a certain amount of concessions to private extractive companies.

In both cases the result is the same: the country's non-renewable resource stock S_0 is *de facto* split up in two stocks, S_0^S and S_0^P, which are both managed in different ways. The problem of managing S_0^S, the resource stock attributed to social use, corresponds to a pure Social Planner problem. The stock extraction hence depends on the consumption preferences and the capital and resource stocks available to the economy. It is in general governed by two equations: a form of the Hotelling rule and an equation describing the evolution of the consumption path of the society depending on the interest rate, the social rate of time preference and the elasticity of intertemporal substitution.

In contrast to S_0^S, the conditions for the depletion of S_0^P are very different. The politician manages 'his' stock in the framework of a pure consumption economy. This results in a monotonically decreasing consumption path, depending on the politician's elasticity of intertemporal substitution and his rate of time preference.

The reason why a political leader decides not to take *all* of the non-renewable resource for his own benefits is that he is not uncontested. According to the type of regime which ranges from democracy to autocracy, the reasons for the incumbent being challenged are likely to differ.[2] In a democratic regime the incumbent is challenged by political opponents during recurrent elections. As the political leader is the direct recipient of the resource revenues, it is highly profitable to stay in power. Consequently, the incumbent will have an incentive to care about the well-being of the country's population in order to avoid his deselection in case the electorate was dissatisfied with his governance.

Also in case of an autocratic regime, it is unlikely that political elites are never uncontested. The presence of resource rents provides incentives for potential political challengers to seek power, for instance by conducting a *coup d'état*.[3]

We have argued *why* a politician would not accroach *all* of the resource stock of a country. What are the factors which determine *how much* of the resource he takes for himself? What determines the division of S_0 into S_0^P and S_0^S? In order to answer this question, we have to put more structure on the problem. In the following section we present a mathematical representation of the mostly intuitive reasoning delineated above and examine the influence of certain parameters of the functional forms chosen on the division of S_0.

2.2 A Political Economy Model of Resource Extraction

The political leader's utility function is a linear combination of the utility of his private consumption, defined more broadly as private benefits, and the social welfare function.[4] Thus, let the political leader's one-period utility function be denoted as:

$$u(C_t^P, C_t^S) = (1-\gamma)u_P(C_t^P) + \gamma u_S(C_t^S) \tag{1}$$

with $u_P(C_t^P)$ being the political leader's utility from private consumption, C_t^P, defined more broadly as private benefits, and $u_S(C_t^S)$ denoting the social welfare function in period t, depending on the level of societal consumption C_t^S. The parameter $\gamma \in (0,1)$ determines to which extent the politician accounts for social welfare.[5] It will be one of

[2]Labelling a country's regime as an autocracy or a democracy is not an easy task and there exists a branch of political science literature concerned with this issue. For simplicity one could follow Deacon (2003) in distinguishing between autocracies, democracies and mixed regimes.

[3]As an example, Casellli (2006) notes that oil wealthy Nigeria has had eight successful coups since its independence in 1960.

[4]The objective function will be similar to the one employed by Robinson & Torvik (2005). They model the politician i's per period utility as $U_t^i = X_t^i + \frac{1}{2}\alpha Y_t^i$, with $i = A, B$ denoting two regional parties and two groups of voters of equal size $\frac{1}{2}$. Politicians and voters with the same label belong to the same region. In their probabilistic voting model each politician cares about his own utility and about the political outcome for agents in his region. X_t^i is the income of the politician in period t, Y_t^i is the income of each member in group i and the parameter α governs how the politician values the outcome for his own group.

[5]Note that $\gamma = 1$ denotes the usual Social Planner's problem, whereas $\gamma = 0$ corresponds to the political leader being an absolute dictator who entirely disregards any social welfare considerations. We

the crucial parameters in determining the sizes of S_0^P and S_0^S.

The model sketched in this section is a general equilibrium, closed economy model without population growth. Exhaustible resources are used together with capital to produce the only (both consumption and investment) good of the economy according to a Cobb-Douglas production function. We abstract from labour and leisure decisions in this model. In order to focus on the political economy framework, we leave open economy considerations aside.

The rate of resource depletion equals $R_t \geq 0$ at each time instant t and the time path of resource depletion must satisfy the resource constraint:

$$\int_0^\infty R_t dt \leq S_0 \quad \text{or} \quad \dot{S}_t = -R_t, \quad S(0) = S_0. \tag{2}$$

As described above, the resource can either be used for productive activities or appropriated by the political leader, thus $R_t = P_t + E_t$, where E_t denotes the resource extraction that is employed by the productive sector of the society for example as energy input into the production process, whereas P_t is used by the political elite for private consumption.

Furthermore, we assume that $P_t = C_t^P$, i.e. the resource yields direct benefits or 'consumption' to the political leader. This is clearly a simplification. The interpretation is that the natural resources can be appropriated by the political leader in such a way that they do not yield any benefit to the population and do not serve as input into productive activity. The political leader or the political elite might thus use the resource revenues to buy off his opponents, construct white elephants, i.e. investment projects with negative social surplus (Robinson & Torvik, 2005), or suppress the opposition. Another interpretation would be that the political elite sells the resource at world market prices abroad and buys goods abroad; one could think of arms or luxury goods for instance.

Physical or human capital K_t and natural resources E_t are used to produce output Y_t. The production function $Y_t = F(K_t, E_t)$ is of a standard Cobb-Douglas form with decreasing returns to scale. In this section we do not present and derive the entire model.

The political leader faces the following maximization problem:

$$\max \quad (1-\gamma)\int_0^T u_P(C_t^P)e^{-\delta t}dt + \gamma \int_0^\infty u_S(C_t^S)e^{-\rho t}dt, \tag{3}$$

subject to the resource constraint and the society's production function. For the sake of exposition, we moved the mathematical analysis of the Hamiltonian corresponding to equation (3) to Appendix A.1. Using CRRA utility functions, we solve there for the first

disregard the latter case on the basis of the reasoning presented above.

order conditions and the equations governing the evolution of the social capital and resource stock and the politician's resource stock.

A couple of things are to be noted regarding the intertemporal variant (3) of equation (1). The political leaders discount rate δ differs from the society's rate of time preference, ρ. We assume that $\delta > \rho$. One reason for the politician's intertemporal preferences to be present-biased is that the political leader will be in power in the future only with a certain probability.[6] Also, the planning horizons might differ between the political leader on the one hand, and the society on the other hand. Whereas the society's time horizon is infinite, the politician might well consider only a finite time horizon T. Hence, we suppose that the politicians can be short-lived, as in Grossman & Helpman (1998). Possible reasons for this assumption are that the maximum number of the politicians' terms of office is constrained in a democratic regime. But even in a more autocratic regime, the political leader faces a different time horizon as he will not live infinitely long and thus will not be able to enjoy his direct private benefits infinitely.[7]

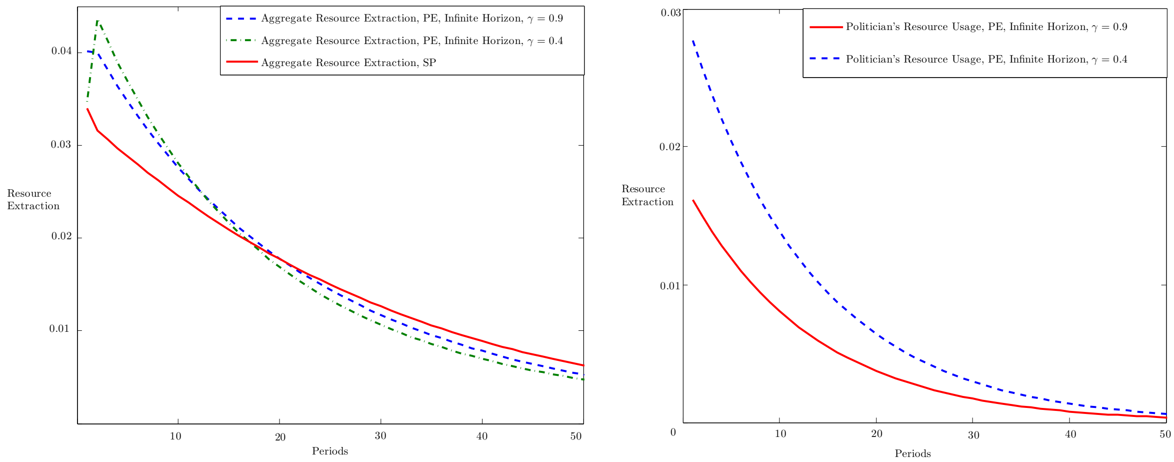

Figure 1: Aggregate Resource Extraction and the Politician's Resource Consumption in a Social Planner Economy and in the Political Economy Framework with Infinite Horizon ($\gamma = 0.4, 0.9$) and Higher Politician's Discount Factor ($\rho = 0.04, \delta = 0.08$), where 'SP' denotes the Social Planner, and 'PE' the political economy case.

How do the division of S_0 and the extraction paths depend on the mentioned parameters? In order to address this question we analyze, both analytically and numerically, how changes in the political economy parameters γ, δ and the time horizon T affect the initial

[6]This relates to models where resource owners face insecure property rights or an expropriation probability (Long, 1975; van der Ploeg, 2012; **?**). Despite the higher discount rate, we do not yet model reelection uncertainty directly. This is done in Section 3.

