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European Economic Review

DOI:
https://doi.org/10.1016/j.euroecorev.2020.103610

Published: 01/01/2021

Peer reviewed version

Stochastic petropolitics: the dynamics of institutions in resource-dependent economies *

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November 9, 2020

Abstract

We investigate the link between resource revenues volatility and institutions. We build a stochastic differential game with two players (conservatives vs. liberals) lobbying for changing the institutions in their preferred directions. First, uncertainty surrounds the dynamics of institutions and the resource revenues. Second, the lobbying power is asymmetric, the conservatives' power being increasing with resource revenues. We show the existence of a unique equilibrium in the set of affine strategies. We then examine to which extent uncertainty leads to more liberal institutions in the long run, compared to the deterministic case. We finally explore the institutional impact of volatility using a database covering 91 countries over the period 1973-2005. Focusing on financial liberalization, we find that as oil revenue volatility increases, liberalization goes down. This result is robust to different specifications and sample distinctions.

Keywords: Institutional dynamics, petropolitics, lobbying games, stochastic dynamic games, financial liberalization policies.
JEL classification: D72, C73, Q32

*We are indebted to participants in the 2017 Econometric Society African Meeting at Algiers, the 2016 SURED conference at Banyul-sur-Mer and several seminars held at Louvain, Marseille, Paris, Vienna and Zurich for many very useful comments. This research is supported by French National Research Agency ANR-17-EURE-0020 and ANR-16-CE03-0005. We'd also like to thank Yann Bramoullé, the editor, Isabelle Méjean, and four anonymous referees whose detailed comments and suggestions have decisively shaped this version.The usual disclaimer applies.

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1 Introduction

The link between resource-dependence and quality of institutions is generally viewed through the prism of the resource curse problem: resource-dependent economies are then typically shown to misuse resource revenues leading to poor growth performances (see Gylfason, 2001, Sachs and Warner, 2001, and more recently Poelhekke and Van der Ploeg, 2009). In parallel, a lively debate on the institutional foundations of the resource curse has naturally emerged. Significant proponents of this institutional resource curse view are Ross (2001) and Tsui (2011) who argue that oil and natural resources tend to impede democracy. The same view is expressed more provocatively by Friedman (2006): "Is it an accident that the Arab world's first and only real democracy (Bahrein [sic]) happens to not have a drop of oil?." Friedman ends up proposing what he calls *the first law of petropolitics*: "The price of oil and the pace of freedom always move in opposite directions in oil-rich petrolist states."

Perhaps because there is no compelling empirical evidence of such a curse (see for example Alexeev and Conrad, 2009, and Haber and Menaldo, 2011), a new stream of literature has emerged in the recent years pointing out the heterogenous political effects of resource abundance. An excellent representative of this literature is Caselli and Tesei (2016). In an essentially empirical paper, the authors show that while in moderately entrenched autocracies resource windfalls significantly reinforce the autocratic nature of the political system, they have no effect either in strongly entrenched autocracies or in democracies. A more theoretical contribution by Boucekkine et al. (2016) assesses the impact of resource abundance on political survival of autocracies. It is found that resource abundance plays a role in political transitions only when the elite in office are vulnerable enough, vulnerability being reflected in the low repression capacity of the elite and exacerbated by large income inequality.

While the literature exploring the link between the level of resources and the quality of institutions is currently very active, we are not aware of any theory exploring the impact of resource revenues volatility on the internal functioning of national institutions. A substantial part of the literature on commodity price volatility is focused on the design of optimal fiscal and monetary policies to minimize the macroeconomic cost of volatility (see in particular Frankel, 2018). A fundamental theoretical contribution to this line of research is due to Van der Ploeg and Venables (2011) who study in detail optimal policymaking under a windfall of natural resources, regarding in particular public debt management, investment and the distribution of funds for consumption. A second line of research explores the relationship between volatility and growth in the context of resource-rich countries. For example, Poelhekke and Van der Ploeg (2009, 2010) analyze this relationship depending on the degree of financial liberalization. A last stream of the literature is more directly related to institutional quality, though not to institutional change. It is essentially composed of empirical works that outline the essential differences in economic policy responses to resource revenues booms depending on the political regime ruling resource-rich countries (see Arezki and Bruckner, 2012).

This paper complements the literature above by exploring the link between resource windfalls **volatility** and institutional **change**. Our aim is to address several research questions such as: is the volatility of commodity revenues good or bad for the quality of institutions? Does a rising volatility exacerbate the initial conservative nature of a given political system or does it lead to its liberalization? Some basic interesting ideas and mechanisms are already suggested by Friedman (2006). For example, regarding international integration, he argued that as the price of oil rises, petrolist states are less dependent on maintaining positive diplomatic and trade relationships with other countries because these countries do need the natural resources they can provide. In such times, petrolist states tend to extend their fierce control of the private sectors (eventually leading them to renationalization as in Putin's Russia concerning oil and gas sectors), and limit international political and economic openness. The reverse may happen when resource rents go down.

The very same is documented for Middle East and North African (MENA) countries (Schlumberger, 2006). A typical example is domestic and international financial liberalization as connected to resource rents. In this domain as in many others, a tremendous legislative instability has taken place. In the words of Albrecht and Schlumberger (2004), the legislations have been oscillating "between controlled liberalizations and deliberalizations." In the specific case of Algeria, some pro-financial liberalization legislations implemented in the past have been simply cancelled in the good times of the international oil markets (start and stop).[1] Be it for financial liberalization or for other types of political and economic liberalization, it is not so uneasy to grasp a natural mechanism behind this instability. As explained in different contexts by Friedman (2006), Schlumberger (2006) and Boucekkine and Bouklia (2011), these variations in the scope of liberalization depending on the oil barrel price do reflect in first place the self-preservation interest of the *nomenklaturas* dominating these countries for decades. At the same time, these traditional *nomenklaturas* face a growing elite advocating economic reforms, basically market liberalism and economic openness, without though directly questioning the traditional neopatrimonial model. This is crystal clear in Algeria, but also in Gulf monarchies (Hvidt, 2011).

To sum-up, the sequence of liberalizations and deliberalizations essentially reflects the

[1] This is exactly what happened at the end of the last decade when the Algerian government came to cancel the opening of domestic public banks' capital decided in 2003 (see Boucekkine and Bouklia, 2011).

outcomes of a continuous struggle between the conservative, neopatrimonial and nationalist *nomenklatura* and a reformist (liberal) rising group. In periods of high oil prices, the conservative player is in better position to block the reforms (including political liberalization indeed) simply because the resulting massive inflows of capital (export revenues) makes less urgent any further opening to foreign investment and the like. A natural research problem is therefore to inquire what can be the equilibrium outcome of such a struggle for a given (stochastic) law of motion for the commodity price (or the commodity revenues), and its implications. Of course, we do not claim that the commodity price is the unique determinant of the politico-economic equilibrium in this type of countries. We also consider a second source of uncertainty, reflecting all the potential internal and/or external shocks affecting directly the political or constitutional state of the country. For example, uncertainty also originates in the course of internal politics-electoral competition, successive revisions of the constitution etc., or in external political shocks like the 2011 Arab spring shock in the case of Arab countries.

Since the problem under scrutiny is all about the struggle between two rival groups (within the elite), we choose to model it as a lobbying game. Precisely, we shall use the differential lobbying game avenue opened by Wirl (1994). It essentially departs from the original game-theoretic lobbying game developed by Tullock (1980) in that the players do not compete for a given prize but invest in rent-seeking to change the state of the legislative arrangements in their favor. This game-theoretic frame fits better the kind of problems we seek to handle.

We extend Wirl (1994)'s original framework in two directions. First of all, we introduce uncertainties that affect both the dynamics of the resource revenues, and the legislative state, say the legislation on financial liberalization. Depending on the parameterization of the resource revenues process, resources can be renewable or non-renewable, which enriches the discussion. We assume that resource revenues dynamics are autonomous in that they are independent of internal institutional dynamics. This is in essence a small open economy assumption. Second, we explicitly model the impact of the resource revenues on the positions of the two players in the lobbying game: to cope with the anecdotal evidence given above, we assume that larger resource revenues give more power to the conservative player.

When shutting down the two sources of uncertainty, the equilibrium generally displays convergence to a conservative position. Indeed, an initially conservative country will remain conservative asymptotically, irrespective of the nature of resources (renewable or not), the asymptotic position being *infinitely* conservative in almost all the configurations considered. In such a case, Friedman's first law of petropolitics holds (by construction). However when the uncertainty sources are switched on, revenue volatility tends to stabilize institutional dynamics compared to the deterministic benchmark. We ultimately characterize the short-run and long-term properties of the equilibrium depending on the type of resources. In the non-renewable resources case and under mild conditions,[2] the legislative state converges almost surely to zero. For renewable resources, it does converge to an invariant distribution, its most likely asymptotic state of the legislation being unambiguously negative. Not surprisingly, holding renewable resources allows the conservatives to exploit their (superior) bargaining power, which makes the situation is more favorable to them. In sum, while Ross, Tsui and Friedman's view still holds asymptotically in the case of renewable resources, it is seriously undermined in the non-renewable case.

These results are essentially driven by the assumption on the lobbying power advantage increasing in resources: when resources vanish asymptotically, it is not granted at all that the conservatives end up wining the political power in the long run. Finally, we study the impact of a rise in the volatility of resource revenues on the political equilibrium. In the long-run, the unique relevant case, in our theory, is the renewable resource one. When volatility goes up, we show that the most likely asymptotic state rises, implying that increasing volatility worsens the control of the conservatives. As to the short-term political equilibrium, we show that in both the renewable and non-renewable resource cases, the impact of volatility is ambiguous depending on historical conditions and the parameters of the model.

To have a more accurate picture of the latter impact, we conduct an empirical investigation of the impact of volatility of natural resources revenues, essentially oil rents, on financial liberalization. Clearly, other liberalization policies could have been investigated, but we restrict our analysis to the former for convenience because constructing an index of all liberalization policies is beyond the scope of this paper. Our study uses a rich set of controls and shocks, including political ones like ideology, and adopts a methodology similar to Abiad and Mody (2005). The financial liberalization index considered is collected from a new database due to Abiad et al. (2008); it covers 91 countries over the period 1973-2005. Our results point to a negative link between the volatility of rents and liberalization. As the volatility goes up, the financial liberalization index goes down. Moreover, we also explore the interplay between resource volatility, financial liberalization and economic growth in our data. First of all, we confirm the negative and significant effect exerted by resource volatility on Economic growth. Second, we highlight that the financial liberalization index has a positive and significant effect on economic growth. Third, we find that resource volatility has not any significant effect on growth in countries that have already financially liberalized. However, this is quite the

[2] We assume that the volatility of resource revenues is large enough, in a precise sense which will be disclosed in Section 3.1.

contrary for countries with low levels of financial liberalization. They are more likely to see their growth negatively affected by resource volatility. All the above results are in line with Poelhekke and Van der Ploeg (2009, 2010).

The paper is organized as follows. Section 2 presents the game setting, focusing on the dynamics of resource revenue and institutions. Section 3 studies the features of the lobbying equilibrium; most of the discussion being dedicated to the interplay between uncertainty and the level of liberalization. In Section 4, we turn to the empirical analysis that complements the theoretical findings. Section 5 concludes.

2 Model

We consider a game opposing two rival groups, $i = 1, 2$, who engage in lobbying efforts, $x_i \geq 0$, to push the legislation, $z \in (-\infty, \infty)$, in their preferred direction. The variable z can alternatively be interpreted as the state of economic and/or political liberalization. In both cases, z is an indicator of the quality of institutions, and by convention, the larger z, the better the institutions. Players have opposite views on how the legislation should evolve: Player 1 consists of the reformist group, i.e., wants z to be as high as possible, whereas player 2 exerts efforts to lower z. As in Wirl (1994), $z = 0$ is the neutral level of legislation, or liberalization. We extend his framework in two essential ways.

