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Natural resource extraction, corruption, and expropriation

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Abstract We develop a formal model that looks at the mutually endogenous determination of foreign direct investments in the extraction of natural resources, at the decision of host governments to expropriate these investments, and at the level of corruption. Higher investments in resource extraction make expropriation more attractive from the perspective of national governments. A low expropriation risk is in turn an important determinant of international investments and is therefore associated with high levels of resources extraction. Moreover, investments in the resource sector also raise corruption. Our theoretical predictions are confirmed by estimations of a simultaneous equation model in which we endogenize expropriation risk, corruption, and resource extraction.

Keywords Natural resources · Expropriation · Foreign direct investment · Institutions

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1 Introduction

Conflicts between foreign investors and domestic governments seem to be particularly frequent and acrimonious in the natural resources sector. Prominent examples of conflicts about revenue sharing and outright expropriation of foreign investments include Repsol in Argentina, Rio Tinto in Guinea, and First Quantum Minerals in the Democratic Republic of Congo, which alone are estimated to have cost some 13bn US-$ (Stevens et al. 2013). These are only recent visible cases illustrating bad relations between investors and host country governments. According to the World Bank (2009), 30 countries have revised oil contracts and taxation systems between 1999 and 2010, and Stevens et al. (2013) mention 25 cases in which increases in taxes and royalties were announced and implemented. These events only exemplify a wave of conflicts before arbitration panels and outright expropriations correlated with high prices for natural resources.

One possible explanation for expropriations in the resource sector is that exploitation of non-renewable natural resources like minerals, oil, and gas typically involves uncertainty and a considerable time-span before extraction can actually begin and returns can be realized. Moreover, given a high capital demand and a lack of own technical expertise, resource rich countries often need to rely on foreign investors to exploit their resource wealth. Since most of these investments are sunk, foreigners are vulnerable to an appropriation of their assets by host countries' governments. If prices for natural resources increase, so do resource rents and conflicts about their distribution.[1] Apart from outright expropriation, conflicts also arise about taxation and how rents are to be shared (Joffé et al. 2009).[2] Another factor is that natural resource-rich countries are often characterized by deficient institutions, meaning high levels of corruption, a lack of rule of law, and non-inclusive political institutions. This is connected with insufficient protection of property rights, and reinforces the risk of expropriation and renegotiation of revenue-sharing agreements (Collier 2010; Deacon 2011; Van der Ploeg 2011).

In this paper, we look at the interaction between expropriation risk, quality of institutions (in particular corruption), and investments of foreign firms in resource-rich countries. While the literature often treats at least one of these dimensions as

[1] Historically, resource-rich countries participated very little in the gains from their resources (Venn 1986; Yergin 1991). It is not surprising that this often led to fierce conflicts about revenue sharing, waves of expropriation, and to the creation of state-owned companies especially after de-colonization (see Bremmer and Johnston 2009; Hendrix and Noland 2014; Hogan et al. 2010, or Tomz and Wright 2010).

[2] Notorious cases in which the terms of contracts and agreements have been changed repeatedly by the host countries' governments are Venezuela (Manzano and Monaldi 2010) or Russia (Gustafson 2012). For an overview of cases, see the papers collected in Hogan and Sturzenegger (2010).

exogenous, we are among the first to explicitly model the interaction between all three factors and to endogenize them.[3]

In our theoretical model, expropriation incentives increase in resource revenues and thereby are related to foreign investments—as higher investments lead to more resource output. Foreign investments in turn are declining in the risk of expropriation and also depend on the expected price of the natural resource. While a higher expected price makes investments more attractive, it also raises the risk of expropriation. Furthermore, foreign investments are declining in the level of corruption, i.e., in the bribes firms have to pay (Wei 2000). We model corruption as an implicit tax on firms' investments that is determined by an independent bureaucracy. The corruption rate in the host country is increasing in resource output and is declining in the costs of corruption, i.e., in the risk of being detected.

We also test the theoretical predictions of our model empirically. Using data on natural resource extraction and institutional quality between 2000 and 2010 for a sample of 46 resource-rich countries, we are able to support our theoretical results. In particular, we estimate a system of equations that endogenizes the risk of expropriation, resource extraction and corruption by employing instruments that are derived from our theoretical model. We apply two estimation techniques: Firstly, the Three-Stage Least Square method (3SLS)—to estimate the structural equations of our model *simultaneously*—and secondly, an instrumental variable estimator based on the Two-Stage Least Square approach (2SLS)—to estimate each equation in the system *individually*. With both methods, we show that the risk of expropriation negatively affects resource extraction, whereas higher resource extraction in turn leads to a higher risk of expropriation. Our findings also support the theoretical hypothesis that resource extraction raises the level of corruption.