[7]Though his time horizon might be somewhat lengthened in case he wants to establish or maintain a dynasty.

resource extraction, i.e. E_0 and P_0, the respective social and the politician's resource usage paths and hence the size of the resulting stocks S_0^S and S_0^P. Furthermore, we numerically assess the welfare consequences for both the society and the politician. The parameters used for these numerical exercises can be found in Table 1 in Appendix B, where we also describe our numerical approach in detail.

The two graphs in Figure 1 give us an idea which parameters play a role in determining the extraction paths and both the politician's and social stock sizes. Unsurprisingly, γ has a major impact on both the size of the stocks and the initial consumption.[8] Also, the political elite's time horizon seems important. In the sequel we separately investigate the effects of γ, the discount rate δ and the politician's finite time horizon by changing these parameters one at a time, and holding everything else equal as in the baseline scenario. In the baseline scenario the social weight equals $\gamma = 0.9$, the politician's discount rate is equal to the social rate of time preference $\delta = \rho = 0.04$ and the politician's time horizon T is infinite.

Let us first determine the impact of the social weight γ on the division of S_0 and also on the extraction path. For the moment we also assume that the politician's discount rate δ is equal to the social rate of time preference ρ. Proposition 1 summarizes the analytical argument:

Proposition 1. *Everything else being equal, a higher social weight γ results in a lower S_0^P and a lower C_0^P. The politician appropriates less of the resource* and *behaves less extractive initially the higher the social weight is.*

Proof. See Appendix A.3. □

Our numerical example illustrates this. A change in the social weight γ has the most severe consequences for the division of the initial resource stock and the social welfare. In our numerical example, the initial resource stock of $S_0 = 1$ is divided into $S_0^P = 0.38$ and $S_0^S = 0.62$ for $\gamma = 0.9$. With $\gamma = 0.6$, the resource stock that is available for social production falls to less than two-thirds of its original size: $S_0^P = 0.6$ and $S_0^S = 0.4$. The politician behaves more extractive in the initial periods, as can be seen in the first graph of Figure 2: his initial resource consumption shifts clearly upwards. The second graph in Figure 2 indicates that despite the higher initial consumption of the political elite, the aggregate initial resource usage does not need to increase due to a drop in the society's resource consumption. A decrease in the social weight also decreases society's welfare,

[8]In this model consumption and interest rate are determined endogenously like in a Ramsey type model. Hence, consumption and capital stock might increase initially before decreasing due to a falling production and falling resource levels.

whereas the politician's private benefits increase. Yet, his weighted welfare consisting of the social and his private welfare also decreases with γ: an increase in the political elite's private welfare cannot offset the social welfare loss.[9]

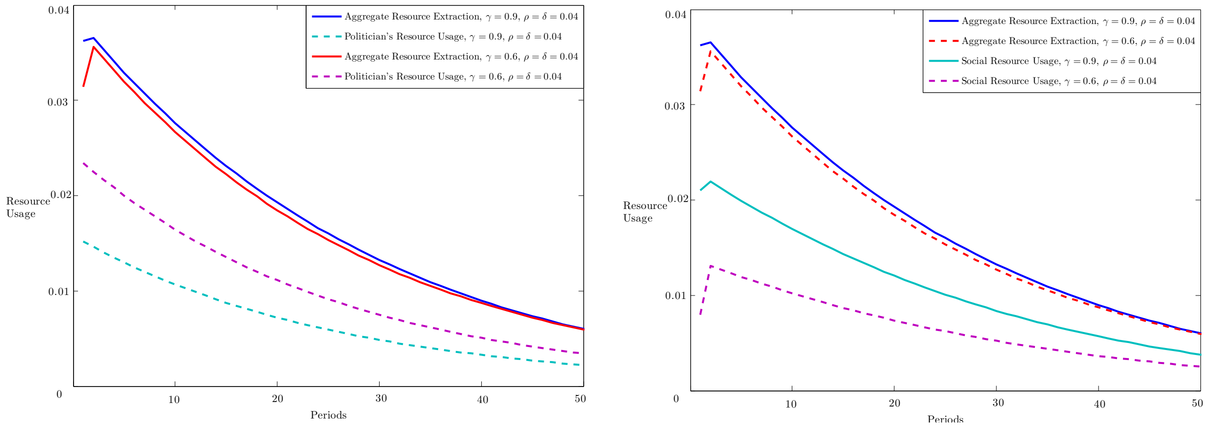

Figure 2: Aggregate Resource Usage Paths and Politician's Resource Consumption for $\gamma = 0.9$ and $\gamma = 0.6$

An increase of the political leader's discount rate clearly results in a more present biased resource consumption path, as can be seen in the first graph of Figure 3. Surprisingly, higher discount rates of the political elite affect the division of the initial resource stock positively for the society: whereas the resource stock is divided into $S_0^P = 0.38$ and $S_0^S = 0.62$ for $\delta = 0.04$, the socially available resource stock amounts to $S_0^S = 0.78$ if $\delta = 0.08$ and to $S_0^S = 0.84$ if $\delta = 0.12$.[10] The social resource stock hence increases in δ. A higher δ, however, also results in higher initial resource usage of both the political elite and the society. Hence, aggregate resource usage is higher initially for higher values of the politician's discount rate, as shown in the right graph in Figure 3. Proposition 2 gives an explanation for the numerical findings:

Proposition 2. *Everything else being equal, the politician's higher discount rate δ results in a higher C_0^P. The politician's resource consumption path is more present biased and, hence, he behaves more extractive. In case a higher discount rate also brings about higher private welfare of the politician, more resource S_0^S is available for social production. The consequences are a higher initial social resource consumption and hence higher initial overall consumption of the resource.*

Proof. See Appendix A.3. □

[9]Whereas for $\gamma = 0.9$ social welfare amounts to $W^S = 1.71$, it decreases to $W^S = -1.99$ in case of $\gamma = 0.6$. The political elite's private welfare rises from $W^P = -129.33$ to $W^P = -123.17$, whereas the weighted welfare decreases from $W = -11.39$ in case of $\gamma = 0.9$ to $W = -50.46$ if $\gamma = 0.6$.

[10]For this numerical exercise we hold everything else constant; $\gamma = 0.9$ in all cases.

Despite the higher resource stock that is available for productive activities of the society, social welfare is not increasing in higher values of δ as initial social consumption decreases.[11]

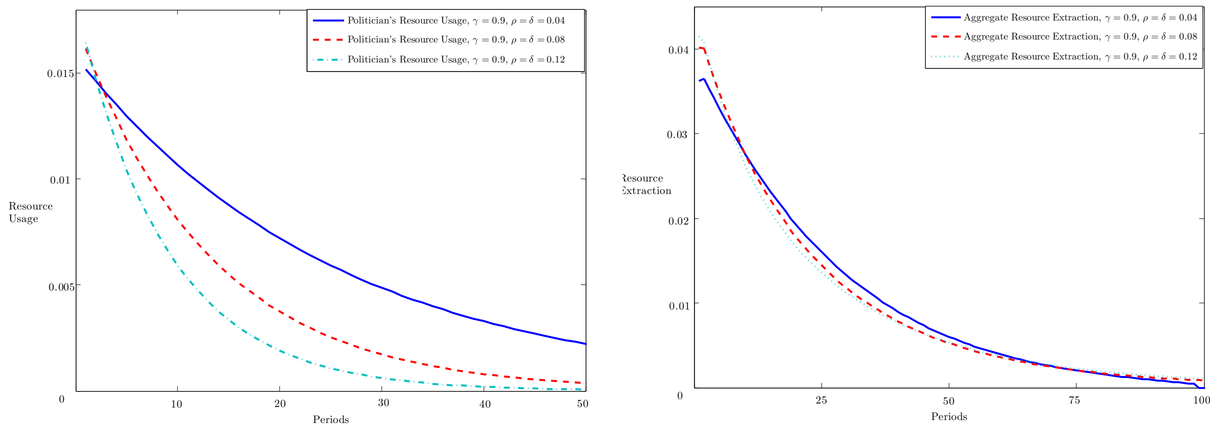

Figure 3: Politician's and Aggregate Resource Usage Paths for $\delta = 0.04$, $\delta = 0.08$ and $\delta = 0.12$

So far we have assumed that the political leader operates with an infinite horizon in his optimization problem. An infinite horizon seems reasonable regarding the welfare of a society as a benevolent Social Planner might want to maximize the welfare of the society as long as it exists - and assumes that it does not cease to exist until the infinite future. Regarding private welfare, however, the politician is well aware of the limited time he will serve in office. This gives him a finite time horizon to obtain private benefits. A finite time horizon of the political elite results in a higher initial resource stock of the society. The social resource stock is in fact higher the shorter the politicians' time horizon is.[12] This is very intuitive: with a shorter term of office, the politician has less time to accroach resources for himself. This positive result, however, is to a certain degree outweighed by his behaviour which is more extractive the shorter his time horizon is, as shown in the left graph of Figure 4.