First, we take into account the uncertainty surrounding the evolution of z. The legislative process is uncertain in the (obvious) sense that the legislation z does not only depend on the investments made by the lobbyists: it also depends on other political, economic, and social circumstances that we account for by making stochastic the law of motion of state z. In addition, interpreting z as the level of liberalization, it is fair to say that there are many factors – internal or external shocks – that also affect the evolution of z.

Second, the economy relies on windfall revenues from natural resources, R. In the resource-dependent economy, these revenues play a crucial role since they determine the positions of the players in the lobbying game. Consistently with the first law of petropolitics, we further assume that the larger R, the more efficient is the investment of player 2 in moving the legislation z. Of course, considering the impact of resource revenues also raises the question of their evolution in time and requires the volatility of these rents be taken into account (just think about the volatility in the price of oil). This adds a second source of uncertainty to our problem.

In our setting, the two types of uncertainties, and the link between z and R, are incorporated by means of two stochastic state equations:

$$dz = [x_1 - g_z(R)x_2]dt + \sigma_z z\, dW, \tag{1}$$

$$dR = g_R(R)dt + \sigma_R R\, dW, \tag{2}$$

where $W = (W_t)_{t\geq 0}$ is a standard Wiener process,[3] and σ_i, $i = z, R$, measure volatilities of z and R, respectively. Initial conditions R_0 and z_0 are given, with $z_0 < 0$ as we focus on initially conservative countries. Function $g_z(R)$ is increasing in R, which reflects the fact that player 2 is more efficient in times of high windfalls. In general, function $g_R(R)$ may take any form, depending on whether the resources are renewable or not. The important point is that what matters to lobbyists is the resource revenue (they barely control extraction directly anyway), which typically has a deterministic – positive or negative – time trend, but is essentially stochastic because of the volatility of international prices and unpredictable technological innovations or resource discoveries.

It is worth noting that our objective is to model the crucial ideological battle internal to the elite in many resource-rich countries. Clearly, geometric Brownian motions may not be accurate descriptions of resource revenues and institutional dynamics.[4] However, we consider that working with these processes is enough to capture that proponents of this battle are surrounded by uncertainties. In addition, they are known to be very convenient to get closed-form solutions, which is a prerequisite for the analysis to come.

For simplicity, we consider hereafter the following functional forms:

$$\begin{aligned} g_z(R) &= 1 + \varepsilon R, \\ g_R(R) &= \eta + \xi R, \end{aligned} \tag{3}$$

with $\varepsilon \geq 0$, and $\eta, \xi \in \mathbb{R}$. Despite their linearity, these forms are meaningful enough to conduct the analysis. Indeed, it is quite easy to retrieve the expression of $g_R(R)$ in (3) and the dynamics of R given by (2) from two separate state equations in the resource stock, and the resource price. Define $R = pE$ as the resource revenues, with p the price (in the absence of market power), and E the extraction (or harvesting) rate. For simplicity let us assume that the extraction rate takes the following form: $E = eS$, with S the stock of resource and e a constant effort representing the share of the stock extracted at each date. This is enough to capture the

[3] The same Wiener process is used in the two equations. Considering two different Wiener processes with given correlation would complicate tremendously the analysis, without adding too much economic insight.

[4] In particular, jumps and discontinuities in the resource price, underlying the dynamics of revenues, are disregarded.

decreasing time path of extraction over time. Define the dynamics of p and S as follows:

$$dp = \alpha p dt + \sigma_p p dW,$$
$$dS = (a - eS)dt.$$

This boils down to considering uncertainty in the evolution of the price only, which also follows a constant deterministic and positive trend α (this is the simplest version of the Hotelling rule). Combining these two equations, we obtain the one characterizing the evolution of R:

$$dR = [(\alpha - e)R + eap]dt + \sigma_p R dW.$$

Now making a change of variable, with $\eta = eap$, $\xi = \alpha - e$, and $\sigma_R = \sigma_p$, is enough to retrieve equation (2), given the specification in (3). Using this analogy, hereafter we assume that: $\eta \geq 0$ but $\xi < 0$. Indeed, taking $a = 0$, which implies $\eta = 0$, leads to the analysis of the case of a non-renewable resource like oil. The concept of "decline curves" (see Anderson et al., 2018) provides a natural justification for the exogenous process underlying the evolution of the stock of resources. Our simple description of the dynamics of non-renewable resources actually fits pretty well with the empirical observation of an exponential decline in the production of oil and gas. In addition, our producing country takes the price as given. Then this is the interplay between the deterministic (increasing) trend in the oil price, α, and the exogenous exponential decay in oil production, e, that explains the sign of ξ. Whenever this country's production decreases faster than the upward trend in the prices, its revenues from the oil market progressively shrink and $\xi < 0$. This is admittedly the most relevant case when one adopts a medium to long term perspective.

The case with $a > 0$ – and furthermore η constant and positive – is a very simple representation of the evolution of revenues from a renewable resource. Considering this case allows us to highlight striking differences in the long term behavior of the economy at little expositional cost. In addition, in this case too, it is reasonable to assume that $\xi < 0$ in order to avoid the artificial feature that resource revenues go to infinity in the absence of uncertainty.

Let us now turn to the definition of players' payoffs. Players maximize the present value of benefit from their efforts of liberalization minus the associated cost:

$$\max_{x_i} \mathbb{E} \left\{ \int_0^\infty e^{-rt} \left[\omega_i(z) - \beta(x_i) \right] dt \right\}, \tag{4}$$

with $r > 0$ the (same) rate of time preference, subject to state constraints (1) and (2), with z_0 and R_0 given. To keep things as simple as possible, players' instantaneous benefit, $\omega_i(z)$, from the level of legislation or liberalization, takes an affine form:

$$\omega_i(z) = a_0 + b_i z, \tag{5}$$

where $b_1 = a_1 = -b_2$, with $a_0, a_1 > 0$. The opposite sign of the term in z reflects players' opposite interests with respect to the legislation. By convention, player 1 payoff is increasing in z, *i.e.*, we put a $+$ in front of a_1. Moreover, exerting lobbying is a costly activity. As Wirl (1994) has argued, the costs associated with lobbying are likely to be convex in effort, and so we use a quadratic cost function: $\beta(x_i) = \frac{b}{2}x_i^2$. Last but not least, notice that R does not affect the payoff functions directly. Corruption motives or office rents, which would imply that part of the revenue is captured by player 2 and shows in her payoff, are left aside. This allows us to focus on a game where the players are entirely devoted to push the legislation in the direction they wish, which is the essence of lobbying.

The model above entails two types of uncertainties: one affecting the legislation state, z, say the *legislative uncertainty*, and the other resulting from *resource revenues volatility*. These uncertainties are closely connected. So we cannot do without one of them when examining the outcome of the stochastic game of lobbying. However, due to the quite complex structure of this game, that encompasses two state variables and non-linear state functions, we have to resort to another restriction to handle the problem. Compared to Wirl (1994), who uses a quadratic form for the benefits from liberalization, *i.e*, who has an extra term $a_2 z^2$ with $a_2 \leq 0$ in $\omega_i(z)$, we work with affine forms. Though the resulting equilibrium is particular,[5] the theoretical analysis brings clear-cut results regarding the long-term impact of resource revenue volatility on liberalization for the two types of resources, which is far from granted given the stochastic nature of the problem and the dimension of the state space.

3 Institutional dynamics under uncertainties

We now characterize the Markov Perfect equilibrium (MPE) of the game. Particular attention will be paid to the long run behavior of the MPE and its implications for the dynamics of institutions. All the proofs are relegated in the Appendix.

[5]In fact, as it will be apparent soon, removing the quadratic term is a means to neutralize the effect of z – and thus to isolate the specific effect of R – on the equilibrium.

3.1 Equilibrium analysis

We solve for the MPE whereby players strategies are decision rules defined in terms of the state of the system, and pay attention to affine rules only. We obtain (see the Appendix A.1):

Proposition 3.1. *Under legislative and resource revenue uncertainties, there exists a unique affine MPE where players' efforts to change the legislation are:*

$$x_1(t) = \frac{a_1}{br}, \;\; x_2(t) = \frac{a_1(1+\varepsilon R(t))}{br}. \tag{6}$$

The resulting canonical dynamical system is given by

$$\begin{cases} dz = -\dfrac{a_1\varepsilon}{br}(2+\varepsilon R)Rdt + \sigma_z z\, dW, \\ dR = (\eta + \xi R)dt + \sigma_R R\, dW. \end{cases} \tag{7}$$

Thus player 1's equilibrium effort is constant while player 2's effort linearly depends on the resource revenue R. More precisely, one can observe that equilibrium strategies are independent of the legislative state, z. Given the exogenous nature of the dynamics of R, this implies that MPE strategies ultimately form dominant strategies. This comes from the affine formulation of the payoff functions. This case may seem to be extremely peculiar. Still, we prove that this is the unique equilibrium in the set of affine strategies. Furthermore, it is definitely useful as it allows us to emphasize the pure impact of resource revenues on the political game: player 1, who is by assumption not directly affected by these windfalls, has a constant feedback, whereas player 2 does care about resource revenues because they increase her lobbying power. Then it appears that player 2's lobbying effort goes up as the economy gets more revenue from natural resources. This is shown to have crucial and contrasted implications for the long-term for either renewable and non-renewable resources.

Let us start with a quick investigation of the deterministic MPE, which we use as a benchmark. First, assuming that $\sigma_R = \sigma_z = 0$, we can establish that (see the Appendix A.2):

Proposition 3.2. *The deterministic MPE asymptotic behavior depends on whether η is positive or not:*

(2.a) If $\eta > 0$, then we have $\lim_{t\to\infty} R(t) = -\frac{\eta}{\xi}$, and $\lim_{t\to\infty} z(t) = -\infty$.

(2.b) If $\eta = 0$, then resources revenues vanishes eventually $\lim_{t\to\infty} R(t) = 0$, and

$$\lim_{t\to\infty} z(t) = a_1\frac{\varepsilon R_0}{br\xi} + \frac{a_1\varepsilon^2 R_0^2}{2br\xi} + z_0 < 0 \tag{8}$$

As mentioned in Section 2, the case with $\eta = 0$ (and $\xi < 0$) describes the dynamic behavior of an economy that relies on non-renewable resources revenues like oil. We observe that the economy will reach in the long run a steady state with finite R and z if and only if the effect of decreasing extraction rates exceeds the positive trend of the resource price (case *2.b*).[6] The other parametric case, with $\eta > 0$, better represents economies that own and sell renewable resources. In this situation, the economy ends up in an infinitely conservative state, with $z = -\infty$. The intuition is rather simple in this deterministic world: as the proponents of the conservative line get their bargaining position improved when resource revenues go up, they can exploit this advantage over the reformists during most of, if not all, the transition. One gets conservative political states asymptotically, especially when resources are renewable. This is fully consistent with Friedman's first law of petropolitics.

The next important question is: could uncertainty, by acting as a stabilization mechanism, change the general conclusion drawn from the analysis of the benchmark? Before answering this question, it proves useful to define what is meant by stochastic stability: According to Merton (1975), a dynamic stochastic process is said to be (asymptotically) stable if and only if there is a unique distribution which is time and initial condition independent, and toward which the process tends. Using this definition, we can prove that (see the Appendix A.3):

Proposition 3.3. *Suppose that the level of volatility in the $R-$process and $z-$process satisfy*

$$\sigma_R^2 > 2\xi + \sigma_z^2. \tag{9}$$

(1) When $\eta > 0$, R and z converge to stationary distributions whose density functions are given by[7]

$$\begin{aligned} \pi_R(R;\eta) &= \frac{n\ R^{\frac{2\xi}{\sigma_R^2}}}{\sigma_R^2 R^2} \exp\left\{-\frac{2\eta}{\sigma_R^2\ R}\right\}, \quad R > 0, \\ \pi_z(z,R) &= \tfrac{m}{\sigma_z^2 z^2} \exp\left\{\tfrac{2a_1\varepsilon R(2+\varepsilon R)}{br\sigma_z^2}\ \tfrac{1}{z}\right\}, \quad z \neq 0, \end{aligned} \tag{10}$$

(2) When $\eta = 0$, both stochastic processes converge to a steady state (R_∞, z_∞) with

$$R_\infty = z_\infty = 0. \tag{11}$$

The comparison between Propositions 3.2 and 3.3 clearly highlights the stabilization power

[6] Actually, in this case, the resource will be exhausted asymptotically.