Our paper is related to three different strands of literature. Firstly, we build on the huge literature on the relation between foreign direct investment and the risk of expropriation (Cole and English 1991; Eaton and Gersovitz 1983; Thomas and Worrall 1994). Our theoretical and empirical findings for resource extractive industries are consistent with results on FDI in general, for which a negative influence of the risk of expropriation and "bad" institutions such as corruption have been identified (Asiedu 2006; Busse and Hefeker 2007; Hajzler 2012; Hefeker and Kessing 2016). In particular, in countries in which the rule of law is absent, governments are unable to commit credibly not to renegotiate the terms of contracts and not to expropriate. The absence of a binding commitment mechanism leads to less foreign investment and sub-optimally low levels of output.[4] A sizable theoretic literature looks at optimal contracts trading off the risk of expropriation and risk sharing with respect to fluctuations in the price of the underlying resource (e.g., Stroebel and Benthem 2013). In our paper, expropriation occurs in equilibrium due

[3] Azzimonti and Sarte (2007) and Hajzler and Rosborough (2016) also deal with the interaction of all three factors. However, their theoretical mechanisms work differently than ours, and they consider FDI in general while we focus on the resource sector.

[4] Of course, it could also be that firms are not able to commit to their part of the contract and renege on their investment or tax obligations (Guriev et al. 2011). In fact, charging firms with not fulfilling their obligations is often used as an argument for expropriation. We abstract from this complication here and assume that firms always fulfill their part of the contract.

to an insufficient institutional quality. Since the government cannot commit ex ante to sufficient compensation payments, the risk of expropriation cannot be eliminated completely.

Secondly, our results confirm earlier studies showing that the risk of expropriation depends positively on the price of the underlying resource and on the rents it generates (Bohn and Deacon 2000; Guriev et al. 2011; Hajzler 2012). This is particularly obvious if governments receive a fixed compensation for the depletion of a resource and if this compensation does not increase with the resource price. But even if host government and foreign investors alike benefit from higher resource prices and higher revenues, too high profits for foreign firms may lead to public and political resistance in host countries and calls for "fairer" shares of national resources.

Thirdly, our paper is related to the discussion on corruption.[5] Like in Acemoglu and Verdier (1998) and Shleifer and Vishny (1993), we ask how government control and punishment of corruption feed back into corruption and the incentives to invest in a given country. Moreover, as in Ades and di Tella (1999) we look at the incentives to engage in rent seeking, and thus replicate earlier results that show how higher resource revenues and rents lead to more rent seeking, corruption and weaker institutions in general, thus suggesting a vicious circle between resources and bad institutions if institutions are weak in the first place.[6] We endogenize the level of corruption as one particular measure of institutional quality and take others as given. However, unlike other recent papers (e.g. Asiedu et al. 2009 or Biglaiser et al. 2016), we do not ask how policy reforms could be implemented, or how international institutions, such as the International Monetary Fund or conditional bilateral and multilateral aid may influence corruption or the risk of expropriation.

In our theoretical model in Sect. 2, we bring together these literatures in a simultaneous determination of expropriation risk, corruption, and resource extraction. Section 3 provides an empirical test of this interaction, and Sect. 4 concludes.

2 The model

Consider a small open country, endowed with a tradable natural resource. Extraction of the resource requires capital investments provided by a given number of n symmetric international firms.[7] Each firm i invests k_i units of capital. For simplicity, we assume that the extracted quantity Q of the resource increases one to one with the invested capital stock such that $Q = \sum_{i=1}^{n} k_i$ holds. Firms can sell the resource on the world market for a given price p, and this price is unknown to the

[5] For general surveys, see Aidt (2003) or Banerjee et al. (2012).

[6] See Arezki and Brückner (2011), Bhattacharyya and Hodler (2010), Bulte and Damania (2008), Karl (1997), Mohtadi et al. (2016), Mehlum et al. (2006), Ross (2012), or Tsui (2011).

[7] It should be mentioned that we do not consider state owned enterprises that may also be important players in resource extraction in some countries but only look at international private investors and their risk of expropriation.

firms ex ante at the time of their investment decision. Corrupt bureaucrats in the host country appropriate a part of the firms' assets, and thereby impose an iceberg cost on investments of all firms.[8] That is, each firm has to raise $\tau > 1$ units of capital to produce one unit of resources in the host country, whereas $\tau - 1$ units of the investment are appropriated by local bureaucrats. The level of τ therefore stands for the extent of corruption in this country.

After the investment decision has been made by the firms, the resource price realizes, and firms obtain an aggregate gross revenue of pQ. The government in the host country receives βpQ as a predetermined tax payment (or revenue participation). We assume that the tax rate β is given and can not be changed ex post. The government, however, may decide to expropriate the international firms completely.[9] In this case, the government retains the entire revenue pQ but bears fixed expropriation costs f, which may be interpreted as political and economic costs resulting from a loss of reputation, costs of economic sanctions, or of curtailed access to international capital markets in subsequent periods.[10]

The following sequence summarizes the timing of events:

(1) International firms decide on their capital investments k_i and thereby determine aggregate resource output Q.
(2) Bureaucrats decide on τ.
(3) Nature determines the price p according to a distribution function $G(p)$ with density $g(p)$.
(4) The host government decides on expropriation and payoffs are realized.