The right graph of Figure 4 indicates that higher initial resource usage from the side of the politician and the society leads to higher overall initial resource consumption. Also, despite the higher resource stock that is available for the productive activities of the society, social welfare does not increase for shorter political time horizons.[13] We summarize our

[11] Whereas for $\delta = 0.04$ social welfare amounts to $W^S = 1.71$ (with an initial consumption equalling $C_0 = 1.59$), it decreases to $W^S = -1.13$ ($C_0 = 1.5$) in case of $\delta = 0.08$. The political elite's private welfare rises from $W^P = -129.33$ to $W^P = -68.67$, whereas the weighted welfare increases from $W = -11.39$ in case of $\delta = 0.04$ to $W = -7.857$ if $\delta = 0.08$. The corresponding numbers for $\delta = 0.12$ are $W^S = -1.9$, $C_0 = 1.47$, $W^P = -47.16$ and $W = -6.4221$.

[12] For $T = 50$ the social resouce stock amounts to $S_0^S = 0.65$ and the politician's resource stock equals $S_0^P = 0.35$; for $T = 10$ the resource stocks amount to $S_0^S = 0.84$ and $S_0^P = 0.16$ and for $T = 5$ the resource stocks equal $S_0^S = 0.92$ and $S_0^P = 0.08$.

[13] For $T = 50$ the separate welfares amount to $W^S = 1.583$ and $W^P = -107.41$; for $T = 10$ the they

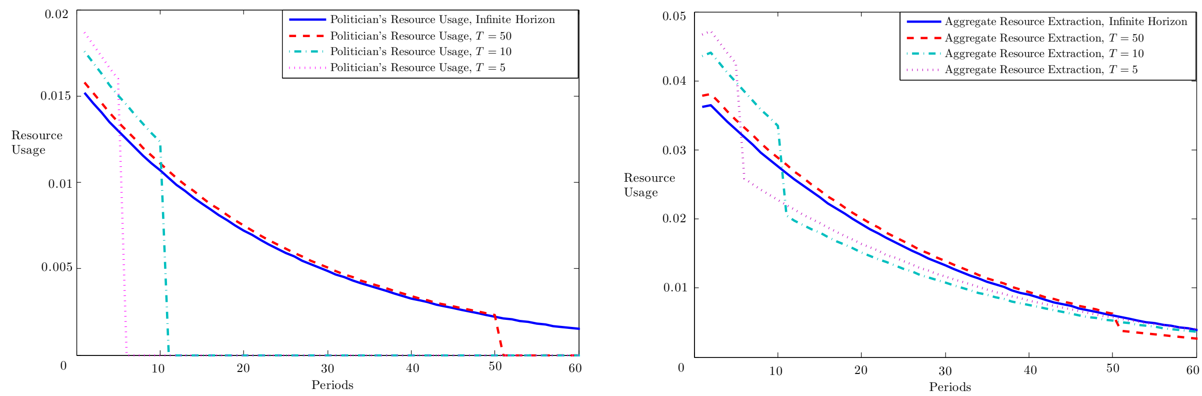

Figure 4: Politician's and Aggregate Resource Usage Paths in the Infinite Horizon Case and for $T = 50$, $T = 10$ and $T = 5$

findings in Proposition 3:

Proposition 3. *Everything else being equal, the politician's shorter time horizon T results in a higher C_0^P. The politician hence behaves more extractive. Yet, the shorter his time horizon, the less is he able to consume overall. The amount of resources used for social production, S_0^S, hence decreases in T. This leads to higher initial social resource consumption and hence higher initial overall consumption of the resource for shorter time horizons of the politicians.*

Proof. See Appendix A.3. □

2.3 Political vs. Decentralizied Markets Economy

In the previous section we found that political economy features might have adverse effects on social welfare and the initial resource extraction rate in a model of resource extraction. This results are due to the assumption that the political elite exercises direct control over the resource stock. This assumption holds for various countries. Yet, in other countries, the resource stock is privately owned, but the political elite still strives to maximize its utility which includes private benefits. A way for politicians to obtain funds is to levy taxes and appropriate these for their own good instead of redistributing them for the benefits of the society. The question now is which property rights allocation is preferable if one is concerned about the social welfare loss and the effects on resource extraction rates: the political elite's direct control over resources or private resource ownership in the presence of rapacious politicians and extractive taxation?

Given the politician's weighted welfare function from Section 2.2, we identify a stream of tax revenues and social welfare yielding the same level of welfare to the politician in a setting where he cannot directly accroach resources, but instead taxes resource owners.

equal $W^S = -0.63$ and $W^P = -35.46$ and for $T = 5$ they amount to $W^S = -0.91$ and $W^P = -18.77$.

Thus, taxation is not justified by any of the reasons that are usually brought forward such as the aim to remove existing distortions, distributional grounds, or to provide public goods. The tax revenues in each period are appropriated privately by the politician and do not yield any benefits to the society.

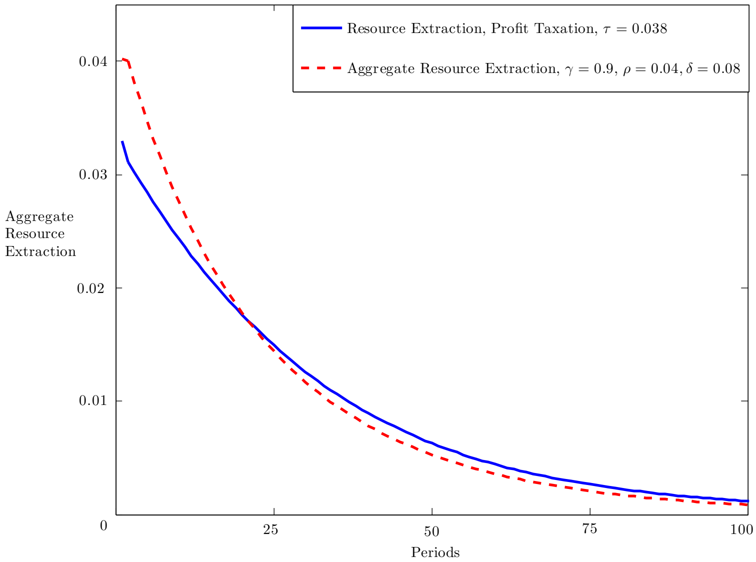

Figure 5: Aggregate Resource Usage Paths in the Infinite Horizon Case for $\delta = 0.08$ and $\gamma = 0.9$, and in the Taxation Case with $\tau = 0.038$

In the choice of the tax base we limit ourselves to taxes on the resource production sector. Resource-based and resource-extracting industries are commonly subject to substantial taxation.[14] In our numerical exercise, we consider a constant profit tax, i.e. a tax on the profit of a firm, $p_t R_t$, assuming no extraction costs.[15]

With a profit tax of $\tau = 0.038$ both the social and the politician's private welfares correspond to the private welfares in the political economy case in Section 2.2, where $\gamma = 0.9$ and $\delta = 0.08$. With equal welfare levels, we compare in Figure 5 the resulting extraction rates of the non-renewable resource to determine which property rights regime is environmentally more destructive. Clearly, although the initial social consumption of the non-renewable resource is higher, the overall initial resource usage is lower in case the politian has to rely on taxation. Thus, everything else being equal, the private ownership

[14] Daubanes & Lasserre (2012) note that, under standard assumptions in the literature on non-renewable resource extraction and optimum commodity taxation, an exhaustible resource should be taxed irrespective of its demand elasticity and the demand elasticity of other commodities. Furthermore, it should be taxed higher than other commodities with the same demand elasticity and the tax rate should vary over time.

[15] In case the tax is deemed finite, it might in some cases induce resource owners to postpone extraction until the expiration date of the tax. A tax which affects the resource owners but does not induce them to postpone extraction even if it is deemed finite, is a tax on interest earnings and capital gains, for instance. For our numerical exercise we assume that the tax is employed forever and hence does not induce resource producers to postpone extraction.

of resource stocks is preferred due to suboptimal effects of governmental ownership on the extraction paths.

3 Endogenous Political Economy Framework

In order to substantiate our intuition about the behavior of politicians in resource rich countries in Section 2.1 we analyzed in a formal way how the division of the initial resource stock and the initial resource extraction depends on parameters in the politician's optimization problem. These parameters, however, are exogenous. In this section we introduce a discrete time model where the weight γ that the political leader attaches to the welfare of society, is endogenized, and the political leader's probability of staying in power depends on social welfare. Furthermore, we show how the politician's discount rate δ, which is higher than the society's rate of time preference ρ, can be derived with the help of the probability π_t of staying in power (Robinson *et al.* , 2006). The aim of this section is to motivate the assumptions about the form of the political leader's welfare function made in Section 2.2.

The internalization of both the social weight and the discount rate, and the discretization of the model confront us with the problem of time consistency with respect to the politician's optimal decision. His optimal resource extraction and social consumption path in the initial period $t = 0$ derived under uncertainty of reelection and implying a certain S_0^P, is not optimal any more after the politician has been reelected. Thus, the politician has an incentive to re-optimize at the beginning of period $t = 1$. Another interpretation is also possible: political succession is equivalent to the case of no commitment described above. Even if the politician is not reelected, it is very probable that he is replaced by another, equally self-interested politician who does not stick to his predecessor's optimal plan but optimizes anew, given the respective period's capital and resource stock.