[7] Note that the density of z is conditional on R. In addition, the parameters $m, n > 0$ are chosen such that $\displaystyle\int_{-\infty}^{0} \pi_z(z,R)dz + \int_{0}^{+\infty} \pi_z(z,R)dz = 1$, and $\displaystyle\int_{0}^{+\infty} \pi_R(R;\eta)dR = 1$.

of uncertainty. First, when the deterministic MPE is stable (case *2.b*), we obtain that the counterpart stochastic MPE is stable too. More importantly, when the conditions are such that the deterministic economy follows an explosive path in terms of z (case *2.a*), a sufficient level of uncertainty in the R-process, as defined by (9), ensures that the stochastic system will reach a stationary state in the long run.

To understand the role and impact of uncertainty, it is enough to focus on the non-renewable resource case. The comparison between Proposition 3.3 and Proposition 3.2, case 2.b, reveals that uncertainty tends to stabilize the institutions. In particular, when the volatility of resource revenues is large enough, it drives the institutions to a balance position corresponding to the center of the legislative line ($z_\infty = 0$), which breaks down Friedman's theorem. The intuition of this result is as follows. In our economy, uncertainty has two sources. Uncertainty surrounding resources revenues turns out to be the most important. Indeed it affects the dynamics of z, subject to the second (institutional) source of uncertainty, through the differential in bargaining power. Its influence results from the dependence of the relative bargaining power on resources revenues. It is critical because it puts the conservatives in a much favorable position when resource revenues go up. The reverse is not true. This is an essential point of our story. This differential bargaining power vanishes eventually, which ends up shutting this channel down. In the long run, this is the intrinsic source of uncertainty in both z and R that prevails. And it turns out that for the resource revenues to drive the system (z, R) to zero almost surely, its volatility should "dominate" the shocks that come from institutional dynamics and affect z. This is exactly what condition (9) in Proposition 3.3 states.

We shall now provide with the model's predictions on the relationship between resource revenue volatility and the level of liberalization either in the short-run or in the long-run.

3.2 Impact of the resource revenues volatility

In the case of non-renewable resource, *i.e.*, with $\eta = 0$, such as revenue from oil, natural gas or other kind of non-renewable resources, the second finding in Proposition 3.3 clearly states that the non-renewable resource will be exhausted asymptotically ($R_\infty = 0$), and the competition between the liberals and the conservatives leads to $z_\infty = 0$. Clearly, if resources are exhausted asymptotically, there is no lobbying power differential in favor of conservatives in the long-run, inducing a symmetric configuration at that temporal term. As a consequence, the legislative state converges to the center of the legislative line, provided the volatility of resource revenues is large enough. In this sense, the "oil impedes democracy" assumption is clearly qualified as a long-term outcome in our stochastic setting. It should be also noted that the long-term stationary state is independent of the value of resource volatility, σ_R, in this case. This makes such a case roughly irrelevant for the study of the long-term relationship between the latter and the legislative state. We therefore turn to the renewable resources case ($\eta > 0$). Using the first finding of Proposition 3.3, we can establish the following:

Corollary 3.4. *Under condition (9),*

(1) *The most likely position of resource revenue in the long run is equal to* $\widehat{R} = \frac{\eta}{\sigma_R^2 - \xi}$.

(2) *For any windfall level,* $\widehat{z}(R) = -\frac{a_1 \varepsilon R(2+\varepsilon R)}{br\sigma_z^2}$ *is the most likely position of the state of legislation. This position is central (*$\widehat{z}(R) = 0$*) if and only if* $R = 0$.

(3) *The most likely position* $\widehat{R}$ *is decreasing in* σ_R *while* $\widehat{z}(\widehat{R})$ *is increasing in* σ_R.

Intuitively, renewable resources coupled with unequal and resource-dependent lobbying power favorable to conservatives should not be harmful to the latter in the long-run. This is made clear in the proposition above as the most likely asymptotic legislative state $\widehat{z}(R)$ is negative. Two more comments are in order here. First of all, notice that the larger parameter ε, the more conservative is the asymptotic legislative state. In other words, as the lobbying position of the conservatives improves (for given resource revenue R), the more conservative is the asymptotic legislative state. Second, it is important to notice that not only uncertainty is stabilizing as mentioned in the previous section, it also clearly undermines the position of the conservatives: as volatility goes up, the most likely long-run revenue is depressed ($\frac{d\widehat{R}}{d\sigma_R^2} < 0$), which in turn weakens the control of conservative party: $\frac{d\widehat{z}(\widehat{R})}{d\sigma_R^2} > 0$.

Let us now turn to the short-run, which is especially interesting to understand the impact of volatility on windfall from non-renewable resources on the legislative state. Taking the derive of $R(t)$ given in (21) with respect to σ_R, we get

$$\frac{\partial R(t;\sigma_R)}{\partial \sigma_R} = R(t)\,\left(-\sigma_R t + W_t\right) + \eta \int_0^t e^{\left(\xi - \frac{\sigma_R^2}{2}\right)(t-s) + \sigma_R W_{t-s}} (\sigma_R s - W_s) ds. \tag{12}$$

Focusing on the non-renewable resource case, *i.e.*, imposing $\eta = 0$, we observe that the sign of this derivative is only determined by the sign of the Brownian motion with drift $(-\sigma_R t + W_t)$. Then, from the properties of this process, it is possible to conclude that $\frac{\partial R(t;\sigma_R)}{\partial \sigma_R} > 0$ for t low enough, *i.e.*, precisely in the short run. Now, remembering that the conservatives' lobbying effort in increasing in $R(t;\sigma_R)$ at the MPE, this is likely to affect the legislative state negatively. A result that would be the opposite of the one we get in the long run. Technical details are provided in the Appendix A.4.2 where we also deal with the case $\eta > 0$ and look at the precise impact of a change in σ_R on $z(t;\sigma_R)$.[8]

The analysis conducted up to now unveils the importance of the resource revenues volatility on the legislative state. Though the long-run impact of renewable resources revenue volatility can be clearly characterized as in Corollary 3.4, the short-run impact is ambiguous either for renewable or for non-renewable resources (the long-term impact for non-renewable resources being irrelevant). However, for the case of non-renewable resources, the discussion above suggests that volatility may affect the legislation negatively in the short-run. To uncover how liberalization policy depends on volatility, we shall resort to an econometric analysis. Precisely we shall study the impact of oil revenues volatility on a particular liberalization policy, financial liberalization, as a reference case.

4 Financial liberalization under volatile natural resource revenues

4.1 Data and Empirical Model

Data on the financial liberalization index are collected from the database provided by Abiad et al. (2008) that covers ninety-one countries over the period 1973-2005. The index is the aggregated measure of eight financial reform dimensions: 1) credit controls and excessively high reserve requirements, 2) aggregate credit ceilings, 3) interest rate liberalization, 4) entry barriers in the banking sector, 5) privatization in the financial sector, 6) securities market reforms, 7) banking supervision, and 8) capital account transactions. For each dimension, a country is given a final score on a graded scale from 0 to 3, with 0 corresponding to the highest degree of repression and 3 indicating full liberalization. Therefore, the overall measure takes on integer values between 0 and 24. For ease of interpretation, the Financial liberalization index is normalized so that it ranges from 0 to 1, with 0 corresponding to a completely repressed financial sector, and 1 corresponding to a fully liberalized financial sector.

Two variables are available to measure and construct resource revenue volatility. The first main variable corresponds to oil rents. Public data such as the BP dataset (Statistical Review World Energy) also contains oil price and oil production for most oil countries since 1965. Cost data are obtained from the World Bank Genuine Savings database. The second variable corresponds to natural resources rents (measured as percentage of GDP). It is collected from the World Bank indicator, which we multiply by the income per capita (also taken from the

[8]The overall effect is more difficult to determine since all the changes in $R(s)$ from instant $s = 0$ to $s = t$, resulting from a variation of σ_R, matter for signing $\frac{\partial z(t;\sigma_R)}{\partial \sigma_R}$.

World Bank indicators) to get a measure of the total revenue from natural resources. This second variable will be used for testing the robustness of our results. We construct the cyclical resource revenue volatility in a given year and country as the standard deviation of a centered four-year window of de-trended oil rents, or natural resources. This method has become somewhat standard (see Jaimovich and Siu, 2009). This is our first measure of resource volatility. The entire process is done separately for each country. Based on this measure, we construct two other measures. In the first one, we apply the Hodrick-Prescott (HP) filter with smoothing parameter 6.25 to the entire series. Recently, it has been shown that the Hodrick-Prescott (HP) filter introduces spurious dynamic relations in the data. Filtered values at the end of the sample are very different from those in the middle and are also characterized by spurious dynamics. The alternative has been proposed by Hamilton (2018). It overcomes all of the above mentioned.[9] This will be our baseline method for constructing resource volatility from the different measures developed above. The other two without – no filtering and HP filtering – will also be used for robustness checks.

4.1.1 Empirical Benchmark model

In line with Abiad and Mody (2005), the main model specification is the following:

$$\begin{aligned} &FL_{it} = \theta_1 FL_{it-1} + \theta_2 Resourcevolatility_{it} + \\ &\theta_3 shocks_{it} + \theta_4 ideology_{it} + \theta_5 structure_{it} + \gamma_i + \gamma_t + e_{it}. \end{aligned} \tag{13}$$

Given the discrete and ordinal nature of the dependent variable, equation (13) is estimated using the ordered probit method (see McKelvey and Williams, 1975). The dependent variable FL_{it} is the level of financial liberalization index. The main variable of interest is $Resourcevolatility_{it}$. According to our model, we expect θ_2 to be negative. In other words, the larger the volatility of resource revenues, the less liberal the financial system. Moreover, we include the lag of the level of financial liberalization, FL_{it-1} as control variable.

The variable $shocks_{it}$ is intended to account for several types of economic shocks. It includes dummy variables capturing banking crises, currency crises, and inflation crises. We also use political variables that range into the $ideology_{it}$ category. More precisely, we test the honeymoon hypothesis by including a dummy highlighting the incumbent executive's first year in office. In addition, we give an account of the political orientation to reforms by adding

[9]Hamilton calculates the cyclical component based on 2-year-ahead forecast error (see Hamilton, 2018, for details).

dummy variables for left-wing and right-wing governments.[10] As far structure variables are concerned, we include trade openness. Finally, γ_i and γ_t capture the regional and time fixed effects respectively.

4.1.2 Identification Issues

There are two ways to address the potential simultaneity in the determination of changes in the financial liberalization index and resource revenues volatility. First we can apply a joint maximum likelihood estimation (MLE) as in Chrysanthou and Vasilakis (2018).[11] In this case, the model is composed of a system of two equations

$$\begin{aligned} &FL_{it} = \theta_1 FL_{it-1} + \theta_2 Resourcevolatility_{it} + \\ &\theta_3 shocks_{it} + \theta_4 ideology_{it} + \theta_5 structure_{it} + \lambda\zeta_i + \eta_{it} \end{aligned} \tag{14}$$

and,

$$\begin{aligned} &Resourcevolatility_{it} = \beta_1 FL_{it-1} + \beta_2 X_{i,t} + \\ &\beta_3 shocks_{it} + \beta_4 ideology_{it} + \beta_5 structure_{it} + \zeta_i + \omega_{it} \end{aligned} \tag{15}$$

where $X_{i,t}$ is a variable that is used as an instrument to identify the system of the two above equations. Following the literature, we can use two different instruments separately. The first one has been put forward by Alexeev and Conrad (2009), Tsui (2011) and Cotet and Tsui (2013), who instrument the oil rents with oil reserves. The second instrument is the lagged value of resource volatility.