To determine the equilibrium, we proceed by backward induction. In stage 4, the government decides to expropriate if $pQ - f > \beta pQ$. This inequality determines the following threshold price $\tilde{p}$, above which expropriation occurs:

$$\tilde{p} \equiv \frac{f}{(1 - \beta)Q}. \quad (1)$$

The ex ante probability for firms of being expropriated is $1 - G(\tilde{p})$. This probability declines in the cut-off $\tilde{p}$. According to (1), the cut-off price $\tilde{p}$ declines in the aggregate output level, increases in the expropriation costs f and in the tax rate β, i.e.,

[8] Alternatively, one may assume that bureaucrats appropriate a share of expected revenues, e.g. $(\tau - 1)E[p]Q$ with $E[p]$ denoting the ex ante expected value of the resource price. Our theoretical results would not change qualitatively using this formulation. Since we match the quantities of extracted resources with the quality of institutions in our empirical analysis, we prefer the formulation here.

[9] As some of the examples mentioned in the introduction show, expropriation in the real world is not that clear-cut and may also occur via renegotiation of revenue sharing agreements or through tax hikes. In such a situation, governments expropriate firms only partially, and no clear-cut line can be drawn between expropriation and taxation. We abstract from this complication and focus on full expropriation only in our model.

[10] Alternatively, and without changing the central findings of our model, one could assume a fixed compensation payment f from the expropriating government to the international firm.

$$\frac{\partial \tilde{p}}{\partial Q} < 0, \qquad \frac{\partial \tilde{p}}{\partial f} > 0, \qquad \text{and} \qquad \frac{\partial \tilde{p}}{\partial \beta} > 0. \tag{2}$$

Before the price p is drawn, bureaucrats decide about τ by maximizing their payoff

$$\Pi^B = (\tau - 1)Q - \frac{1}{2}v\tau^2. \tag{3}$$

In this equation, $v > 0$ determines the slope of the (linearly increasing) marginal costs of being corrupt. These can be moral costs (people do not want to be corrupt) or also costs of being detected and punished, as in Acemoglu and Verdier (1998) or Shleifer and Vishny (1993). The first order condition for the bureaucrats determines the corruption rate τ as

$$\tau = \frac{Q}{v}. \tag{4}$$

According to (4), the higher is output the higher is corruption in the host country.

In the first stage of the model, each individual firm decides about its investment level. Firms take into account the implications on aggregate expropriation risk and corruption, as determined by (1) and (4), respectively. For given investment levels k_j of other firms, firm i decides about k_i, knowing that $Q = k_i + \sum_{j \neq i} k_j$, and $\partial Q / \partial k_i = 1$. Firm i maximizes its expected payoff, defined as

$$E\left[\Pi_i^F\right] = (1 - \beta)k_i \int_0^{\tilde{p}} pg(p)dp - \tau c k_i. \tag{5}$$

The variable c denotes the constant unit cost of resource extraction. The first-order condition for this firm is

$$\begin{aligned} (1 - \beta) \int_0^{\tilde{p}} pg(p)dp - \tau c + (1 - \beta)k_i \tilde{p} g(\tilde{p}) \frac{\partial \tilde{p}}{\partial k_i} - c k_i \frac{\partial \tau}{\partial k_i} = 0 \qquad \text{or} \\ (1 - \beta) \int_0^{\tilde{p}} pg(p)dp - \tau c - \frac{f k_i \tilde{p} g(\tilde{p})}{Q^2} - \frac{c k_i}{v} = 0. \end{aligned} \tag{6}$$

For the second order condition, note that the investors's decision problem would be linear in k_i if expropriation risk and level of corruption were exogenous. With $\tilde{p}$ being endogenous, the first term in (6) declines in k_i. A higher investment level lowers the expropriation threshold $\tilde{p}$ and thereby reduces the marginal payoff for firm i. Moreover, the corruption rate τ increases in k_i, which also reduces the marginal payoff. This follows from the second term in (6). These two effects alone would result in an expected payoff that is strictly decreasing in k_i such that the second order condition is satisfied. An increase in k_i also influences the expected payoff via the marginal effects of increasing k_i on $\tilde{p}$ and τ, as captured by the third and the fourth term of (6). While the derivative of the fourth term with respect to k_i is negative, the third term may in general increase or decrease in k_i. For a large enough number of firms, however, the derivative of this term is also negative such that the second order condition is satisfied.[11]

Since all firms are symmetric, $k_i = k_j \equiv k$ in equilibrium and $Q = nk$. Inserting from above, this yields the following expression for the equilibrium level of resource extraction:

$$Q = \frac{v(1-\beta)n}{c(1+n)}\left[\int_0^{\tilde{p}} pg(p)dp - \frac{\tilde{p}^2 g(\tilde{p})}{n}\right]. \tag{7}$$

For a sufficiently large number of firms n, the term in squared brackets in (7) is positive and increases in the cut-off price $\tilde{p}$.[12] In the following, we only consider this large number of firms. The equilibrium level of resource extraction then increases in the cut-off price, in the costs of corruption, in the number of firms, and declines in the tax rate β and extraction costs c, i.e.,

$$\frac{\partial Q}{\partial \tilde{p}} > 0, \quad \frac{\partial Q}{\partial v} > 0, \quad \frac{\partial Q}{\partial n} > 0, \quad \frac{\partial Q}{\partial \beta} < 0, \quad \text{and} \quad \frac{\partial Q}{\partial c} < 0. \tag{8}$$

Equations (1) and (7) jointly determine the equilibrium cut-off price $\tilde{p}^*$ and the volume of investment in resource extraction $Q^* = nk^*$.