Hence, in this section we focus not only on endogenizing the political economy parameters introduced in Section 2, but also on the differences between the commitment and no commitment solutions.

The political leader in this setup is fully self-interested. He shows no direct concerns for the society which contrasts with approaches taken in models with politicians' partisan preferences (Tabellini & Alesina, 1990; Alesina & Tabellini, 1987; Persson *et al.* , 2007). Similar to Section 2, we assume that the resource stock is not privately owned, but rather that the political elite can appropriate part of the country's resource stock, leaving only a share for productive activities of the society.

In a setting where the political leader would be certain to stay in office for all times (or until the end of his maximum allowed time in office), he would not have any incentives to leave a share of the resource stock for the society. Yet, in our setting, he stays in power only with a certain probability. As argued in Section 2.1, this is a consequence of recurrent elections in democratic regimes. But also in more autocratic regimes the political elite is not uncontested, especially in the case of a resource abundant country (Casellli, 2006). Domestic opposition might try to challenge the incumbent politician by staging a coup, for instance.

The probability of staying in power is a function of social welfare in the preceding period only, i.e. the probability of being in office in period $t+1$ can be denoted as $\pi_{t+1}(u_S(C_t^S))$.[16] The higher the level of society's satisfaction or utility, the higher the political leader's reelection probability. This idea can be found in Ravetti *et al.* (2012), where the authors consider a dictator having the implicit property rights in the resources of the state.[17] The resource flows can be consumed immediately or invested in the productive capacity of the economy in their setting. Also, the ruler can affect the length of his tenure by investing in social betterment (consumption), though the uncertainty regarding a possible end of his regime in each period remains.

The society in our setting is politically not forward-looking. Rather, we assume myopic behavior: the 'popularity' of a politician within the society determines his chances to be reelected or, in general, to stay in office. The level of his 'popularity' among the electorate depends on the level of well-being of the society. This idea forms the basis of opportunistic models of political behavior (Besley, 1977; Drazen & Eslava, 2006), which predict higher governmental spending prior to elections. Empirical studies seem to confirm the existence of political business cycles (Schuknecht, 1996; Block, 2002). Brender & Drazen (2005) find empirical evidence in a large cross-section of countries in the case of 'new' democracies, in both developed and less developed countries. Politicians seem to believe that higher spending increases their probability of being reelected. They suppose that higher governmental expenditures augment the welfare of the society, and that the

[16]In Robinson *et al.* (2006) who try to find political foundations of the resource curse in a two period probabilistic model, the politician's reelection probability depends on the transfers to citizens and employment in the public sector.

[17]In their model, the dictator decides each period whether to stay in power or to loot the country and leave. If he stays, he invests in productivity and obtains part of the benefits from production, but also faces the possibility that he will be expulsed. The expulsion is modelled as a discrete random variable whose realisation depends both on the choice of next period's capital stock and repression level which captures the idea that the dictator can use both consumption-sharing and military spending in order to maintain power. Whereas their idea of a dictator's staying in power probability depending on the well-being of the society is similar to ours, we, in contrast, do not model the intertemporal tradeoff between investing and looting, but focus on the intratemporal tradeoff of immediate consumption and direct enhancement of the chances to stay in power in the next period. The dictator in our model solely decides on the amount of the resource stock that benefits society, whereas the saving decision is made by the society in a general equilibrium framework.

society as their electorate bases its voting decision on the government's ability to provide societal well-being during the time preceding the elections. Hence, from the viewpoint of the political elite, society is not forward-looking and acts myopic. This provides them with an incentive to care for social well-being in order to rise their probability of being reelected and enjoy benefits from holding office for one more period. The politician hence solves a maximization problem where he has to choose every period the amount of resources that are supplied to the society's productive sector, and the amount of his own private benefits. Hence, the amount of resources destined for social production signifies an immediate loss of the politician's consumption and his instantaneous utility. Consequently, at the beginning of every period, the politician faces a trade-off between his own consumption in the given period, and the possiblity of increasing his chances of consumption in the next periods. As the politician cannot 'store' the resource and needs to 'consume' it immediately, i.e. in the period of extraction, accroaching the highest amount of resources possible in the first period is thus never an optimal strategy. Since we focus on the politician's utility derived from accroaching the non-renewable resource, we do not focus on the question of the politician's outside option. In order to avoid the politician averting his deselection at all costs we assume that there is an outside option for the politician which yields a utility level $> -\infty$.

The functional form of the probability of staying in power and its elasticity with respect to social welfare are central characteristics of the political economy framework. They determine the extent to which the politician cares about society, i.e. the weight γ from Section 2.2. The functional forms and their corresponding sensitivities to social welfare are associated with certain political regimes. It seems sensible that the reelection probability in democratic regimes exhibits a higher elasticity with regard to social welfare than in more autocratic regimes.

In the model below we employ an infinite time horizon for the politician in order to make the setting as general as possible. There is a fixed initial stock that is available for extraction at the beginning of the first period which we denote as S_0. The resource constraint thus reads

$$S_{t+1} = S_t - E_t - P_t \quad \text{and} \quad S_0 = \sum_{t=0}^{\infty}(E_t + P_t). \tag{4}$$

Although the subsequent analysis is valid also in the case of $T < \infty$, we need to think about what happens in the last period in the case of a finite T. For any finite T the political leader has no incentive to care for the society in the last period; he might just appropriate what is left of the resource. In our setting the society is myopic. When deciding about reelecting the political leader after his pre-last period in office, it does not consider this danger of affliction in the last period as a consequence of the politician's rapaciousness, but bases its decision solely on the utility obtained in this pre-last period.[18]

The utility maximization problem of the politician reads as follows:

$$\max_{C_t^P, E_t, C_{t+1}^P} \sum_{t=0}^{\infty} \left(\frac{1}{1+\rho}\right)^t \left\{\pi_t(u_S(C_{t-1}^S))u_P(C_t^P)\right\}, \tag{5}$$
$$\text{s.t. (4) holds,} \quad C_t^S = K_t^\alpha E_t^\beta - (K_{t+1} - K_t) \quad \text{and} \quad C_t^P = P_t.$$

It is important to note that in the first period, i.e. here at $t = 0$, the politician is already in power with certainty, i.e. $\pi_0 = 1$ and π_0 does not depend on previous social consumption. The probability of reelection must lie within the interval $\pi_t \in (0, 1)$. Furthermore, the economy produces according to the Cobb-Douglas production function $K_t^\alpha E_t^\beta$.

Using the first order conditions (C.2) to (C.7) in the Appendix C, we obtain the following proposition:

Proposition 4. *The consumption path of the politician evolves in the following way*

$$\frac{(C_{t+1}^P)^{-1/\psi}}{(C_t^P)^{-1/\psi}} = \frac{(1+\rho)\pi_t(u_S(C_{t-1}^S))}{\pi_{t+1}(u_S(C_t^S))}. \tag{6}$$

We define the politician's discount rate δ_t by $\frac{\pi_{t+1}(C_t^S)}{\pi_t(C_{t-1}^S)(1+\rho)} \equiv \frac{1}{1+\delta_t}$. If $\pi_{t+1} < \pi_t$, then $\delta_t > \rho$ as in Section 2.

Proof. See Appendix C.2. □

The uncertainty about the politician being in power in the next period, i.e. $\pi_{t+1} \in (0, 1)$ is an addition to his discount factor. It implies higher extraction levels than in a Social Planner's optimum.[19]

[18]Yet, if we allow for a small amount of foresight, it does not seem very plausible that the society will not account for this possibility of penury in the last period. This might drastically lower the political elite's probability of staying in power. On the other hand, it seems unlikely that the politician would not anticipate the effect of his rapacious behavior in the last period on the electoral behavior and thus would not act according to a significantly lower probability of holding onto power. This would alter the probabilities of staying in power that the political leader accounts for in his maximization problem.

[19]The idea that lifetime uncertainty affects the rate at which felicity is discounted can also be found in the Blanchard-Yaari model. Yet, to obtain a higher discount factor $\delta > \rho$ in their continuous time model, one has to assume a specific functional form for the probability to be alive at time τ: $\phi(\tau) = \mu e^{-\mu\tau}$, with $\phi(\tau)$ being the probability of death at date τ and μ being the contribution to the discount factor $\delta = \rho + \mu$.

In contrast to the results in Section 2.2, the solution to the intertemporal maximization problem in (5) is not intertemporarily consistent. The politician would need a commitment technology to actually implement the extraction paths which are optimal for this problem. The reason is that after having decided on the resource allocation in t as a solution to the trade-off between his consumption now and the probability of enjoying consumption in period $t+1$, the politician faces 'elections' at the end of period t.[20] At the beginning of period $t+1$, the political leader has an incentive to re-evaluate the optimal extraction paths, given the fact that he has been reelected. His resource consumption hence does not follow the path described by (6) as, at the beginning of period t he knows that $\pi_t(u_S(C^S_{t-1})) = 1$ and his period $t+1$ consumption that was described optimally by (6) at time $t = 0$, is not optimal any more. The solution to the political leader's optimization problem and the ultimately resulting division of the resource stock into S^S_0 and S^P_0 are not straightforward to determine and have to be found iteratively, by re-optimization in every period.