Also note that ζ_i is a latent variable inducing dependence between $u_{1it} = \lambda\zeta_i + \eta_{it}$ and $u_{2it} = \zeta_i + \omega_{it}$, with λ a loading factor (free parameter; see Miranda and Rabe-Hesketh, 2006). The reduced form does not include dynamics. Assuming a bivariate normal distribution for (u_{1it}, u_{2it}), given that $(\zeta_i, \eta_{it}, \omega_{it})$ are $iidN(0,1)$, the respective residual covariance matrix Ω corresponds to

$$\Omega \equiv Cov\left[(u_{1it}, u_{2it})'\right] = \begin{pmatrix} \lambda^2 + 1 & \lambda \\ \lambda & 2 \end{pmatrix}$$

giving a correlation coefficient

$$\rho = \frac{\lambda}{\sqrt{2\left(\lambda^2 + 1\right)}}.$$

The second way is to proceed with the system-GMM methodology that it is extensively used for the analysis of political institutions (Caselli et al. 2016, Tsui, 2011) to take into ac-

[10] Centrist governments are the omitted category.

[11] The authors extended this methodology to panel data.

count the initial levels of financial institutions. This methodology comes with the following advantages. First, we can estimate the relationship between the financial liberalization index and resource volatility in differences, which is a means to remove the problem of omitted factors in levels and the country-specific characteristics that might be captured with the CRE-ordered probit model. Second, using the lags as instruments allows to fix potential reverse causality issues. This approach leads to a slightly different model compared to equation (13):

$$\Delta FL_{it} = \beta_1 \Delta FL_{it-1} + \beta_2 \Delta Resourcevolatility_{it} + \beta_3 \Delta Z_{it} + \eta_{it} \tag{16}$$

where Z_i includes all the control variables and η_{it} is an iid error normal distributed.

4.1.3 Other Data

The empirical study also relies on political, shocks, and structure variables, all of them being used as controls. The political variables we use are the following. The first year in office dummy is based on YRSOFFC that describes "How many years has the chief executive been in office." Using the variable EXECRLC, we obtain the political orientation variables left-wing party, right-wing and center. The database designates party orientation based on the presence of certain terms in the party name and description. Those described as conservative, Christian democratic, or right-wing are classified in one group named "Right". Those named as "centrist" are the second group (the basis in our regressions). Finally those defined as communist, socialist, social democratic, or left-wing are referred to as the "Left". Data for political variables are collected from World Bank Political Institutions.All the above variables are collected for the period from 1973 to 2005 to match with the data on the financial liberalization index.

The crises variables are collected from Reinhart and Rogoff (2011). This database offers different dummy variables for financial crises such as inflation and hyperinflation crises, currency crises which include balance of payment crises, and banking crises. The sample of date goes from 1890 to 2011. Again, we restrict our attention to the period from 1975 to 2005, and to the ninety-one countries listed before. Finally, data for Media Freedom and trade openness are collected from Global Media Freedom Dataset (Whitten-Woodring et al. 2015) and World Bank Indicators respectively.

4.2 Main Results

This section displays and discusses the results for our baseline ordered probit model. Table 1 presents the estimation results of the key determinants of the financial liberalization index.

The Columns 1 to 4 of Table 1 show the estimation results for equation (13) using different constructed measures: Hamilton's approach (Columns 1 and 2), no filtering resource volatility (Column 3), HP filter (Column 4). Moreover, Column 5 presents the results we use the alternative definition of resource volatility, that is the standard deviation of the natural resources rents (measured as percentage of GDP) multiplied by the income per capita using the Hamilton's approach. In addition, Columns 6 and 7 provide additional results for the baseline model, once the sample has been divided into advanced and developing countries. The separation between developing and advanced countries is based on the income level, according to the distinction made by the World Bank.[12]

The main variable of interest in all the regressions is the resource revenue volatility. All the columns show that the coefficient attached to this variable is negative and significant at 5%. An increase in a standard deviation of resource volatility decreases the financial reform likelihood by 0.05 percentage points.[13] Thus, we find that as the resource revenue volatility increases, financial liberalization is impaired. This result undoubtedly confirms the the conclusion drawn from the theoretical analysis. It is also worth noticing that the main result holds across all the columns, *i.e.*, whatever the approach and measure considered. Additional results can be summarized as follows. In all the columns of Table 1, the lag of Financial liberalization has a positive, and significant at 1-percent level, effect. Moreover, all the columns but the first one in include additional control variables, that do not affect the general result. The coefficient of the currency crisis dummy variable (last column) is positive and non significant for all the regressions. The bank crisis dummy is significant, featuring a negative coefficient, only in column 7, suggesting that financially liberalization is less likely in times of bank crises in high income countries.

The coefficients associated with the political orientation are significant and positive in Columns 2 to 6. The left-wing dummy variable displays a smaller coefficient than the right-wing dummy variable, the former coefficient becoming negative but no longer significant in the high-income countries sample. This all indicates that right-wing governments are more likely to liberalize the financial sector. The coefficient of the political dummy – the first year in office – is negative but not significant (see columns 2, 3, 4 and 7). The sign of this coefficient changes in columns 5 and 6 but it remains not significant. Lastly, a country's openness to trade, as measured by the sum of imports and exports relative to GDP, is never significant.

[12]For robustness of our results, we perform similar estimations including only the large oil endowment countries from our main sample (similar strategy has been followed by Tsui (2011), our main results remain robust. The Table is available in the Appendix B.)

[13]The marginal effect of the resources revenues volatility is on average 0.05 for all the columns.

Table 1: Baseline model: Ordered Probit Estimates

	(1) FL_{it}	(2) FL_{it}	(3) FL_{it}	(4) FL_{it}	(5) FL_{it}	(6) FL_{it}	(7) FL_{it}
FL_{it-1}	19.3044***	18.9057***	18.9180***	18.9722***	18.6958***	18.7186***	20.8303***
	(0.6977)	(0.7067)	(0.6865)	(0.6892)	(0.6699)	(0.7761)	(1.5933)
$RESOURCEVOLATILITY_{i,t}$	-0.8050***	-0.8191***	-0.5108***	-1.3137***	-0.7191***	-1.1458***	-0.7102***
	(0.1994)	(0.1933)	(0.1560)	(0.3237)	(0.2033)	(0.2871)	(0.2592)
$RIGHT_{i,t}$		0.2207***	0.1816**	0.1880***	0.2056***	0.2035**	0.1191
		(0.0757)	(0.0708)	(0.0711)	(0.0748)	(0.0940)	(0.1246)
$FIRSTYEAR_{i,t}$		-0.0008	-0.0125	-0.0164	0.0013	0.0654	-0.1054
		(0.0679)	(0.0628)	(0.0627)	(0.0664)	(0.0849)	(0.1149)
$CURRENCY_{i,t}$		0.0308	0.0160	0.0048	0.0238	-0.0712	0.1370
		(0.0692)	(0.0646)	(0.0649)	(0.0686)	(0.0805)	(0.1446)
$OPEN_{i,t}$		0.0187	-0.0023	0.0043	0.0172	0.0124	-0.0372
		(0.0255)	(0.0263)	(0.0255)	(0.0260)	(0.0299)	(0.0562)
$LEFT_{i,t}$		0.1121*	0.1244**	0.1249**	0.1114*	0.1177	-0.0122
		(0.0671)	(0.0633)	(0.0633)	(0.0663)	(0.0757)	(0.1300)
$BANK_{i,t}$		-0.0692	-0.0480	-0.0558	-0.0802	0.0323	-0.3145**
		(0.0719)	(0.0703)	(0.0699)	(0.0726)	(0.0857)	(0.1431)
$INFLATION_{i,t}$		0.0879	0.1492*	0.1477*	0.1275	0.1060	0.4681
		(0.0922)	(0.0854)	(0.0853)	(0.0920)	(0.0965)	(0.3645)
Log-Likelihood	-4125.174	-3861.871	-4231.210	-4228.912	-3853.958	-2923.418	-837.939
Sample-Size	1777	1644	1788	1788	1612	1155	489

Notes: ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels respectively. Standard Errors are adjusted for country level clustering.

4.2.1 IV analysis

In section 4.2.1, we deal with the possible simultaneity between resources revenue volatility and financial liberalization index. Table 2 reports the results of the joint-MLE estimation of the system (14)-(15). To identify the system of two equations, an additional variable is used as an instrument in (15). In Columns 1 to 4, and as explained earlier, we use the oil reserves. In columns 1 to 3, we include the resource volatility measure based on respectively Hamilton's approach, HP filter, and no filter. In addition, in columns 5 and 6, we use the lagged value of resource revenue volatility, when computed by means of Hamilton's approach and HP filter.

Our results are as follows. The coefficient attached to resource revenue volatility is negative and highly significant in all the columns. As in Table 1, we find that the left-wing and right-wing variables are significant. As to the shock variables, bank, currency and inflation dummy crises also feature similar signs. The currency and inflation dummy crises remain significant while the coefficient of the bank crises dummy variable is not significant. In column 3, the media freedom variable is included, which has a positive and significant effect on the financial liberalization index. Moreover, the Error-Correlation is not significant in all the columns of Table 2. This indicates that there is no evidence of simultaneity between the resource revenue volatility and financial liberalization. As a consequence, the estimations obtained applying an order probit model are preferable to those obtained with the joint-MLE.

Table 2: Joint Likelihood estimation Estimates probit

	(1)	(2)	(3)	(4)	(5)	(6)
	$FL_{i,t}$	$FL_{i,t}$	$FL_{i,t}$	$FL_{i,t}$	$FL_{i,t}$	$FL_{i,t}$
$FL_{i,t}$						
$RESOURCEVOLATILITY_{i,t}$	-0.0435***	-1.6781***	-1.4186**	-1.0597***	-0.0377***	-1.5719***
	(0.0139)	(0.5895)	(0.5979)	(0.3768)	(0.0113)	(0.5945)
FL_{it-1}	0.9255***	13.7179***	13.6136***	13.6824***	0.9308***	13.6684***
	(0.0071)	(1.4957)	(1.4734)	(1.5029)	(0.0070)	(1.5008)
$RIGHT_{i,t}$	0.0091***	0.2803***	0.2691***	0.2760***	0.0093***	0.2759***
	(0.0035)	(0.1038)	(0.1043)	(0.1043)	(0.0030)	(0.1044)
$FIRSTYEAR_{i,t}$	0.0000	-0.0430	-0.0471	-0.0434	0.0013	-0.0432
	(0.0036)	(0.0685)	(0.0685)	(0.0683)	(0.0033)	(0.0684)
$CURRENCY_{i,t}$	-0.0018	-0.0650	-0.0573	-0.0596	-0.0013	-0.0656
	(0.0041)	(0.0702)	(0.0748)	(0.0707)	(0.0037)	(0.0709)
$LEFT_{i,t}$	0.0017	0.0174	-0.0254	0.0213	0.0037	0.0156
	(0.0035)	(0.1106)	(0.1093)	(0.1113)	(0.0033)	(0.1111)
$BANK_{i,t}$	0.0033	-0.0700	-0.0534	-0.0683	0.0018	-0.0695
	(0.0030)	(0.0831)	(0.0845)	(0.0834)	(0.0032)	(0.0840)
$INFLATION_{i,t}$	0.0039	-0.0833	-0.0775	-0.0726	0.0030	-0.0799
	(0.0041)	(0.0958)	(0.0926)	(0.0965)	(0.0039)	(0.0967)
$OPEN_{i,t}$	0.0028**	0.0259	0.0118	0.0151	0.0018*	0.0229
	(0.0011)	(0.0572)	(0.0585)	(0.0573)	(0.0010)	(0.0585)
$Media_{i,t}$			-0.3270***			
			(0.0871)			
$RESOURCEVOLATILITY_{i,t}$						
$OILRESERVES_{id}$	0.0178**	0.7387***	0.7291***	0.3403***		
	(0.0070)	(0.1425)	(0.1526)	(0.0978)		
$FL_{i,t-1}$	0.0122*	0.2605	1.3492**	0.0759	0.0351***	1.6810***
	(0.0068)	(0.5845)	(0.6076)	(0.1548)	(0.0094)	(0.4759)
$RIGHT_{i,t}$	0.0136	0.0564	0.0594	-0.0647	0.0112	-0.0116
	(0.0183)	(0.4086)	(0.3805)	(0.1390)	(0.0150)	(0.3176)
$FIRSTYEAR_{i,t}$	-0.0139	-0.2339	-0.3456	-0.0415	-0.0169**	-0.4390**
	(0.0095)	(0.2121)	(0.2351)	(0.0502)	(0.0084)	(0.2165)
$CURRENCY_{i,t}$	0.0093	0.2668	0.3221	0.1912**	0.0089	0.2618
	(0.0119)	(0.2768)	(0.2966)	(0.0826)	(0.0066)	(0.1661)
$LEFT_{i,t}$	0.0059	0.0630	0.1605	0.0159	0.0054	0.2678
	(0.0092)	(0.3298)	(0.2713)	(0.1150)	(0.0081)	(0.2877)
$BANK_{i,t}$	-0.0089	0.1851	0.1735	0.1285*	-0.0128	-0.1451
	(0.0134)	(0.2118)	(0.2265)	(0.0709)	(0.0119)	(0.1255)
$INFLATION_{i,t}$	-0.0048	0.4008	0.5893	0.0665	-0.0014	0.3003
	(0.0140)	(0.3430)	(0.3723)	(0.1154)	(0.0104)	(0.2384)
$OPEN_{i,t}$	-0.0005	-0.5078***	-0.5042***	-0.1906***	-0.0021	-0.3996***
	(0.0014)	(0.1369)	(0.1279)	(0.0563)	(0.0015)	(0.1301)
λ	-0.1447	0.0133	0.3057	5.9535	-0.4032	0.2218
	(0.1089)	(0.0218)	(0.2625)	(4.8717)	(0.2592)	(0.2038)
$Media_{i,t}$			0.3446			
			(0.2343)			
LAG $RESOURCEVOLATILITY_{i,t}$					0.1926***	4.3987***
					(0.0538)	(0.6673)
Log-Likelihood	3016.529	-4597.691	-4580.122	-5109.984	3460.552	-4620.647
Sample-Size	1412	1793	1793	1793	1587	1793
Error Correlation	0.500	0.009	0.010	0.003	1587	1793