Figure 1 depicts this equilibrium. The upward sloping curve (Q) is condition (7) depicting the optimal extraction level as a function of the reservation price. The downward sloping line ($\tilde{p}$) is the reservation price as determined in (1) as a function of the extraction level. The unique equilibrium can be found in the intersection of both lines. Inserting Q^* into (4) yields the corresponding level of corruption in equilibrium. A change in the exogenous variables f, v, β, n and c shifts the Q and/or $\tilde{p}$ lines and thereby changes the equilibrium investment values and the expropriation cut-off, as discussed in the following.

An increase in the compensation payment shifts the $\tilde{p}$-curve upwards and raises the equilibrium cut-off price thereby making expropriation less probable. The equilibrium level of resource extraction and also the rate of corruption increase:

$$\frac{d\tilde{p}^*}{df} > 0, \quad \frac{dQ^*}{df} > 0, \quad \text{and} \quad \frac{d\tau^*}{df} > 0. \tag{9}$$

An increase in the tax rate shifts the $\tilde{p}$-curve upwards and the Q -curve to the left. The critical price above which expropriation becomes attractive increases in the tax rate. The effect of taxation on equilibrium investments (and extraction of natural resources) is not clear. This is because an increase in the tax rate has an ambiguous influence. On the one hand, it lowers net of tax profits and the incentive to invest

[11] Taking the derivative of the third term in (6) yields $-f\tilde{p}g(\tilde{p})/Q^2 - fk_i\frac{\partial(\tilde{p}g(\tilde{p}))}{\partial Q}/Q^2 + 2fk_i\tilde{p}g(\tilde{p})/Q^3$. In equilibrium $k_i = Q/n$, such that the derivative can be written as $-f\tilde{p}g(\tilde{p})/Q^2 - f\frac{\partial(\tilde{p}g(\tilde{p}))}{\partial Q}/(nQ) + 2f\tilde{p}g(\tilde{p})/(nQ^2)$. For a large enough n, the second and third term in this expression become very small such that the whole derivative is negative.

[12] This can be seen by taking the derivative $\partial[\cdot]/\partial\tilde{p} = \tilde{p}g(\tilde{p})\frac{n-2}{n} - \frac{\tilde{p}^2 g'(\tilde{p})}{n}$ in (7). This derivative is positive for $n > 2$ and $g'(\tilde{p}) \leq 0$. For $g'(\tilde{p}) > 0$, the derivative is monotonically increasing in n and positive for $n \to \infty$. The term $[\cdot]$ itself is also monotonically increasing in n and positive for $n \to \infty$.

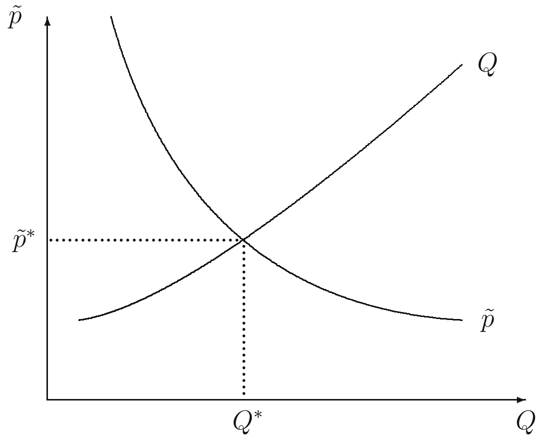

Fig. 1 Equilibrium cut-off price and resource extraction

and extract. On the other hand, it reduces the risk of expropriation and thereby raises the incentive to invest. A similar ambiguous effect holds for the influence on the rate of corruption:

$$\frac{d\tilde{p}^*}{d\beta} > 0, \quad \frac{dQ^*}{d\beta} \lesseqgtr 0, \quad \text{and} \quad \frac{d\tau^*}{d\beta} \lesseqgtr 0. \tag{10}$$

An increase in the corruption costs v shifts the Q-curve to the right, lowers τ^*, $\tilde{p}^*$, and raises Q^*:

$$\frac{d\tilde{p}^*}{dv} < 0, \quad \frac{dQ^*}{dv} > 0, \quad \text{and} \quad \frac{d\tau^*}{dv} < 0. \tag{11}$$

Obviously, higher costs of corruption limit corruption activities and thus make investments in resource extraction more attractive. By raising investments, however, they also increase the incentive to expropriate and thus lower the critical resource price at which expropriation occurs. A decline in the costs of resource extraction raises corruption and the risk of expropriation as resource extraction increases:

$$\frac{d\tilde{p}^*}{dc} > 0, \frac{dQ^*}{dc} < 0, \quad \text{and} \quad \frac{d\tau^*}{dc} < 0. \tag{12}$$

Finally, the Q-curve is also shifted to the right by an increase in the number of investing firms, yielding

$$\frac{d\tilde{p}^*}{dn} < 0, \frac{dQ^*}{dn} > 0, \quad \text{and} \quad \frac{d\tau^*}{dn} > 0. \tag{13}$$

With more firms being active in the country, each firm has a smaller negative influence on institutional conditions in the host country and thereby raises its investments. This results in a higher expropriation risk and more corruption.