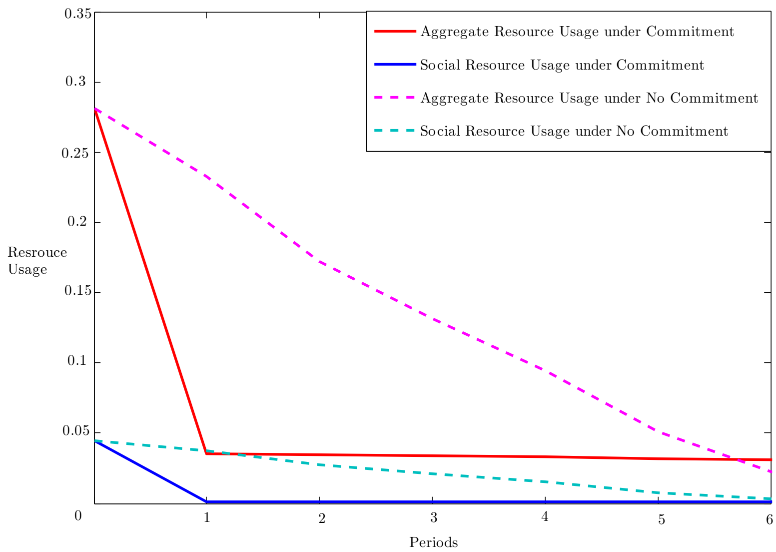

Figure 6: Aggregated and Social Resource Usage under Commitment and under No Commitment

In the sequel we display numerical examples of the extraction paths in the commitment case and compare the solutions to the first periods of an optimization outcome where commitment is not possible. Figure 6 shows the initial aggregate and social resource usage under commitment and in the absence of commitment. The resource usage under commitment corresponds to the optimal resource usage path for the politician and the society at the beginning of $t = 0$. The politician is consequently obliged to execute these extraction paths without the possibility of re-evaluating at any time. In contrast, in the

[20]As explained above, we do not only refer to democratic elections but to events or the absence of events that determine whether the politician will also be in office in period $t+1$. Examples comprise the presence or absence of a successful *coup d'état*, rebellions, civil wars etc.

case of no commitment, the politician can and does re-optimize at $t = 1$ and at the beginning of all subsequent periods. The bold line in Figure 7 marks the political resource usage path if the politician re-optimizes at every $t = 1, 2, \ldots$. How do we find this path? Numerically, we solve for the optimal resource extraction path at $t = 0$ first, given K_0 and S_0, and take the resulting values for S_1 and K_1 to solve for an optimal resource extracton path under commitment with the given resource stocks at period $t = 1$. Hence, the dashed lines in Figure 7 show how the optimal extraction paths under commitment look like, for every t and with given K_t and S_t respectively.

The condition for the politician's no commitment extraction path to exist is, however, his reelection: obviously, to be able to re-optimize, he needs to stay in power. This is a rigid requirement. At this point, it is hence more instructive to consider the political succession interpretation here: whether the same politician is in office at time t as at time $t + 1$ does not matter. The incentive to re-optimize and not to stick to the 'optimal plan' of his predecessor, whether it was the politician himself or another politician, is the same.

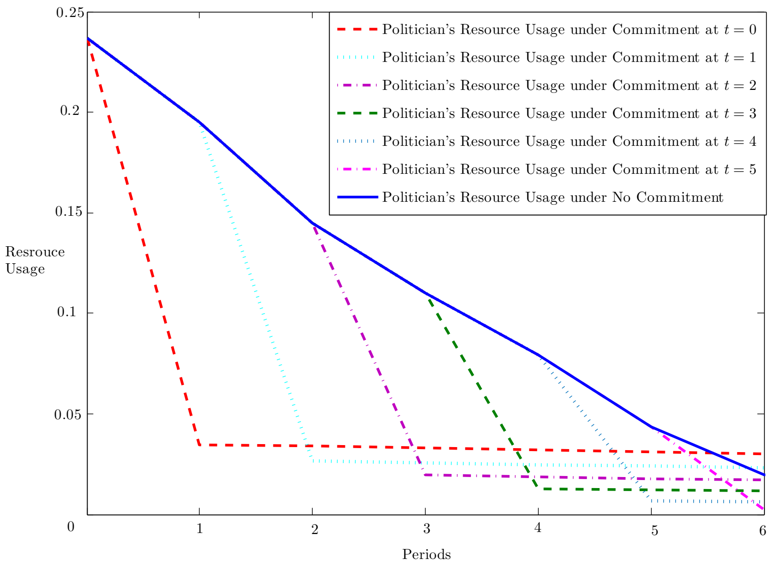

Figure 7: Resource Usage of the Politician under Commitment and under No Commitment

Hence, although the aggregate and the social resource usage levels are initially equal in both cases because the politician under commitment and under no commitment face the same conditions at $t = 0$, the resource usage in the no-commitment case stays on a higher level in the subsequent periods. This also implies that the politician accroaches a larger share of S_0 under no commitment, as indicated by Figure 7.

Also in terms of welfare the society fares better under commitment as can be seen in Figure 8. Under commitment, the social consumption path rises first before falling in our example, whereas the corresponding path under no commitment falls steadily from the start. This is the case despite higher initial social resource consumption in the no commit-

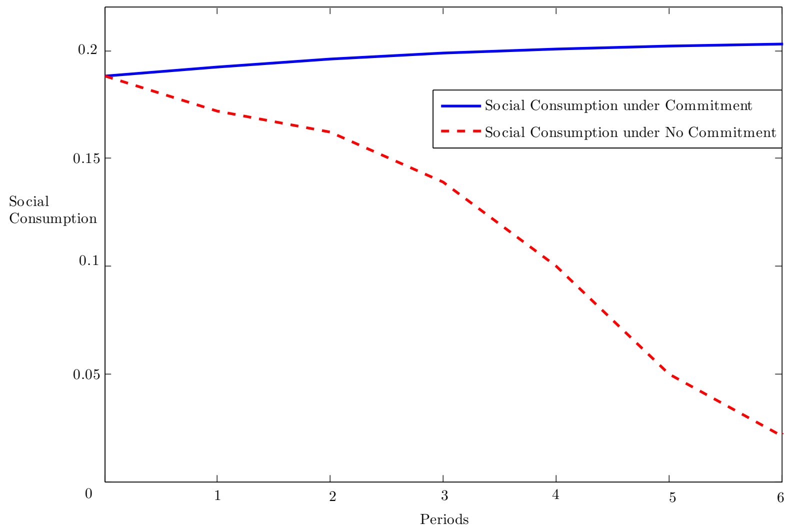

Figure 8: Social Consumption under Commitment and No Commitment

ment than in the commitment case. The reason is that under commitment the politician discounts the future less and has a higher incentive to smooth out social consumption.

This is reflected in the endogenous social weights that the politician attaches to the welfare of society: We computed the implicit γ's corresponding to the social welfare every period. The first graph of Figure 9 compares the endogenous γ's in the commitment and no-commitment case for the first periods: whereas the social weight monotonically decreases under no commitment, it first increases under commitment. The right graph of Figure 9 reveals that also under commitment the social weight eventually falls (non-monotonically) to the levels of γ under no commitment.

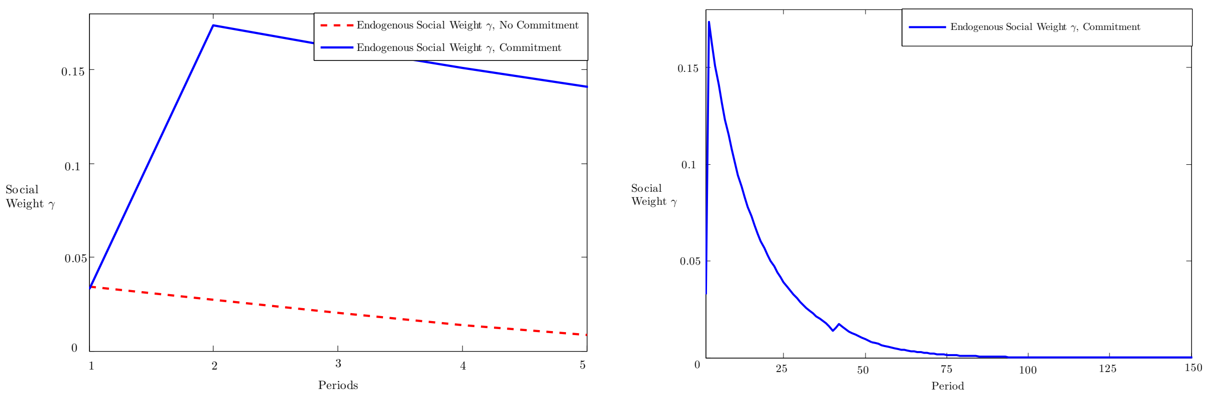

Figure 9: Endogenous Social Weight γ in the Short and Long Run

The level of social welfare with the corresponding implicit social weight γ_t and the politician's probability of staying in power are the outcomes of the politician's optimization problem every period. The resulting probability is reflected in the discount rate of the politician: the pure rate of time preference is augmented by the probability terms as in

Proposition 4. The graph in Figure 10 shows that the discount factors in the commitment and no commitment cases decrease, and hence the discount rates increase over time.[21] The reason lies in the corresponding endogenous reelection probabilities. The bold lines in Figure 10 compare the endogenous probabilities under commitment and no commitment for the first periods. The staying in power probability for the politician clearly falls in the no commitment case, which is necessary for $\delta_t > \rho$, according to our Proposition 4. In contrast, for this parametrization, the endogenous probabilities under commitment first increase slightly, before decreasing to a stable level. Thus, if the politician is able to commit to his optimal policies, his implicit discount rate might be even lower than society's pure rate of time preference: a higher probability of reelection next period and hence the prospect of almost certain consumption in the next period preclude rapacious behavior.