Notes: ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels respectively. Standard Errors are adjusted for country level clustering.

Table 3 finally shows the results obtained in the last model (17) using the GMM for the estimation. We also obtain a negative and significant effect of resource volatility on changes in financial liberalization. This holds true for all the Columns. Columns 1 and 2 present the results calculating the resource volatility in a 4-years rolling window applying the Hamilton's approach. On the contrary, Columns 3 and 4 report the outcomes using the HP-Filtered resource revenue volatility and non-filtered resource volatility in a 4-years rolling window. Finally, columns 5 and 6 provides the same results for sub-samples of advanced vs. developing countries using the resource volatility measured with the approach of Hamilton (2018). The magnitude coefficient of resource volatility is around 0.05 on average in most columns, which is similar to the marginal effect identified with the CRE ordered probit estimation (see footnote 12).

Table 3: System GMM regressions

	(1) ΔFL_{it}	(2) ΔFL_{it}	(3) ΔFL_{it}	(4) ΔFL_{it}	(5) ΔFL_{it}	(6) ΔFL_{it}
FL_{it-1}	-0.0544**	-0.0500**	-0.0448**	-0.0338*	-0.0937***	-0.0418
	(0.0227)	(0.0230)	(0.0207)	(0.0175)	(0.0304)	(0.0378)
$RESOURCEVOLATILITY_{i,t}$	-0.0375***	-0.0381***	-0.0985***	-0.0619***	-0.0252**	-0.0526***
	(0.0108)	(0.0110)	(0.0295)	(0.0164)	(0.0104)	(0.0170)
$CURRENCY_{i,t}$	-0.0096	-0.0096	-0.0078	-0.0056	-0.0042	-0.0091
	(0.0062)	(0.0062)	(0.0051)	(0.0050)	(0.0072)	(0.0074)
$OPEN_{i,t}$	-0.0155**	-0.0138*	-0.0143*	-0.0115	-0.0061*	-0.0085
	(0.0069)	(0.0076)	(0.0078)	(0.0072)	(0.0036)	(0.0061)
$BANK_{i,t}$	0.0166	0.0187	0.0140	0.0115	-0.0157	0.0169
	(0.0206)	(0.0207)	(0.0200)	(0.0188)	(0.0134)	(0.0221)
$INFLATION_{i,t}$	-0.0068	-0.0071	-0.0020	0.0010	-0.0286	0.0001
	(0.0069)	(0.0068)	(0.0063)	(0.0062)	(0.0178)	(0.0056)
$RIGHT_{it}$	0.0087*	0.0115	0.0087	0.0095	0.0023	0.0047
	(0.0051)	(0.0071)	(0.0062)	(0.0059)	(0.0039)	(0.0093)
$LEFT_{it}$	0.0007	0.0036	0.0042	0.0067	-0.0015	-0.0007
	(0.0047)	(0.0066)	(0.0061)	(0.0052)	(0.0051)	(0.0071)
$FIRSTYEAR_{i,t}$	0.0046	0.0051	0.0029	0.0035	0.0012	0.0073
	(0.0038)	(0.0039)	(0.0036)	(0.0036)	(0.0037)	(0.0054)
$Media_{i,t}$		0.0069	0.0015	0.0066	0.0032	-0.0072
		(0.0098)	(0.0093)	(0.0084)	(0.0166)	(0.0224)
Sample-Size	1644	1644	1788	1788	489	1155
AR(2)-p-value	0.687	0.687	0.518	0.517	0.985	0.719
Hansen test (p-value)	0.372	0.374	0.525	0.531	1	1

Notes: ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels respectively. Standard Errors are adjusted for country level clustering.

4.3 Effects of Resource Volatility on Economic Growth

In this subsection, we want to link our study with earlier works on the impact of volatility on economic growth, not economic liberalization. Indeed, in the literature, some empirical support has been provided to the hypothesis that volatility of natural resource windfall is the quintessential feature of the natural resource curse, and furthermore that this is only so in countries with poorly developed financial markets (see Poelhekke and Van der Ploeg, 2009, 2010). In other words, there is evidence that the lack of financial liberalization paves the way for a negative impact of volatility on growth of GDP per capita.

Even though this is neither the aim nor the main contribution of the paper, we test whether our findings are consistent with the above empirical literature. Following Acemoglu et al., (2008), we estimate the following equation,

$$\Delta Y_{it} = \beta_1 \Delta Y_{it-1} + \beta_2 \Delta Resourcevolatility_{it} + \beta_3 \Delta X_{it} + u_{it} \tag{17}$$

where Y_{it} is the income per capita, $Resourcevolatility_{it}$ is the resource revenue volatility and $X_{i,t}$ includes all the control variables, like investment and openness. For the estimation of the above equation, we use the System-GMM method (see Acemoglu et al., 2008) to take into account the Nickel bias and other potential endogeneity issues. Table 4 reports the results. Column 1 shows the baseline estimates. The baseline model includes the following variable: trade openness (World Bank Indications), Investment in Physical capital (Penn World tables), the logarithm of GDP per capita (World Bank Indicators), Resource volatility, age dependency ratio of working-age population (World Bank Indicators) and the logarithm of the population (World Bank Indicators). We note that resource volatility has a negative and significant impact on GDP growth at 5%. In particular an increase in resource volatility decreases the yearly GDP growth by 0.43 percent on average. In column 2, we add the financial liberalization index, as a control variable. We find that the Financial liberalization index has a positive and significant effect on GDP growth.

In Column 3, we construct a dummy variable that takes the value one when the Financial liberalization is above its mean, and zero otherwise. This is an alternative way for investigating the effect of financial liberalization on GDP growth. We find that the higher financial liberalization in a country, the higher its GDP growth. In Column 4, we add another variable which it is the interaction between the financial liberalization dummy and resource volatility. This interaction has a negative and insignificant coefficient. This outcome indicates that resource volatility has not any significant effect on highly financially liberalized countries. Finally, in Columns 5 and 6, we split our sample of countries into two groups. The first (second) one recovers countries that display a level of the financial liberalization index above (below) its median value. We find that in financially liberalized countries, resource volatility has not any significant effect. On the contrary, for countries with low levels of financial liberalization, resource volatility is shown to be an important factor of GDP growth, affecting it negatively. All the above results are in line with former conclusions by Poelhekke and Van der Ploeg (2009, 2010). In all the columns, all the control variables but the investment, the age dependence ratio and the initial level of GDP are not significant. Moreover, the test of second-order autocorrelation in the residuals shows that there is no evidence of additional serial correlation. Beside, the Hansen J-test shows that over-identification restrictions are not rejected.

Table 4: Resource Volatility and Growth

	(1)	(2)	(3)	(4)	(5)	(6)
	$logGDP_{i,t}$	logGDP	logGDP	logGDP	logGDP	logGDP
lagGDP	0.8936***	0.8287***	0.8703***	0.8759***	0.9672***	0.8649***
	(0.0349)	(0.0408)	(0.0315)	(0.0297)	(0.0078)	(0.0730)
Age dependency ratio	-0.0088***	-0.0073***	-0.0088***	-0.0084***	-0.0019***	-0.0074***
	(0.0020)	(0.0020)	(0.0018)	(0.0018)	(0.0006)	(0.0028)
Investment	0.0036*	0.0034*	0.0034*	0.0031	0.0026*	0.0027
	(0.0021)	(0.0020)	(0.0020)	(0.0020)	(0.0014)	(0.0025)
$RESOURCE_VOLATILITY_{i,t}$	-0.430**	-0.360**	-0.360*	1.240	0.07	-0.45*
	(0.0022)	(0.0017)	(0.0019)	(0.0166)	(0.0010)	(0.0024)
Openness	-0.0187	0.0259	-0.0029	0.0016	0.0130	0.0029
	(0.0284)	(0.0284)	(0.0274)	(0.0275)	(0.0112)	(0.0266)
$Population_{i,t}(logs)$	0.0302	0.0448	0.0262	0.0287		
	(0.0296)	(0.0309)	(0.0295)	(0.0290)		
$FL_{i,t}$		0.0303***				
		(0.0101)				
I_t			0.1987**	0.2073**		
			(0.0870)	(0.0886)		
$I_t * volatility$				-0.0163		
				(0.0171)		
Constant	0.6260	0.5819	0.7721	0.6564	1.1172***	0.5911
	(0.5733)	(0.6353)	(0.5538)	(0.5150)	(0.3002)	(0.8973)
Sample-Size	1274	1274	1274	1274	665	588
AR(2)-p-value	0.773	0.376	0.154	0.147	0.798	0.166
Hansen test (p-value)	0.986	0.982	0.986	0.995	0.881	0.592

Notes: ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels respectively. Standard Errors are adjusted for country level clustering.

5 Conclusion

We have explored both theoretically and empirically the direct impact of resource volatility on the institutional state, here captured by the national (economic) liberalizations. As outlined in the introduction, we believe this is the first work taking this avenue, the existing resource curse literature devoted to the impact of resource volatility being overwhelmingly focused on the impact on growth and macroeconomic stabilization. On the theoretical ground, we have developed a stochastic differential game of lobbying with two players (conservatives vs liberals) and two sources of uncertainty (political uncertainty and uncertainty inherent in resource revenues dynamics). A key specification based on national and regional case studied highlighted in the introduction, resides in the fact that the lobbying power of conservatives increases with the level of resource revenues. We solve for the Markov perfect equilibrium and proves that there exists a unique one in the set of affine strategies. Moreover, we prove that the equilibrium legislative state almost surely converges pointwise in the case of non-renewable resources while it converges to an invariant distribution in the renewable resources case. In the latter case, we demonstrate that the most likely long-term state is more favorable to the conservatives but it becomes less illiberal when resource volatility rises. When it comes to the short-term impact of resource volatility, we demonstrate that it is essentially ambiguous, which is not a surprising outcome. On the empirical ground, we use a database covering 91 countries over the period 1973-2005 to identify the role of oil revenues volatility on financial liberalization. We find that as oil revenue volatility increases, liberalization goes down.