3 Empirical implementation

Equations (1), (4), and (7) of the theoretical model establish a joint relationship between resource extraction and institutional quality in resource-rich countries. Note that *each* of these three equations has a *ceteris paribus causal interpretation* explaining the behavior of the three different types of agents in our model: Eq. (1) describes the optimal behavior of the host government and implies that the ex ante expropriation risk increases in the level of resource extraction, whereas it declines in expropriation costs as well as in taxation of resource revenues. According to (7), which results from profit maximization of international firms, a higher expropriation risk lowers investments and thereby the level of resource extraction. Furthermore, this equation postulates a negative influence of extraction costs and taxation and a positive one of the costs of being corrupt on resource extraction. Finally, (4) explains the behavior of corrupt bureaucrats, and according to this equation the extent of corruption rises with the level of resource extraction and declines in the costs of being corrupt.

That is, Eqs. (1), (4), and (7) constitute a simultaneous equations model (SEM), which can be written as

$$exprop\_risk_i = \alpha_0 + \alpha_1 nr\_extract_i + \alpha_2 exprop\_cost_i + \alpha_3 tax_i + \epsilon_{1i}, \tag{14}$$

$$\begin{aligned} nr\_extract_i = \delta_0 + \delta_1 exprop\_risk_i + \delta_2 tax_i + \delta_3 extract\_cost_i \\ + \delta_4 corrupt\_cost_i + \epsilon_{2i}, \end{aligned} \tag{15}$$

$$corrupt_i = \gamma_0 + \gamma_1 nr\_extract_i + \gamma_2 corrupt\_cost_i + \epsilon_{3i}. \tag{16}$$

The subscript i is the country index, *exprop_risk* stands for the expropriation risk and *nr_extract* for the amount of natural resource extraction (Q); *tax* denotes the tax rate β and *exprop_cost*, *extract_cost*, and *corrupt_cost* indicate the different costs of expropriation, extraction, and corruption corresponding to the model parameters f, c, and v; ϵ_j with $j \in (1, 2, 3)$ are the usual equation specific error terms. Our main coefficients of interest with their corresponding model predictions are $\alpha_1 > 0$, $\delta_1 < 0$, and $\gamma_1 > 0$.

The above SEM directly follows the logic of our theoretical model and is therefore used to estimate its predictions. The SEM contains three endogenous variables (*exprop_risk*, *nr_extract*, *corrupt*) and, by assumption, four strictly exogenous ones (the tax rate and the three types of costs). Each of the Eqs. (14)–(16) satisfies the necessary order condition for identification as the number of excluded exogenous variables from the respective equation is at least as large as the number of endogenous variables. That is, assuming strict exogeneity of the tax rate and the three types of costs, the above SEM provides us with internal instrument variables (IVs) that can be used to identify and estimate each of the equations. Specifically, *exprop_cost* can be used as an IV for expropriation risk in Eq. (15), and both extraction and corruption costs can be used to instrument resource extraction in (14). Accordingly, (15) is just identified while Eqs. (14) and (16) are overidentified as from the latter even three exogenous variables are excluded. For the sufficient condition for identification (the rank condition) to hold, the respective IV(s) need(s) to have a significant non-zero effect on the endogenous variables. As shown below, the indicators we have chosen for the model variables do exhibit such a property.

Given that Eqs. (14)–(16) are correctly specified and each of them passes the identification criteria, we apply the common estimation strategy: Since our main interest is in establishing a joint relationship between the endogenous variables, we estimate Eqs. (14)–(16) simultaneously employing the Three-Stage Least Square estimator (3SLS). By taking into account a possible simultaneous correlation between the error terms in the individual equations, the 3SLS estimator leads to more efficient results than the standard 2SLS estimator, which estimates each equation individually. However, if one of the equations in our system is misspecified, the 3SLS approach delivers inconsistent estimates of all system parameters (see, Wooldridge 2010, Ch. 8 and 9). The most critical assumption for the empirical model to be correctly specified in our context is that *all* excluded IVs are indeed strictly exogenous, i.e., not correlated with the error terms ϵ_j. Matching our model variables with real indicators, we can naturally not guarantee that this assumption holds and deal with this fact by testing different indicators and specifications. In addition, we also provide estimation results produced by using the 2SLS estimator. With this method we obtain robust and consistent estimates for a *single* equation provided that IVs excluded from this particular equation are exogenous. Specifically, given that, for instance, the variable *extract_cost* is not correlated with ϵ_j (and significantly affects resource extraction), the 2SLS method provides us with consistent estimates in Eqs. (14) and (16).

3.1 Data and indicators

Resource extraction, extraction costs, government revenue

Searching for indicators and corresponding data for our model parameters, most difficulties arose with respect to the governments' share of total resource revenues (the tax rate). The best source with a sufficient cross-country coverage that we could obtain are two IMF reports on resource-rich countries (IMF 2010, 2012), which contain data on governments' revenues from two types of natural resources, hydrocarbons and minerals, as a share of total fiscal revenues and as a share of GDP. The respective values are averages over 2000 to 2010 and are available for 56 counties, classified as resource-rich.[13]

Data on quantities extracted and extraction costs as well as world market prices for each type of natural resources comes from the World Bank. This data was underlying the so-called *Adjusted Net Saving* dataset, the WB's measure of national wealth, and contains numbers for oil and natural gas extraction as well as for the