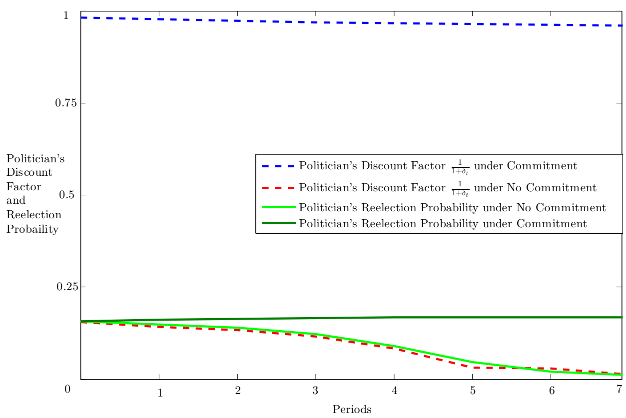

Figure 10: Politician's Discount Factors and his Reelection Probabilities under Commitment and under No Commitment

What do these findings mean for our initial question about the extent of rapaciousness of the political elite? Endogenizing the social weight and the politician's discount rate lead to time inconsistency of the political elite's optimal choices. The resulting social weight is much lower and the politician's disocunt rate is much higher in the no commitment case as compared to the commitment case. Just as in Section 2.2, a lower γ means lower social welfare and a higher stock S_0^P consumed by the politician, whereas a higher discount rate results in higher initial resource usage. We can conclude that political succession and the disability to commit worsen both social welfare and the suboptimality of the resource extraction path.

[21] The differences in discount rates are enormous: in our example, the discount rate under no commitment is over 250 times higher than under commitment. Relating to the debate on appropriate discounting in project analysis and also for a Social Planner and the recommendation in Weitzman (2014) to use declining discount rates, an increasing discount rate schedule seems less than suboptimal.

4 Conclusions

We have build a political economy model of resource depletion which accounts for the fact that most of the world's non-renewable resources are state-owned or state controlled. The inclusion of political economy features into a model of resource extraction results in a division of the initial resource stock into a stock depleted for the good of the society and a stock purely used to benefit the political elite. We analyze how the politicians' rapaciousness and the pace of resource extraction depend on these political economy features. We find that a lower social weight decreases the resource stock available to society but does not necessarily increase initial resource usage. In contrast, both the politicial elite's higher discount rate and a shorter time horizon tend to rise initial resource usage, yet leaving more resources available to society. Comparing these outcomes with the resulting resource extraction path in an economy with privately owned resources where the politicians have to raise their revenues via taxation, we conclude that private ownership of resource stock is prefereable with respect to the resource extraction path. We endogenize the politician's social weight and the discount rate making them dependent on the reelection probability. In this setting we are faced with a time inconsistency issue: the absence of commitment has a negative effect on the resource availability for the society and the resource extraction path.

Further work on the political economy framework of resource depletion could focus on the endogenized version of the model. The politician's incentives can be analyzed further by employing different functional forms for the probability of staying in power depending on the (democratic) inclusiveness of the regime. This would give us a more detailed picture of the consequences for social welfare and non-renewable resource extraction in countries with state-owned resouces.

References

Alesina, Alberto, & Tabellini, Guido. 1987 (July). *A Positive Theory of Fiscal Deficits and Government Debt in a Democracy.* NBER Working Papers 2308. National Bureau of Economic Research, Inc.

Benchekroun, Hassan, & Withagen, Cees. 2011. The optimal depletion of exhaustible resources: A complete characterization. *Resource and Energy Economics*, **33**(3), 612–636.

Besley, T. 1977. *Electoral Strategy and Economic Policy.* Tech. rept.

Block, Steven A. 2002. Political business cycles, democratization, and economic reform: the case of Africa. *Journal of Development Economics*, **67**(1), 205 – 228.

BP. 2008. *BP Statistical Review of World Energy 2007.*

Brender, Adi, & Drazen, Allan. 2005. Political budget cycles in new versus established democracies. *Journal of Monetary Economics*, **52**(7), 1271–1295.

Bulte, Erwin, & Damania, Richard. 2008. Resources for Sale: Corruption, Democracy and the Natural Resource Curse. *The B.E. Journal of Economic Analysis & Policy*, **8**(1), 5.

Casellli, Francesco. 2006. *Power Struggles and the Natural Resource Curse.* Tech. rept. London School of Economics.

Dasgupta, Partha. 2001. Valuing Objects and Evaluating Policies in Imperfect Economies. *Economic Journal*, **111**(471), C1–29.

Daubanes, Julien, & Lasserre, Pierre. 2012 (Feb.). *Optimum Commodity Taxation with a Non-Renewable Resource.* CIRANO Working Papers 2012s-04. CIRANO.

Deacon, Robert. 2003. *Dictatorship, Democracy, and the Provision of Public Goods.* University of California at Santa Barbara, Economics Working Paper Series 11925. Department of Economics, UC Santa Barbara.

Drazen, Allan, & Eslava, Marcela. 2006 (May). *Pork Barrel Cycles.* NBER Working Papers 12190. National Bureau of Economic Research, Inc.

Frankel, Jeffrey A. 2010 (Mar.). *The Natural Resource Curse: A Survey.* NBER Working Papers 15836. National Bureau of Economic Research, Inc.

Grossman, Gene M., & Helpman, Elhanan. 1998. Intergenerational Redistribution with Short-Lived Governments. *The Economic Journal*, **108**(450), pp. 1299–1329.

Gylfason, Thorvaldur. 2001. Natural resources, education, and economic development. *European Economic Review*, **45**(4-6), 847–859.

Leite, Carlos, & Weidmann, Jens. 1999 (July). *Does Mother Nature Corrupt - Natural Resources, Corruption, and Economic Growth.* IMF Working Papers 99/85. International Monetary Fund.

Long, Ngo Van. 1975. Resource extraction under the uncertainty about possible nationalization. *Journal of Economic Theory*, **10**(1), 42–53.

Mehlum, Halvor, Moene, Karl, & Torvik, Ragnar. 2006. Institutions and the Resource Curse. *Economic Journal*, **116**(508), 1–20.

Persson, Torsten, Roland, Gerard, & Tabellini, Guido. 2007. Electoral Rules and Government Spending in Parliamentary Democracies. *International Quarterly Journal of Political Science*, **2**(2), 155–188.

Ramanathan, V. 1980. Climatic effects of anthropogenic trace gases. *In:* Bach, W., Pankrath, T., & Williams, J. (eds), *Interactions of Energy and Climate*. D. Reidel Publishing Co.

Ravetti, Chiara, Sarr, Mare, & Swanson, Tim. 2012. *Nations Aiding and Abetting the Looting of Nations*. Tech. rept. The Graduate Institute, Geneva.

Robinson, James A., & Torvik, Ragnar. 2005. White elephants. *Journal of Public Economics*, **89**(2-3), 197–210.

Robinson, James A., Torvik, Ragnar, & Verdier, Thierry. 2006. Political foundations of the resource curse. *Journal of Development Economics*, **79**(2), 447–468.

Sachs, Jeffrey D., & Warner, Andrew M. 1995 (December). *Natural Resource Abundance and Economic Growth*. Working Paper 5398. National Bureau of Economic Research.

Sachs, Jeffrey D., & Warner, Andrew M. 2001. The curse of natural resources. *European Economic Review*, **45**(4-6), 827–838.

Schuknecht, Ludger. 1996. Political Business Cycles and Fiscal Policies in Developing Countries. *Kyklos*, **49**(2), 155–170.

Tabellini, Guido, & Alesina, Alberto. 1990. Voting on the Budget Deficit. *The American Economic Review*, **80**(1), pp. 37–49.

Tornell, Aaron, & Lane, Philip R. 1999. The Voracity Effect. *The American Economic Review*, **89**(1), pp. 22–46.

van der Ploeg, Frederick. 2011a. Natural Resources: Curse or Blessing? *Journal of Economic Literature*, **49**(2), 366–420.

van der Ploeg, Frederick. 2011b. Rapacious Resource Depletion, Excessive Investment and Insecure Property Rights: A Puzzle. *Environmental & Resource Economics*, **48**(1), 105–128.

van der Ploeg, Frederick. 2012. *Resource Wars and Confiscation Risk*. Tech. rept.

Weitzman, Martin L. 2014. Should Governments Use a Declining Discount Rate in Project Analysis? *Review of Environmental Economics and Policy*, **8**, 145–163.