Needless to say, our study does not pretend at all to deliver a general theory of the institutional impact of resource volatility. It is primarily concerned with the identification and the study of a particular mechanism outlined in many case studies, namely the resource-dependent behaviour of conservative elite in numerous resource-rich countries. There are many more aspects to investigate. One aspect, not treated in our theory, is the possible feedback from the institutional state to resource revenues. It can be for example argued that market orientation of national governments tends to increase the exploration for new natural resources reserves, potentially leading to more extraction and revenues (see Arezki et al., 2019). One may also want to extent the analysis, for the case of oil, by considering more sophisticated price dynamics with discontinuous and abrupt changes (see Willmot and Mason, 2013). Finally, following the literature on the state capacity (see Besley and Persson, 2009), adding a second best structure and explaining why each group seeks to influence the legislation (as a prerequisite for the implementation of specific public policies) is another promising future line of research.

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A Mathematical appendix

A.1 Proof of Proposition 3.1

The proof is conducted in two steps: Step 1 proves the existence and Step 2 establishes the uniqueness.

A.1.1 Existence of a MPE in the class of affine strategies

Denote player i's value function as $V_i(z,R)$. Player i's Hamilton-Jacobi-Bellman (HJB) equation is

$$rV_i(z,R) = \max_{x_i}\left[F_i(x_i,z) + \frac{\partial V_i}{\partial z}\cdot(x_1 - (1+\varepsilon R)x_2) + \frac{\partial V_i}{\partial R}(\eta + \xi R) + \frac{1}{2}\sigma D^2 V_i \sigma'\right], \qquad (18)$$

with $\sigma = (\sigma_z z, \sigma_R R)$, σ' its transpose, $D^2 V_i$ the Hessian matrix of $V_i(z,R)$, and $F_i(x_i,z)$ a compact notation for the integrand of player i's objective function:

$$F_1(x_1,z) = a_0 + a_1 z - \frac{b}{2}x_1^2 \quad \text{and} \quad F_2(x_2,z) = a_0 - a_1 z - \frac{b}{2}x_2^2.$$

Let us work with the following affine-quadratic value function

$$V_i(z,R) = A_i + B_i z + \frac{C_i}{2}z^2 + D_i R + \frac{E_i}{2}R^2 + H_i z R, \qquad (19)$$

where $A_i, B_i, C_i, D_i, E_i, H_i$ are the unknowns of the problem. First order conditions yield the expression of players' efforts in terms of these unknowns:

$$x_1 = \frac{(B_1 + C_1 z + H_1 R)}{b} \quad \text{and} \quad x_2 = -\frac{(1+\varepsilon R)(B_2 + C_2 z + H_2 R)}{b}. \qquad (20)$$

Identification step: substituting x_1 and x_2 into the right hand side of (18), for each player, we obtain a polynomial that is of the fourth degree in R and of the third degree in z. Given that the value function in (19) is a second degree polynomial in R and z, terms in R and z with power larger than 2 in the RHS must vanish, which requires

$$C_i = 0, \quad \text{and} \quad H_i = 0 \text{ for } i = 1,2.$$

The rest of the identification step yields:

Player 1	Player 2
$rA_1 = a_0 + \frac{B_1^2}{2b} + \frac{B_1 B_2}{b} + \eta D_1$	$rA_2 = a_0 + \frac{B_2^2}{2b} + \frac{B_1 B_2}{b} + \eta D_2$
$rB_1 = a_1$	$rB_2 = -a_1$
$rD_1 = \frac{2\varepsilon B_1 B_2}{b} + \eta E_1 + \xi D_1$	$rD_2 = \frac{\varepsilon B_2^2}{b} + \eta E_2 + \xi D_2$
$rE_1 = \frac{\varepsilon^2 B_1 B_2}{b} + \left(\xi + \frac{\sigma_R^2}{2}\right) E_1$	$rE_2 = \frac{\varepsilon^2 B_2^2}{b} + (\sigma_R^2 + 2\xi) E_2$

This system is solved in the coefficients to get players' strategies at the MPE:

$$x_1 = \frac{a_1}{br}, \text{ and } \quad x_2(R) = \frac{a_1(1+\varepsilon R)}{br},$$

and using these strategies, we obtain the dynamic system (7). We can finally solve this system to obtain the MPE expressions of z and R at any instant t:

$$\begin{aligned} R(t) &= e^{\left(\xi - \frac{\sigma_R^2}{2}\right)t + \sigma_R W_t} \left[R_0 + \eta \int_0^t e^{-\left(\xi - \frac{\sigma_R^2}{2}\right)s - \sigma_R W_s} ds \right], \\ z(t) &= e^{-\frac{\sigma_z^2}{2}t + \sigma_z W_t} \left[z_0 + \int_0^t A(s)\, e^{\frac{\sigma_z^2}{2}s - \sigma_z W_s} ds \right] \end{aligned} \tag{21}$$

with $A(t) = -\frac{a_1 \varepsilon}{br}(2 + \varepsilon R(t))R(t)$.

This completes the proof of the existence of a MPE in affine strategies.

A.1.2 Uniqueness of the MPE

To establish the uniqueness result in the affine strategy space – where both strategies are affine functions of the state variable R – we proceed in two steps. The first step follows the above existence result and shows that in the specific strategy space where player 1's strategy is independent of R and player 2's strategies is affine in R, the above MPE is unique. Step 2 goes beyond these results by showing that player 1's strategy must indeed be a constant.

Step 1. Uniqueness in a specific strategy space

Claim: *In the strategy space where player 1's effort is a constant and player 2's one is an affine function of R, the above pair of Markovian strategies, (x_1, x_2), is the unique MPE.*

Hereafter, our aim is to prove this claim, working by contradiction. For that purpose, note that value functions at any MPE can be rewritten as

$$V_i(R_0, z_0) = \max_{x_i'} J_i(x_i', x_j) \equiv J_i(x_i, x_j) \text{ for } i = 1, 2,$$

where, with a slight abuse of notation, $J_i(.,.)$ represents player i's maximized value of the objective function, given the state equations.

Suppose that there exist multiple MPEs, then by definition they must yield the same value, which only depends on the initial conditions R_0 and z_0. Furthermore, if (x_1, x_2) is a MPE, then from the definition of the best responses, the following must hold:

$$\begin{aligned} J_1(x_1, x_2) &\geq J_1(x_1', x_2), \quad \forall x_1', \\ J_2(x_1, x_2) &\geq J_2(x_1, x_2'), \quad \forall x_2'. \end{aligned} \tag{22}$$

Now assume that the game has another (different) MPE, $(\overline{x}_1, \overline{x}_2)$, in the same strategy space, *i.e.*, $\overline{x}_1 = A$, and $\overline{x}_2 = C + FR$, with A, C, F three unknown coefficients satisfying $\overline{x}_1 \neq x_1$ and $\overline{x}_2 \neq x_2$.

Then the difference between the two maximized objective values associated with the two MPEs must be nil. For instance, for player 2:

$$J_2(x_1, x_2) - J_2(\overline{x}_1, \overline{x}_2) = V_2(R_0, z_0) - V_2(R_0, z_0) = 0. \tag{23}$$

This difference can also be rewritten as

$$J_2(x_1, x_2) - J_2(\overline{x}_1, \overline{x}_2) = \left[J_2(x_1, x_2) - J_2(x_1, \overline{x}_2)\right] + \left[J_2(x_1, \overline{x}_2) - J_2(\overline{x}_1 . \overline{x}_2)\right], \tag{24}$$

where the first term in square brackets in the RHS is non-negative by (22). Computing the second term, we get:

$$J_2(x_1, \overline{x}_2) - J_2(\overline{x}_1, \overline{x}_2) = \int_0^\infty e^{-rt} a_1 (\overline{z}_1(t) - \overline{z}(t)) dt,$$

where $\overline{z}_1(t)$ and $\overline{z}(t)$ are solutions of the following equations

$$\begin{aligned} d\overline{z}_1(t) &= (x_1 - (1 + \varepsilon R)\overline{x}_2)dt + \sigma_z z dW_t, \\ d\overline{z}(t) &= (\overline{x}_1 - (1 + \varepsilon R)\overline{x}_2)dt + \sigma_z z dW_t, \end{aligned} \tag{25}$$

with the same initial condition z_0 given.

From the explicit solutions of (25), we then have

$$J_2(x_1, \overline{x}_2) - J_2(\overline{x}_1, \overline{x}_2) = a_1(x_1 - \overline{x}_1) \int_0^\infty e^{-rt} \int_0^t e^{-\frac{\sigma_z^2}{2}(t-s) + \sigma_z W_{t-s}} ds \, dt. \tag{26}$$

We know, from (23) and (24), that this difference must be non positive. So it must be that

$$x_1 \leq \overline{x}_1. \tag{27}$$

Now, consider the second possible decomposition:

$$J_2(\overline{x_1}, \overline{x_2}) - J_2(x_1, x_2) = [J_2(\overline{x_1}, \overline{x_2}) - J_2(\overline{x_1}, x_2)] + [J_2(\overline{x_1}, x_2) - J_2(x_1, x_2)], \tag{28}$$

and adopt the same computation procedure as above to get:

$$J_2(\overline{x_1}, x_2) - J_2(x_1, x_2) = a_1(\overline{x}_1 - x_1) \int_0^\infty e^{-rt} \int_0^t e^{-\frac{\sigma_z^2}{2}(t-s)+\sigma_z W_{t-s}} ds\ dt.$$

Given that the first term in (28) is non negative by (22), we can now conclude that

$$x_1 \geq \overline{x}_1. \tag{29}$$

Combining (27) and (29), we necessarily have $\overline{x}_1 = x_1$, which yields a contradiction. Working along the same lines with player 1's maximized value, $J_1(x_1, x_2)$, we would get the same contradiction ($\overline{x}_2 = x_2$).

This completes the proof of the claim.

Step 2. Uniqueness in the affine strategy space.

Suppose that $(\overline{x}_1, \overline{x}_2) = (A + BR, C + FR)$ is a MPE with coefficients A, B, C, F to be determined. The HJB equation (18) is still valid, and from the FOCs we get:

$$\overline{x}_1 = \frac{1}{b} \frac{\partial V_1(z, R)}{\partial z} = A + BR,$$

and

$$\overline{x}_2 = \frac{1 + \epsilon R}{b} \frac{\partial V_2(z, R)}{\partial z} = C + FR.$$

Taking indefinite integrals on both sides with respect to z, we obtain

$$V_1(z, R) = b(A + BR)z + K_1(R),$$

where $K_1(R)$ could be any function independent of z that can however depend on R.

From this, we can easily compute the Hessian matrix and the matrix product:

$$D^2V_1 = \begin{pmatrix} 0 & bB \\ bB & \frac{d^2K_1}{dR^2} \end{pmatrix}$$

and,

$$\frac{1}{2}\sigma\ D^2V_1\ \sigma' = \frac{1}{2}\left[2bB\sigma_z\sigma_R zR + \sigma_R^2 R^2 \frac{d^2K_1}{dR^2}\right].$$

Substituting all the terms above into the HJB equation (18), the left hand side reduces to

$$rV_1(z,R) = rbAz + rbBzR + rK_1(R)$$

while the right hand side (RHS) is equal to

$$\begin{aligned} RHS &= a_0 + a_1 z + \frac{A^2 + 2ABR + B^2R^2}{2b} - b(A+BR)(1+\epsilon R)(C+FR) + bB(\eta + \xi R)z \\ &+ \frac{1}{2}\left[2bB\sigma_z\sigma_R zR + \sigma_R^2 R^2 \frac{d^2K_1}{dR^2}\right]. \end{aligned}$$

Focusing on the coefficients associated with the term in zR, on both sides, it must hold that

$$rbB = bB\xi + bB\sigma_z\sigma_R,$$

an equality that is satisfies for $b > 0$ and $\forall\xi, \forall\sigma_z > 0, \forall\sigma_R > 0$, if and only if $B = 0$. Therefore, at the MPE, if player 2's strategy is affine in terms of R, then player 1's strategy must be a constant.

As we already showed in Step 1 that the (x_1, x_2) is the unique MPE in its strategy space, we can now conclude that (x_1, x_2) is in fact the unique MPE in the affine strategy space.