[13] According to IMF (2010, 2012) a country is resource-rich if its natural resources contribute to at least 20% of its total fiscal revenues and/or at least 20% of its total exports. Moreover, data in IMF (2012) is averaged from 2006 to 2010 whereas the corresponding data from IMF (2010) is averaged from 2000 to 2007. From both values we calculate a simple unweighted average of the respective indicator.

extraction of 10 different types of minerals.[14] All quantities are available in metric tons (*mt*) except for gas, which is notated in terajoule (*TJ*), and therefore is converted into metric tons using the formula $1\ TJ = 22.8846\ mt$. The extraction costs are unit costs in US-$/*mt*, and they are, naturally, resource specific. For each country, we first calculate average values for total resource revenues—by multiplying prices with respective quantities—as a share of current GDP (in US-$) and relate this variable to the IMF's (2010, 2012) data on government's revenues as a share of GDP to obtain the variable *tax*.

To construct country specific data on the volume of resource extraction (*nr_extract*), extraction costs, and total revenues, we rely on information concerning the type of natural resources provided in IMF (2010, 2012). If, for instance, a country is characterized as a hydrocarbon producer, the volume is the sum of oil and gas extracted, and the corresponding costs are unit costs of producing one ton of oil (according to WB data, oil and gas unit costs are identical).[15] If a country's resource revenues stem from, say, copper extraction (as in the case of Chile), we consider the cost data for copper extraction for this country. In cases in which, according to IMF (2010, 2012), a country produces more than one type of resources or in which the type is simply characterized by "minerals", extraction quantities and revenues are the sum of the respective resources, and extraction costs in these cases are the weighted averages of unit costs using the share of the specific resource output in aggregate resource extraction as the respective weight.

Among 56 countries listed in the IMF reports, Sao Tome and Principe as well as Timor-Leste are not listed in the World Bank's data on resource extraction. Furthermore, for Botswana, Laos, and Suriname we do not have extraction data for the resources which, according to IMF (2010, 2012), contribute to these countries' resource revenues. Finally, Liberia, Mali and Kyrgyz Republic are excluded from our sample as being only gold producers with extremely low output.

Institutional indicators: expropriation risk and corruption

Our main measure of expropriation risk stems from the Heritage Foundation database and is part of its well known Index of Economic Freedom. It measures the degree of property rights protection and also accounts for the likelihood that private property will be expropriated. We label this variable as *exprop_risk*(*hf*) and transform the raw data such that a higher score implies lower protection and accordingly a higher risk of expropriation. Corruption is measured by the widely used "control of corruption" indicator from the World Governance Indicators (WGI) dataset. This is a composite indicator that aggregates different data sources and measures "the extent to which public power is exercised for private gain, including both petty and grand forms of corruption" (Kaufmann et al. 2010, p. 4). Again, the original data is transformed with high values indicating high levels of corruption.

To test the sensitivity of our results with respect to the choice of these indicators, we also rely on an alternative data source, the *International Country Risk Guide*

[14] The minerals included are bauxite, copper, lead, nickel, phosphate, tin, zinc, iron, gold, and silver.

[15] These costs are still country-specific primarily due to the countries' geographical characteristics.

(ICRG) by the PRS (2012). The ICRG database contains both indicators: a measure of the expropriation risk, namely "investment profile" assessing the investment risk resulting from direct or indirect forms of expropriation, and a measure of corruption. The corresponding variables are labeled as $exprop\_risk(icrg)$ and $corruption(icrg)$ and indicate with higher values an inferior institutional environment.

Expropriation and corruption costs

To account for expropriation costs, we assume that these are higher in economically open countries. Policies aimed at facilitating foreign investments and trade, promoting foreign competition, and transferring technology can also be seen as measures to reduce political risks for foreign investors and trading partners. A government of a country that is relatively strongly integrated in the world economy is less likely to violate foreign agents' property rights thereby counteracting its own open economy policies.[16] We employ an index of de jure (instead of de facto) openness to limit potential endogeneity problems. To obtain a broad index of de jure openness, we combine three different indicators that measure the extent of formal and legal regulations of international trade and capital movements: (i) the so-called *kaopen* index developed by Chinn and Ito (2008) that builds on data of the IMF's Annual Report on Exchange Arrangements and Exchange Restriction; (ii) the "restriction" component of the KOF Index of Globalization by Dreher (2006) that comprises data on "hidden import barriers", "mean tariff rates", "taxes on international trade" and "capital account restrictions"; (iii) the "trade freedom" component of the Heritage Foundation's Index of Economic Freedom, which is based on trade-weighted average tariff and non-tariff barriers. We standardize the original indices and take the mean.[17]

The validity of *openness* as a measure for the risk of expropriation can be theoretically justified and is also supported by our empirical results as shown below (see Table 1). However, whether it also satisfies the exclusion restriction can certainly be questioned. It may be reasonable to assume that *openness* also directly affects resource extraction and not only through the risk of expropriation. In this case, the assumption $E(\epsilon_2|openness) = 0$ would be violated resulting in inconsistent estimates of all model parameters in the 3SLS approach. To account for this potential problem, we also consider an alternative model specification that includes the "executive constraint" (*exconst*) indicator from the Polity IV dataset as a measure for expropriation costs. This indicator has been used, for example, in Guriev et al. (2011) and it captures the extent of institutionalized constraints on the decision-making powers of chief executives (Marshall et al. 2013).