Withagen, Cees. 2012. *Nash and Stackelberg cartel-versus-fringe models*. Discussion Paper. Department of Spatial Economics, VU University Amsterdam.

A Derivations

A.1 Maximization of the Hamiltonian

In this appendix we solve the Hamiltonian corresponding to the maximization problem (3) presented in Section 2.2. We solve for the first order conditions in order to characterize the equations governing the evolution of the capital and resource stock in the model.

For the following calculations we assume that the instantaneous utility functions from equation (1) for the society and the politician are of the following standard form:

$$\begin{aligned} u_S(C^S) &= \frac{(C^S)^{1-1/\theta} - 1}{1 - 1/\theta}, \quad \text{if} \quad \theta \neq 1, \quad u_S(C^S) = \ln(C^S) \quad \text{if} \quad \theta = 1, \quad \text{and} \\ u_P(C^P) &= \frac{(C^P)^{1-1/\psi} - 1}{1 - 1/\psi}, \quad \text{if} \quad \psi \neq 1, \quad u_P(C^P) = \ln(C^P) \quad \text{if} \quad \psi = 1, \end{aligned} \tag{A.1}$$

where $\theta \equiv -\frac{u'_S(C^S)}{C^S u''_S(C^S)}$, is the elasticity of intertemporal substitution of the society, and $\psi \equiv -\frac{u'_P(C^P)}{C^P u''_P(C^P)}$ denotes the same for the politician. Its inverse corresponds to the coefficient of relative risk aversion and of relative intertemporal inequality aversion.

The present value Hamiltonian for the maximization problem (3) in Section 2.2 reads as follows:

$$H \equiv (1-\gamma)e^{-\delta t}u_P(C_t^P) + \gamma e^{-\rho t}u_S(C_t^S) + \lambda_t(K_t^\alpha {E_t}^\beta - C_t^S) - \mu_t(P_t + E_t), \tag{A.2}$$

with λ_t and μ_t being the shadow price of a unit of extra capital and the scarcity rent of the natural resources.

The first order conditions for the Hamiltonian read as follows:

$$\frac{\partial H}{\partial C_t^P} = e^{-\delta t}(1-\gamma)u'_P - \mu(t) = 0 \tag{A.3}$$

$$\frac{\partial H}{\partial C_t^S} = \gamma e^{-\rho t}u'_S(C_t^S) - \lambda(t) = 0 \tag{A.4}$$

$$\frac{\partial H}{\partial E_t} = \lambda(t)\beta K_t^\alpha {E_t}^{\beta-1} - \mu(t) = 0 \tag{A.5}$$

$$\frac{\partial H}{\partial K_t} = -\dot{\lambda}(t) = \lambda(t)\alpha K_t^{1-\alpha}{E_t}^\beta \tag{A.6}$$

$$\frac{\partial H}{\partial S_t} = -\dot{\mu}(t) = 0 \tag{A.7}$$

Furthermore, the following transversality condition should be satisfied.

$$\lim_{t\to\infty}[e^{-\rho t}\lambda(t)K(t) + e^{-\delta t}\mu(t)S(t)] = 0. \tag{A.8}$$

Total differentiation of (A.3) yields:

$$\dot{\mu}(t) = -\delta e^{-\delta t}(1-\gamma)u'_P + e^{-\delta t}(1-\gamma)u''_P\dot{C}_t^P$$

As $-\dot{\mu}(t) = 0$, we have that the politician's consumption path evolves in the following way (using the specification in (A.1)):

$$\frac{\dot{P}_t}{P_t} = -\psi\delta. \tag{A.9}$$

Total differentiation of (A.4) gives:

$$0 = -\dot{\lambda}(t) - \rho e^{-\rho t}\gamma(C_t^S)^{-1/\theta} + e^{-\rho t}\gamma\left(-\frac{1}{\theta}(C_t^S)^{-1/\theta-1}\right)\dot{C}_t^S$$

which can be rewritten as

$$\dot{\lambda}(t) = \left[-\rho - \frac{1}{\theta}\frac{\dot{C}_t^S}{C_t^S}\right]e^{-\rho t}\gamma(C_t^S)^{-1/\theta}$$

This yields the following equation for the development of the multiplier:

$$\frac{\dot{\lambda}(t)}{\lambda(t)} = -\rho - \frac{1}{\theta}\frac{\dot{C}_t^S}{C_t^S} = -r_t,$$

where $r_t = \alpha K_t^{\alpha-1}E_t^{\beta}$ denotes the endogenous interest rate in the economy. This characterizes the evolution of social consumption:

$$\frac{\dot{C}_t^S}{C_t^S} = \theta(r_t - \rho). \tag{A.10}$$

The first order conditions also imply the usual Hotelling rule for the movement of the shadow price $q_t = \beta K_t^{\alpha}E_t^{\beta-1}$:

$$\frac{\dot{q}_t}{q_t} = r_t. \tag{A.11}$$

The efficiency in resource production is preserved for the resources ultimately used for social production.

A.2 Maximization given S_0^P and S_0^S

There is another solution approach additional to the Hamiltonian presented in (A.2). In contrast to solving the Hamiltonian as in the previous Appendix A.1, this second approach gives us the intuition to prove Propositions 1, 2 and 3 in Section 2.2.

Given that the initial resource stock S_0 is split into two separate stocks S_0^P and S_0^S, we face *de facto* two separate maximization problems:

From the pure Social Planner's perspective, the society's utility maximization problem reads:

$$\max \int_{s=0}^{\infty} u_S(C_t^S)e^{-\delta t}dt, \tag{A.12}$$

subject to the resource constraint $\int_0^{\infty} E_t dt \leq S_0^S$, subject to a Cobb-Douglas production function $Y_t = K_t^{\alpha} E_t^{\beta}$ and a budget constraint $\dot{K} = Y_t - C_t^S$.

We solve the Hamiltonian and obtain the same consumption evolution path as before in (A.10) and the same Hotelling rule as in (A.11).

The politician maximizes his intertemporal welfare function:

$$\max \int_{t=0}^{T} u_P(C_t^P)e^{-\delta t}dt, \tag{A.13}$$

where $C_t^P = P_t$, and subject to the resource constraint $\int_0^T P_t dt \leq S_0^P$.

The Hamiltonian looks as follows:

$$H \equiv e^{-\delta t} u_P(C_t^P) - \mu P_t. \tag{A.14}$$

In this case we consider a pure 'consumption economy'; the shadow price of consumption is simultaneously the shadow price of the resource. The first order conditions imply that the optimal consumption path and the depletion rate change in the same way as before in (A.9). The depletion path is thus monotonically decreasing and the speed is governed by the discount rate and the elasticity of intertemporal substitution. If both ψ and δ are high the initial consumption and resource depletion will be relatively high in the first periods. Due to plitican's resource constraint we can compute the initial C_0^P for a given S_0^P:

$$C_0^P = S_0^P \left[\int_{t=0}^{T} e^{-\psi\delta t} \right]^{-1} dt = \frac{\psi\delta}{1 - e^{-\psi\delta T}} S_0^P. \tag{A.15}$$

Let us define the maximized problem of the society in (A.12) as $W^S(S_0^S)$, while the maximized welfare of the politician is $W^P(S_0^P)$. Having thus found the optimal investment, depletion and consumption programs for the two problems separately with $S_0^i, i = S, P$ given, we can maximize the joint welfare function varying S_0^P and implicitly S_0^S such that their sum equals a given S_0:

$$(1-\gamma)W^P(S_0^P) + \gamma W^S(S_0^S) \qquad \text{s.t.} \quad S_0^P + S_0^S = S_0, \text{ or} \tag{A.16}$$

$$(1-\gamma)W^P(S_0^P) + \gamma W^S(S_0 - S_0^P), \qquad S_0 \text{ given.} \tag{A.17}$$

A.3 Proofs of the Propositions 1, 2 and 3

Proof of Proposition 1. For a fixed S_0^P, the politician's initial resource consumption is given by

$$C_0^P = S_0^P \int_0^\infty e^{-\psi\delta t} dt = S_0^P \psi\delta \text{ and by}$$

$$C_0^P = S_0^P \int_0^T e^{-\psi\delta t} dt = S_0^P \frac{\psi\delta}{1 - e^{-\psi\delta T}}$$

in the case of an infinite and finite time horizon respectively. The political leader's maximized intertemporal welfare can hence be written as a function of S_0^P:

$$\begin{aligned} W^P = \max \int_0^\infty u_p(C_t^P) e^{-\delta t} dt &= \int_0^\infty \frac{\left[S_0^P \psi\delta e^{-\psi\delta t}\right]^{1-1/\psi} - 1}{1 - 1/\psi} dt \\ &= \int_0^\infty \frac{\left[C_0^P e^{-\psi\delta t}\right]^{1-1/\psi} - 1}{1 - 1/\psi} dt. \end{aligned} \tag{A.18}$$

As noted before and displayed in Appendix A.2, the politician's maximization problem in (3) can be translated into the welfare maximization problem in (A.16), where, at the optimum, the politician has to choose a S_0^P such that:

$$\gamma \frac{\partial W^S(S_0 - S_0^P)}{\partial S_0^P} = -(1-\gamma) \frac{\partial W^P}{\partial S_0^P}.$$

Since the right hand side is negative overall, $\frac{\partial W^S(S_0 - S_0^P)}{\partial S_0^P} < 0$. Due to the concavity of the politician's welfare function in resource consumption, and hence in S_0^P, a rise in γ implies a rise in the social welfare W^S which has to be matched by a drop in W^P. A lower W^P implies both a lower S_0^P and C_0^P, according to (A.18). □

Proof of Proposition 2. We can write the politician's initial resource consumption as $C_0^P = S_0^P \psi\delta$. Suppose S_0^P stays constant; then if δ increases, C_0^P has to increase.