That completes the proof of Proposition 3.1.

A.2 Deterministic outcomes

When removing uncertainty, the solutions in (21) reduce to

$$\begin{aligned} &R(t) = \left(R_0 + \tfrac{\eta}{\xi}\right)e^{\xi t} - \tfrac{\eta}{\xi}, \\ &z(t) = z_0 - \tfrac{a_1\varepsilon}{br}\left[\left(R_0 + \tfrac{\eta}{\xi}\right)\tfrac{e^{\xi t}-1}{\xi} - \tfrac{\eta}{\xi}t\right] - \tfrac{a_1\varepsilon^2}{br}\left[\left(R_0 + \tfrac{\eta}{\xi}\right)^2 \tfrac{e^{2\xi t}-1}{2\xi} + \tfrac{\eta^2}{\xi^2}\,t - \left(R_0 + \tfrac{\eta}{\xi}\right)\tfrac{2\eta(e^{\xi t}-1)}{\xi^2}\right]. \end{aligned}$$

A.3 Stability of the MPE (proof of Propositions 3.3)

Noticing that the expression of R given in (21) can be rewritten as

$$R(t) = R_0 e^{\left(\xi - \frac{\sigma_R^2}{2}\right)t} + \eta \int_0^t e^{\left(\xi - \frac{\sigma_R^2}{2}\right)(t-s) + \sigma_R (W_t - W_s)} ds. \tag{30}$$

From Boucekkine et al. (2018), we know that the first term is stable if and only if

$$\sigma_R^2 > 2\xi,$$

which holds under the assumption $\xi < 0$. Moreover, if $\eta = 0$, then the resource revenue process, as given by (30), is stochastically stable.

The following proposition establishes the boundedness of the z-process whatever $\eta \geq 0$.

Proposition A.1. *Suppose $\sigma_z > 0$, then there exist $M_R = M_R(\xi, \sigma_R) > 0$ and $M_z = M_z(\xi, \sigma_R, \sigma_z) > 0$, such that, both stochastic processes R and z are almost surely bounded in the sense of absolute values:*

$$0 \leq R(t) \leq M_R, \quad | z(t) | \leq M_z, \quad \forall t \geq 0.$$

Before we proceed to the computation of the invariant distribution, note that in Proposition 3.3, we voluntarily pay attention to the case $\eta > 0$ only. The reason for this is quite simple. If $\eta = 0$, the density function (10) reduces to

$$\pi_R(R; \eta = 0) = \frac{n}{\sigma_R^2} R^{\frac{2}{\sigma_R^2}(\xi - \sigma_R^2)},$$

but then it is impossible that

$$\int_0^\infty \pi_R(R; \eta = 0) dR = 1.$$

When $\eta = 0$, the limit of the density function (10) can not serve as a density function.

A.3.1 Proof of Proposition A.1

We now study the second term of (30). Let $X(t)$ be the solution of the following homogenous stochastic equation

$$\begin{cases} dX(t) = \xi X(t) dt + \sigma_R X(t) dW_t, \forall t \geq s, \\ X(s) = 1. \end{cases}$$

By Ito's Lemma, the solution satisfies

$$\ln(X(t;s)) = \left(\xi - \frac{\sigma_R^2}{2}\right)(t-s) + \sigma_R(W_t - W_s).$$

Taking mathematics expectation then taking limits yields

$$\lim_{t\to\infty} \frac{\mathbf{E}\ln(X(t;s))}{t} = \xi - \frac{\sigma_R^2}{2} < 0.$$

Therefore, for any $\epsilon \in \left(0, \frac{\sigma_R^2}{2} - \xi\right)$, there exits $\delta = \delta(\epsilon)$, such that

$$\mid X(t;s) \mid \leq \delta e^{\left(\xi - \frac{\sigma_R^2}{2} + \epsilon\right)(t-s)}, \quad \forall t \geq s.$$

Hence, we have

$$\int_0^t X(t;s)ds \leq \delta \int_0^t e^{\left(\xi - \frac{\sigma_R^2}{2}+\epsilon\right)(t-s)} ds = \frac{\delta}{-\left(\xi - \frac{\sigma_R^2}{2} + \epsilon\right)} \left[1 - e^{\left(\xi - \frac{\sigma_R^2}{2}+\epsilon\right)t}\right].$$

Taking limits on both sides, we have

$$\lim_{t\to\infty} \eta \int_0^t X(t;s)ds \leq \frac{\eta\delta}{-\left(\xi - \frac{\sigma_R^2}{2} + \epsilon\right)},$$

Finally, take $\epsilon = \frac{1}{2}\left(\frac{\sigma_R^2}{2} - \xi\right)$, then $\delta = \delta(\xi, \sigma_R)$ and

$$\lim_{t\to\infty} \eta \int_0^t X(t;s)ds \leq \eta H(\xi, \sigma_R) < +\infty,$$

where $H(\xi, \sigma_R)$ is a constant which depends on ξ and σ_R only. Thus, the second part of (30) is bounded too.

Combining the analyses of the first and second part of (30), we obtain that the function $R(t)$ is finite for any $t \geq 0$. Substituting the above bounded results of $R(t)$ into the expression of $z(t)$ given in (21), and applying the same analysis, we can conclude that $z(t)$ is also almost surely bounded given $-\sigma_z < 0$. That finishes the proof.

A.3.2 Proof of Proposition 3.3

The proof of existence of steady state density distribution of stochastic process $R(t)$ follows the same arguments as Merton (1975), which we present the detail in the following.

Given $R(t)$ is a diffusion process, its transition density function will satisfy the Kolmogorov-Foller-Planck "forward" equation. Let $P(R,t)$ as the conditional probability density for process $R(t)$ at time t, given initial condition $R(0) = R_0$. Then the corresponding Kolmogorov-Foller-Planck "forward" equation would be

$$\frac{\partial P}{\partial t} = -\frac{\partial}{\partial R}[(\eta + \xi R)P(R,t)] + \frac{\partial^2}{\partial R^2}\left(\frac{\sigma_R^2 R^2}{2}P(R,t)\right).$$

The above equation can be rewritten as

$$\frac{\partial P}{\partial t} = (\sigma_R^2 - \xi)P(R,t) + (4\sigma_R R - \xi R - \eta)\frac{\partial P}{\partial R} + \frac{\sigma_R^2 R^2}{2}\frac{\partial^2}{\partial R^2}P(R,t). \tag{31}$$

Suppose that R has a steady state distribution, independent of R_0, then

$$\lim_{t\to\infty} P(R,t) = \pi_R(R) \quad \text{and} \quad \lim_{t\to\infty}\frac{\partial P}{\partial t} = 0.$$

Thus, the stationary density function $\pi_R(R)$ is the solution of the following second order differential equation:

$$0 = \frac{d}{dR}\left[-(\eta + \xi_R R)\pi_R(R)] + \frac{d}{dR}\left(\frac{\sigma_R^2 R^2}{2}\pi_R(R)\right)\right]. \tag{32}$$

Taking indefinite integrals on both sides of (32), it follows

$$\frac{d}{dR}(\sigma_R^2 R^2 \pi_R(R)) = 2(\eta + \xi_R R)\pi_R(R) + k_1, \;\; \forall k_1.$$

Define

$$p(R) = \sigma_R^2 R^2 \pi_R(R),$$

then $\pi_R(R) = \frac{p(R)}{\sigma_R^2 R^2}$ and unknown function $p(R)$ satisfies equation

$$\frac{d\sigma_R^2 R^2 \pi_R(R)}{dR} = 2(\eta + \xi_R R)\frac{p(R)}{\sigma_R^2 R^2} + k_1, \;\; \forall k_1.$$

By variation of parameters, the general solution of the above differential equation is

$$p(R) = e^{\int \left(2(\eta+\xi_R R)\frac{p(R)}{\sigma_R^2 R^2}\right) dR} \left[k_1 \int e^{-\int \left(2(\eta+\xi_R R)\frac{p(R)}{\sigma_R^2 R^2}\right) dR} + k_2\right], \ \ \forall k_2.$$

It is easy to check that

$$\int \left(2(\eta+\xi_R R)\frac{p(R)}{\sigma_R^2 R^2}\right) dR = -\frac{2\eta}{\sigma_R^2 R} + \frac{2\xi}{\sigma_R^2}\ln(R) + k_3, \ \ \forall k_3,$$

and

$$e^{\int \left(2(\eta+\xi_R R)\frac{p(R)}{\sigma_R^2 R^2}\right) dR} = k_4 R^{\frac{2\xi}{\sigma_R^2}} e^{-\frac{2\eta}{\sigma_R^2 R}}, \ \ \forall k_4 > 0.$$

Thus, we have

$$p(R) = R^{\frac{2\xi}{\sigma_R^2}} e^{-\frac{2\eta}{\sigma_R^2 R}} \left[k_1 \int R^{-\frac{2\xi}{\sigma_R^2}} e^{\frac{2\eta}{\sigma_R^2 R}} dR + k_2\right].$$

Furthermore, the function $\pi_R(R) = \dfrac{p(R)}{\sigma_R^2 R^2}$ qualifies as a density function, such that

$$\int_0^{+\infty} \pi_R(R) dR = 1$$

if and only if $k_1 = 0$. Thus, we obtain the density function $\pi_R(R)$ as presented in Proposition 3.3.

That completes the analysis of the existence of the density function except at the inaccessible of one natural boundary $R = 0$, where we recall the stochastic differential equation

$$dR(t) = (\eta + \xi R)dt + \sigma_R R dB_t, \tag{33}$$

with $R \in [0, M_R]$. To finish this part of proof, we follow the method of Merton (1975, Page 390-391) that is we "compare the stochastic process generated by" (33) "with another process which is known to have inaccessible boundaries and then to show that the probability that" R "reaches its boundary" $R = 0$ "is no larger than the probability that the comparison process reaches its" boundary.

Define a new process $X(t) = \ln(R)$. By Ito's Lemma, we get

$$dX = \left(\frac{\eta}{R} + \xi - \frac{\sigma_R^2}{2}\right) dt + \sigma_R dB_t, \tag{34}$$

with $\xi - \frac{\sigma_R^2}{2} < 0$.

Noticing that if $M_R > 1$ and $R \in [1, M_R]$, by continuity, it is impossible that $R(t) \to 0$ as $t \to \infty$. Thus, we only need to consider the case $R \in [0, \min\{1, M_R\}]$.

Take $\delta = \frac{1}{2}\left(\frac{\sigma_R^2}{2} - \xi\right) > 0$, then, provided $\eta > 0$, the inequality

$$\frac{\eta}{R} + \xi - \sigma_R^2 \geq \delta > 0$$

holds if and only if

$$R \leq \frac{2\eta}{3\left(\frac{\sigma_R^2}{2} - \xi\right)} = \underline{R}.$$

Consider a Wiener process $W(t)$ with drift δ and variance σ_R^2 defined on the interval $[-\infty, \underline{R}]$ where $\underline{R}$ is a reflecting barrier, i.e.,

$$dW(t) = \delta dt - \sigma_R dB_t$$

for $W \in [-\infty, \underline{R}]$. Merton (1975, Page 391) and Cox and Miller (1968, page 223-225) have shown that such a process with $\delta > 0$ has a non-degenerate steady state. Thus, $-\infty$ is an inaccessible boundary for $W-$process. Therefore, $-\infty$ is also an inaccessible boundary for $X-$process. Given $X(t) = \ln(R)$, thus, 0 is an inaccessible boundary for $R-$process, provided $\eta > 0$.

For the process z, the same arguments apply as well.

Let us move now to the case $\eta = 0$. Then

$$R(t) = e^{\left(\xi - \frac{\sigma_R^2}{2}\right)t + \sigma_R W_t} R_0,$$

which is almost surely strictly positive and goes to 0.