[16] Theoretical works supporting this line of argument include, e.g., Bartolini and Drazen (1997), Narvaz (2013). Alzer and Dadasov (2013) empirically show that de jure financial openness improves institution quality by reducing expropriation risks, and Levchenko (2013) shows the positive effect of trade integration for institutional quality.

[17] We construct an aggregate index (instead of relying on a single one) in order to reduce measurement errors which might be associated with individual indices and, in particular, to obtain a comprehensive indicator that includes both trade and financial openness.

Table 1 Instruments for institutions and resource extraction

	exprop_risk(hf)	nr_extract	Corruption
Tax	1.948	−0.284	−0.021
	(0.247)	(0.324)	(0.759)
Openness	−7.050**	−0.106	−0.254***
	(0.024)	(0.737)	(0.004)
extract_cost	−3.417**	−1.108***	−0.101
	(0.043)	(0.000)	(0.169)
Transparency	−1.241	0.318*	−0.070
	(0.407)	(0.066)	(0.216)
gpdpc (t−1)	−6.359***	0.613**	−0.315***
	(0.003)	(0.039)	(0.000)
Constant	122.199***	16.763***	3.579***
	(0.000)	(0.000)	(0.000)
N	46	46	46
Adj.R-sq.	0.624	0.520	0.683

First stage results; OLS estimations. p values in parentheses * $p<0.1$; ** $p<0.05$; *** $p<0.01$. By country clustered standard errors are used

To account for the costs of corruption from the perspective of bureaucrats, remember that, in the theoretical model, these costs can result from being detected and punished if agents behave corruptly. In this context, it seems reasonable to use an indicator that captures the degree of transparency in a society. To do this, we use a specific and objective *transparency index* created by Islam (2006). It is based on the availability of information and data on various key socio-economic indicators in different international and national statistics such as the World Development Indicators, the International Financial Statistics, national official websites of the governments, central banks, statistical agencies, etc. Islam (2006) also shows that this index significantly and negatively affects national levels of corruption.[18]

Given data availability, we are left with a sample of 46 countries for which we have all the necessary variables for both natural resources and institutional characteristics. As presented in Table 9, nine of them are high-income countries according to the World Bank classification while the remaining can be grouped to the class of middle- and low-income countries. 36 countries are hydrocarbon producers and the rest generate resource revenues from the extraction of various minerals.

To account for differences in the level of economic development, we additionally include the value of real per capita GDP ($gdppc(t-1)$) in Eqs. (14) and (16) using data from the World Development Indicators. We use its averaged value from the previous decade (1990–2000) to avoid the obvious problem of reverse causality. Furthermore, we take the natural logarithm of all variables—except the institutional indicators—to smooth the variation among them. Table 8 presents summary statistics of all variables used in this paper, and Table 10 gives a detailed variable description with the respective sources.

[18] The influence of access to information and more generally of press and media freedom on corruption is widely documented in the literature (see, e.g., DiRienzo et al. 2007; Brunetti and Weder 2003; Kalenborn and Lessmann 2013).

3.2 Results

A first glance at the data makes clear why a simple analysis of the relationship between expropriation risk, measured by $exprop\_risk(hf)$, and natural resource extraction may be misleading. As shown by Fig. 2, the unconditional relationship between both variables suggests no systematic correlation between them in our sample. However, as our results below show, controlling for other factors, which potentially may influence this relationship, and especially taking into account the endogeneity of *both* variables, helps to establish a significant *mutual* relationship between expropriation risk and resource extraction that has been derived in the theoretical part and is illustrated in Fig. 1.

Table 1 first presents the results obtained from the OLS regressions that correspond to the first-stage estimation outcomes with the two alternative methods 3SLS and 2SLS. Our three endogenous variables are regressed here on all (presumably) exogenous variables of the model. The results show the statistical relevance of our instruments. Most notably, *openness*—as a proxy for expropriation costs—is significantly and negatively related to expropriation risk, and extraction costs significantly affect the level of resource extraction. In Table 2, the SEM (14)–(16) is estimated simultaneously with the 3SLS estimator. Column (1) presents the results obtained by estimating the final stage of equation (14) and using the instrumented values for resource extraction; accordingly, the next columns correspond to equations (15) and (16). The results verify our general theoretical predictions: A higher volume of resource extraction is significantly associated with a higher expropriation risk. A low degree of expropriation risk in turn raises the extraction volume as predicted by the optimal investment decision.[19] Finally, the extent of corruption increases as resource extraction rises.

Comparing the influence of the exogenous variables with the predictions of our model, we obtain the following evidence: *openness* remains significant in affecting expropriation risk, while the predicted negative relationship between the governments' share in resource revenues (*tax*) and expropriation risk cannot be verified. Furthermore, the influence of *tax* on the level of resource extraction is not statistically significant. One reason for this could be that taxation is not fully exogenous. Instead, it could be that the tax may increase in firms' revenues, biasing our estimate downwards. Moreover, increases in the tax rate could also be seen as some from of (partial) expropriation, and would therefore be correlated with expropriation risk.[20]

As expected, we find a positive relationship between *transparency*—our indicator for corruption costs—and the volume of resource extraction, and it has a direct negative effect on the corruption index. Additionally, the results confirm the view

[19] Note that our theoretical model focuses on the investment decision of foreign investors whereas the data on the extraction volume considers resource extraction by domestic and foreign investors. Since parts of declining foreign investments can be substituted by domestic activities of the state or private investors, the relationship between foreign investment and expropriation risk may be even tighter than the one suggested by our results.