For a broad range of parameter values also the politician's private benefits, W^P, increase. This, however, is not optimal: S_0^P and W^P have to decrease to maximize the problem in (A.16). Following the reasoning laid out in Proposition 1, however with a constant γ this time, S_0^P has to decrease. Then both S_0^S and E_0 increase with δ and so does aggregate initial resource extraction R_0. $\square$

Proof of Proposition 3. We can write the politician's initial resource consumption as $C_0^P = S_0^P \frac{\psi\delta}{1-e^{-\psi\delta T}}$. Suppose S_0^P stays constant; for lower T, the term $\frac{\psi\delta}{1-e^{-\psi\delta T}}$ increases due to the decrease of the denominator. Then also C_0^P has to increase. Yet, W^P would rise in case of a shorter T and a constant S_0^P. As explicated in the proof of Proposition 2, this would not be optimal; hence, both C_0^P and S_0^P have to decrase. A higher social resource stock S_0^S together with higher initial consumption of the resource by the society and the politician result in higher overall resource usage. $\square$

B Numerical Method

We cannot obtain full analytical solutions of the model with any of the approaches presented in the Appendices A.1 and A.2. In order to conduct our analysis on the effects of γ, δ and the politician's time horizon, we solve the model numerically. Table 1 displays the parameter values used in the numerical examples for the baseline scenario. Our parameters' values are comparable to those used by Benchekroun & Withagen (2011) in their numerical examples.

Model's Parameters		Our Paper	Benchenkroun and Withagen (2011)
Social Weight	γ	0.9	
Discount Rates	ρ	0.04	0.03
	δ	0.04	
Political Time Horizon	T	∞	
Production Function	α	0.3	0.6
	β	0.1	0.4
Initial Capital Stock		50	1
Elasticity of Intertemporal	θ	1	1
Substitution	ψ	1	

Table 1: Parameter values for the numerical exercises.

From a discretized version of the first order conditions (A.3) to (A.7), and using log-utility, we obtain the following three equations in three unknowns:

$$K_t^\alpha E_t^\beta - (K_{t+1} - K_t) - C_t^S = 0 \tag{B.1}$$

$$\frac{1}{1+\rho}\frac{1}{C_{t+1}^S}(\alpha K_{t+1}^{\alpha-1}E_{t+1}^\beta + 1) - \frac{1}{C_t^S} = 0 \tag{B.2}$$

$$\beta K_{t+1}^\alpha E_{t+1}^{\beta-1}\left(\frac{1}{1+\rho}\right)^{t+1}\gamma\frac{1}{C_{t+1}^S} - \mu_0 = 0 \tag{B.3}$$

From the first order conditions we get that $\mu_t = \mu_0$ in present value terms. For the development of the politician's consumption this means that $P_{t+1} = P_t\frac{1}{1+\delta}$, or $P_t = \frac{1-\gamma}{\mu_0}\left(\frac{1}{1+\delta}\right)^t$. From equation (B.3) evaluated at $t = 0$, we get the expression for the shadow price at $t = 0$: $\mu_0 = \beta K_0^\alpha E_0^{\beta-1}\gamma\frac{1}{C_0}$. Hence, the initial consumption of the political elite equals $P_0 = \frac{1-\gamma}{\mu_0}$.

For the code, we first obtain K_{t+1}, as all variables determining K_{t+1} are already known, then we solve for C_{t+1} from equation (B.2). Inserting this in equation (B.3), we obtain E_{t+1} by solving numerically the following non-linear equation at every time period t:

$$\frac{\beta K_{t+1}^\alpha E_{t+1}^{\beta-1}\left(\frac{1}{1+\rho}\right)^t}{C_t(\alpha K_{t+1}^{\alpha-1}E_{t+1}^\beta + 1)} - \mu_0 = 0. \tag{B.4}$$

To start the process described above, we need initial guesses for C_0 and E_0. In order to find the initial social resource and good consumption levels which correspond to a given S_0, i.e. the levels for which $\int_0^\infty E_t + P_t dt \leq S_0$ holds, we conduct a grid search over possible ranges of E_0 and C_0.

C Endogenized Political Economy Framework

C.1 Maximization of the Lagrangian

This appendix derives the first order condition of the discrete maximization problem (5) in the endogenous politcal economy model of Section 3.

The present value Lagrangian for the endogenized political economy framework reads as follows:

$$\begin{aligned}\mathcal{L} = &\sum_{t=1}^{\infty}\left(\frac{1}{1+\rho}\right)^{t-1}\left\{\pi_{t-1}(u_S(C_{t-1}^S))u_P(C_t^P)\right\}\\ &+\sum_{t=1}^{\infty}\left\{\lambda_t[K_t^\alpha E_t^\beta - (K_{t+1} - K_t) - C_t^S] + \mu_t[S_t - S_{t+1} - E_t - P_t]\right\},\end{aligned} \tag{C.1}$$

with λ_t and μ_t being the Lagrange multipliers.

The following first order conditions need to hold, assuming an instantaneous utility function as in (A.1)

$$\frac{\partial \mathcal{L}}{\partial C_t^P} = \left(\frac{1}{1+\rho}\right)^t \pi_t(u_S(C_{t-1}^S))(C_t^P)^{-1/\psi} - \mu_t = 0 \tag{C.2}$$

$$\frac{\partial \mathcal{L}}{\partial C_t^S} = \left(\frac{1}{1+\rho}\right)^t \frac{\partial \pi_{t+1}}{\partial C_t^S}(C_t^S)^{-1/\theta}\frac{{C_{t+1}^P}^{1-1/\psi}}{1-1/\psi} - \lambda_t = 0 \tag{C.3}$$

$$\frac{\partial \mathcal{L}}{\partial K_{t+1}} = -\lambda_t + \lambda_(t+1)\alpha K_{t+1}^{\alpha-1}E_{t+1}^{\beta} + \lambda_(t+1) = 0 \tag{C.4}$$

$$\frac{\partial \mathcal{L}}{\partial E_t} = \lambda_t \beta K_t^{\alpha} E_t^{\beta-1} - \mu_t = 0$$

$$\frac{\partial \mathcal{L}}{\partial S_{t+1}} = \mu_{t+1} - \mu_t = 0 \tag{C.5}$$

$$\begin{aligned}\frac{\partial \mathcal{L}}{\partial \lambda_t}\lambda_t &= \lambda_t(K_t^{\alpha}E_t^{\beta} - (K_{t+1} - K_t) - C_t^S) = 0\\ \frac{\partial \mathcal{L}}{\partial \lambda_t} &= K_t^{\alpha}E_t^{\beta} - (K_{t+1} - K_t) - C_t^S \geq 0\\ \lambda_t &\geq 0\end{aligned} \tag{C.6}$$

$$\begin{aligned}\frac{\partial \mathcal{L}}{\partial \mu_t}\mu_t &= \mu_t(S_t - S_{t+1} - E_t - P_t) = 0\\ \frac{\partial \mathcal{L}}{\partial \mu_t} &= S_t - S_{t+1} - E_t - P_t \geq 0\\ \mu_t &\geq 0.\end{aligned} \tag{C.7}$$

From the first order conditions we see that the present value of μ_t does not change, i.e. $\mu_{t+1} = \mu_t = \mu_0$.

C.2 Proof of Proposition 4

Proof of Proposition 4. From equation (C.2) we have that:

$$(C_t^P)^{-1/\psi} = \frac{\mu_t(1+\rho)^t}{\pi_t(u_S(C_{t-1}^S))} \quad \text{and} \quad (C_{t+1}^P)^{-1/\psi} = \frac{\mu_{t+1}(1+\rho)^{t+1}}{\pi_{t+1}(u_S(C_t^S))}.$$

As $\mu_{t+1} = \mu_t$, we can substitute one equation into the other. Hence, the evolution of the politician's consumption is characterized by

$$\frac{(C_{t+1}^P)^{1/\psi}}{(C_t^P)^{1/\psi}} = \left(\frac{1}{1+\rho}\right) \frac{\pi_{t+1}(u_S(C_t^S))}{\pi_t(u_S(C_{t-1}^S))}.$$

Rewriting and assuming log-utility gives us:

$$C_{t+1}^P \left(\frac{\pi_{t+1}(u_S(C_t^S))}{1+\rho}\right) = C_t^P \pi_t(u_S(C_{t-1}^S)),$$

which is very intuitive: the marginal utility of resource consumption in the current period t needs to equal the next period's expected marginal utility of consumption (under no commitment $\pi_t(u_S(C_{t-1}^S)) = 1$, as the politician is in the position to decide again, i.e. he has been reelected). $\square$