To study the convergence of the process $z(t)$, we decompose the explicit solution of $z(t)$ into two terms:

$$z(t) = e^{-\frac{\sigma_z^2}{2}t + \sigma_z W_t} z_0 + e^{-\frac{\sigma_z^2}{2}t + \sigma_z W_t} \int_0^t A(s)\, e^{\frac{\sigma_z^2}{2}s - \sigma_z W_s} ds.$$

The first term on the right hand side almost surely converges to 0 for any initial condition z_0 and without any condition on σ_z except strict positivity. As to the second term, we have to prove that the integral is almost surely bounded, while $e^{-\frac{\sigma_z^2}{2}t + \sigma_z W_t}$ almost surely converges to zero, in order to complete the proof.

Denote the integral of second term of the above explicit solution as $z_1(t)$, then replacing $R(t)$ with its explicit form in $A(t)$, it follows:

$$\begin{aligned} z_1(t) = & \int_0^t A(s)\ e^{\frac{\sigma_z^2}{2}s-\sigma_z W_s} ds \\ & = -\frac{a_1\varepsilon}{br}\int_0^t (2+\varepsilon R(s))R_0 e^{\left(\xi-\frac{\sigma_R^2}{2}\right)s+\sigma_R W_s} e^{\frac{\sigma_z^2}{2}s-\sigma_z W_s} ds \\ & = -\frac{a_1\varepsilon}{br}\int_0^t (2+\varepsilon R(s))R_0 e^{\left(\xi-\frac{\sigma_R^2}{2}+\frac{\sigma_z^2}{2}\right)s+(\sigma_R-\sigma_z)W_s} ds \end{aligned}$$

Denote the positive stochastic process

$$X(t;s) = e^{\left(\xi-\frac{\sigma_R^2}{2}+\frac{\sigma_z^2}{2}\right)(t-s)+(\sigma_R-\sigma_z)W_{t-s}}, \quad \forall t \geq s.$$

Then

$$\ln X(t;s) = \left(\xi - \frac{\sigma_R^2}{2} + \frac{\sigma_z^2}{2}\right)(t-s) + (\sigma_R - \sigma_z)W_{t-s},$$

and the mathematics expectation of this log-process checks

$$\mathbb{E}[\ln X(t;s)] = \left(\xi - \frac{\sigma_R^2}{2} + \frac{\sigma_z^2}{2}\right)(t-s).$$

Therefore, if

$$\lim_{t\to+\infty}\frac{\mathbb{E}[\ln X(t;s)]}{t} = \xi - \frac{\sigma_R^2}{2} + \frac{\sigma_z^2}{2} < 0 \Leftrightarrow \sigma_R^2 > 2\xi + \sigma_z^2,$$

then for any $\varepsilon \in \left(0, \frac{\sigma_R^2}{2} - \xi - \frac{\sigma_z^2}{2}\right)$, there exits $M = M(\varepsilon)$, such that

$$X(t;s) \leq M e^{\left(\xi-\frac{\sigma_R^2}{2}+\frac{\sigma_z^2}{2}+\varepsilon\right)(t-s)}, \quad \forall t \geq s.$$

Taking integrals on both sides, we have

$$\int_0^t X(t;s)ds \leq M\int_0^t e^{\left(\xi-\frac{\sigma_R^2}{2}+\frac{\sigma_z^2}{2}+\varepsilon\right)(t-s)} ds = \frac{M}{-\left(\xi - \frac{\sigma_R^2}{2} + \frac{\sigma_z^2}{2} + \varepsilon\right)}\left(1 - e^{\left(\xi-\frac{\sigma_R^2}{2}+\frac{\sigma_z^2}{2}+\varepsilon\right)t}\right).$$

Taking limits on both sides, it follows

$$\lim_{t\to+\infty}\int_0^t X(t;s)ds \leq \frac{M}{-\left(\xi - \frac{\sigma_R^2}{2} + \frac{\sigma_z^2}{2} + \varepsilon\right)}.$$

Let $\varepsilon = \frac{1}{2}\left(\frac{\sigma_R^2}{2} - \xi - \frac{\sigma_z^2}{2}\right)$, then $M = M(\xi, \sigma_R, \sigma_z)$ and

$$\lim_{t\to+\infty} \int_0^t X(t;s)ds \leq \widetilde{M}(\xi, \sigma_R, \sigma_z) < +\infty,$$

where $\widetilde{M}(\xi, \sigma_R, \sigma_z)$ is a constant depending on parameters ξ, σ_R, σ_z only.

Therefore, if

$$\sigma_R^2 > 2\xi + \sigma_z^2,$$

which corresponds to (9) in Proposition 3.3, then $z_1(t)$ is almost surely bounded, and thus $z(t)$ almost surely converges to zero as t goes to infinity.

A.4 Impact of uncertainty

A.4.1 Long-run - proof of Corollary 3.4

Differentiating the $R-$ process density function in (10) with respect to R yields

$$\frac{d\pi_R(R;\eta)}{dR} = \frac{2n}{\sigma_R^4} \exp\left\{-\frac{2\eta}{\sigma_R^2\, R}\right\} R^{2\left(\frac{\xi}{\sigma_R^2}-2\right)} \left[(\xi - \sigma_R^2)R + \eta\right].$$

Thus, if $\xi - \sigma_R^2 < 0$, we have

$$\frac{d\pi_R(R;\eta)}{dR} \gtreqless 0, \quad \text{when} \quad R \lesseqgtr \widehat{R} = \frac{\eta}{\sigma_R^2 - \xi}(> 0).$$

Following the argument of Jorgensen and Yeung (1996), the point $\widehat{R}$ is the most likely position of revenue. Similarly, differentiating the second density function in (10) with respect to z, we obtain

$$\frac{d\pi_z(z)}{dz} = \frac{2m}{\sigma_z^2\, z^4} \exp\left\{\frac{2a_1\varepsilon R(2+\varepsilon R)}{br\sigma_z^2}\;\frac{1}{z}\right\} \left[z + \frac{a_1\varepsilon R(2+\varepsilon R)}{br\sigma_z^2}\right].$$

And hence,

$$\frac{d\pi_z(z)}{dz} \gtreqless 0, \quad \text{when} \quad z \lesseqgtr \widehat{z}(R) = -\frac{a_1\varepsilon R(2+\varepsilon R)}{br\sigma_z^2}(\leq 0), \forall R \geq 0.$$

A.4.2 Short-run

Consider equation (12) in the simplest case with non-renewable resources, $\eta = 0$. In this case, the cumulative effect of past realizations vanishes. However, the short-term impact remains nontrivial. Indeed, recall that the Brownian motion with drift, denoted as $X_t = -\sigma_R t + W_t$, has mean $-\sigma_R t$ and variance $\sqrt{t}$. In the long-run, the trend, $-\sigma_R t$ dominates the Brownian motion, whereas in the short-run, the volatility of the process is the dominant term. The reason is straightforward, for large t, i.e., the long-run, $\sqrt{t} << t$, but for small t, the opposite holds. Therefore, the sign of $\frac{\partial R(t;\sigma_R)}{\partial \sigma_R}$ depends on the date of study and could be ambiguous. For renewable resources, that is when $\eta > 0$, the picture is more complicated since beyond the above mentioned composite effect at the date of study, we have to account for the past realizations of this composite effect, *i.e.*, the second integral term in (12). To illustrate this point, we rewrite (12) as

$$\frac{\partial R(t;\sigma_R)}{\partial \sigma_R} = e^{\left(\xi - \frac{\sigma_R^2}{2}\right) + \sigma_R W_t} R_0 + \eta \int_0^t e^{\left(\xi - \frac{\sigma_R^2}{2}\right)(t-s) + \sigma_R W_{t-s}} (-\sigma_R (t-s) + W_{t-s}) ds.$$

Thus, different from the long-run most likely position where $\widehat{R}$ decreases in σ_R, it is possible that in the short run, $\frac{\partial R(t;\sigma_R)}{\partial \sigma_R} > 0$, either due to the fact that the Wiener process W_{t-s} dominates the trend effect $-\sigma_R(t-s)$ or the initial revenue from the renewable resource is sufficiently large, that is, the first term in the above dominates the second term, and stabilizes the influence of of volatility in the short run. Moreover, the parameters of the model, here σ_R, η and ξ, do matter. The same observations can be made of the subsequent impact of resource volatility on the short-term legislative state as it is demonstrated below.

Indeed, from the solution of z, i.e., the second equation in (21), the impact of volatility on the legislative state at any date t can be expressed as:

$$\begin{aligned} \tfrac{\partial z(t;\sigma_R)}{\partial \sigma_R} &= \left(-\frac{2a_1\epsilon}{br}\right) \int_0^t e^{-\sigma_z^2(t-s) + \sigma_z W_{t-s}} \, (1 + \epsilon R(s)) \, \Big[R(s) \, (-\sigma_R s + W_s) \\ &\quad + \eta \int_0^s e^{\left(\xi - \frac{\sigma_R^2}{2}\right)(s-\tau) + \sigma_R W_{s-\tau}} (\sigma_R \tau - W_\tau) d\tau \Big] \, ds \end{aligned} \tag{35}$$

Even with non-renewable resource $\eta = 0$, the overall sign is ambiguous: though the first term on the right hand side of (35), $\left(-\frac{2a_1\epsilon}{br}\right)$, is always negative and the first three terms under the integral are always positive, the sign of the integral is undetermined since the last term, the Brownian motion with drift, $X_s = (-\sigma_R s + W_s)$, could be positive or negative as explained above. With $\eta > 0$, things get even more complicated because the last term in the integral, that can be positive or negative, show up. As in the short term volatility impact on the level of revenues seen just above, the model's parameters do matter. Now all the parameters of the model matter including those in the payoff functions, and the volatility σ_z.

That completes the proof.

B Robustness

Table 5 presents the estimation results of the key determinants of the financial liberalization index using order probit as an estimation method and including only the high oil endowment countries from our main sample. More precise, the Columns 1 to 4 use different constructed measures for resource volatility variable: Hamilton's approach (Columns 1 and 2), no filtering resource volatility (Column 3), HP filter (Column 4). Moreover, Column 5 presents the results we use the alternative definition of resource volatility, that is the standard deviation of the natural resources rents (measured as percentage of GDP) multiplied by the income per capita using the Hamilton's approach. In all the columns, we notice that the resource volatility has a negative impact to liberalization index. Consequently our main hypothesis remains robust.

Table 5: Baseline model: Ordered Probit Estimates:High oil endowmnent countries

	(1) FL_{it}	(2) FL_{it}	(3) FL_{it}	(4) FL_{it}	(5) FL_{it}
FL_{it-1}	17.8366***	18.0968***	18.0594***	18.1044***	18.0256***
	(1.2427)	(1.2195)	(1.1733)	(1.1794)	(1.2028)
Resource volatility Hamilton approach	-0.8197***	-0.8780***			
	(0.3109)	(0.3256)			
$RIGHT_{i,t}$		0.3005*	0.2892*	0.2983*	0.2429
		(0.1605)	(0.1542)	(0.1541)	(0.1633)
$FIRSTYEAR_{i,t}$		-0.0532	-0.0620	-0.0639	-0.0760
		(0.1366)	(0.1295)	(0.1294)	(0.1426)
$CURRENCY_{i,t}$		0.3772**	0.2915*	0.2854*	0.3544*
		(0.1696)	(0.1668)	(0.1670)	(0.1924)
$OPEN_{i,t}$		-0.0322	-0.0488	-0.0495	-0.0516
		(0.0699)	(0.0673)	(0.0674)	(0.0699)
$LEFT_{i,t}$		0.1938	0.2160	0.2153	0.1241
		(0.1508)	(0.1427)	(0.1425)	(0.1438)
$BANK_{i,t}$		-0.1539	-0.1871	-0.1945	-0.2687**
		(0.1263)	(0.1259)	(0.1257)	(0.1326)
$INFLATION_{i,t}$		0.1585	0.3003	0.3024	0.1523
		(0.1998)	(0.1863)	(0.1861)	(0.2310)
Resource volatility No filtered			-0.7134**		
			(0.3335)		
Resource volatility HP				-1.0263**	
				(0.5206)	
Resource volatitlity(					(0.2330)
Log-Likelihood	-981.668	-949.870	-1023.671	-1024.003	-886.344
Sample-Size	484	469	500	500	422

Notes: ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels respectively. Standard Errors are adjusted for country level clustering.