[20] We owe this observation to a referee.

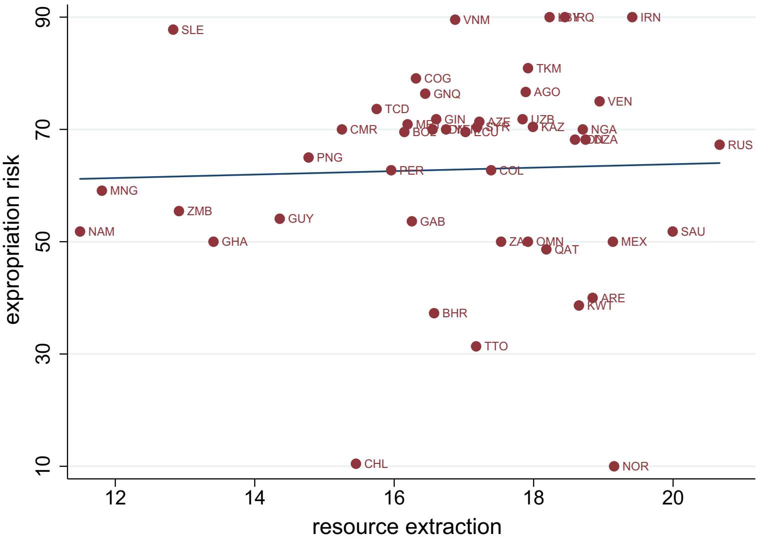

Fig. 2 Expropriation risk and resource extraction

Table 2 Institutions and resource extraction: simultaneous estimations

	exprop_risk(hf)	nr_extract	Corruption
Tax	2.862	−0.191	
	(0.129)	(0.567)	
nr_extract	3.293**		0.150***
	(0.013)		(0.002)
exprop_risk(hf)		−0.047**	
		(0.030)	
Openness	−5.169**		
	(0.011)		
extract_cost		−1.376***	
		(0.000)	
Transparency		0.352*	−0.105**
		(0.086)	(0.017)
gpdpc	−10.152***		−0.518***
	(0.000)		(0.000)
Constant	71.358*	24.867***	2.180***
	(0.085)	(0.000)	(0.001)
N	46	46	46
R-sq.	0.665	0.383	0.713

Final stage of 3SLS estimations. *p* values in parentheses
* $p<0.1$; ** $p<0.05$; *** $p<0.01$

that a higher level of economic development is associated with better institutional quality in terms of lower expropriation risk and corruption.

In Table 3 we re-estimate equations (14)–(16) using the 2SLS estimator, i.e., estimating each equation separately. As discussed above, the approach allows us to

Table 3 Institutions and resource extraction: separate estimations

	exprop_risk(hf)	nr_extract	Corruption
Tax	2.867*	−0.184	
	(0.079)	(0.512)	
nr_extract	2.554**		0.153***
	(0.048)		(0.000)
exprop_risk(hf)		−0.051**	
		(0.019)	
Openness	−8.297***		
	(0.002)		
extract_cost		−1.406***	
		(0.000)	
Transparency		0.234	−0.147***
		(0.285)	(0.006)
gpdpc(t − 1)	−8.116***		−0.500***
	(0.000)		(0.000)
Constant	68.825***	25.723***	2.182***
	(0.000)	(0.000)	(0.001)
N	46	46	46
Adj.R-squared	0.650	0.307	0.697
p value Hansen's J	0.134	0.228	0.052

Final stage of 2SLS estimations. p values in parentheses
* $p<0.1$, ** $p<0.05$, *** $p<0.01$. By country clustered standard errors are used

examine the estimates in each equation independently from the estimation outcome in the two other equations of the model. For example, since *extraction_cost* is excluded from (14) and (16) and given these equations are specified correctly, we can at least claim that the estimates of the coefficient of *nr_extract* in columns (1) and (3) are consistent and robust. As with 3SLS, the results show that higher natural resource extraction is associated with both higher expropriation risk and corruption. Assuming further that *openness* is indeed exogenous to resource extraction, we can also confirm the reverse relationship between expropriation risk and resource extraction in column (2).

In Table 4 we return to the simultaneous approach and report 3SLS estimation results using alternative model specifications. Firstly, we add a measure "executive constraint"(*exconst*) as an additional proxy for expropriation costs in Eq. (14). Secondly, to control for potential differences in resource extraction between hydrocarbon and minerals producers, a dummy variable (*hydrocarbon*) that takes the value of 1 for oil/gas producers is additionally included in Eq. (15). Note that we present here only the final stage regression results. Corresponding OLS results and those obtained from the 2SLS are delegated to the Appendix (see Tables 6, 7). Again, our main findings remain unchanged. Most importantly, the reciprocal relationship between resource extraction and expropriation risk can be established. Furthermore, resource extraction significantly influences corruption.

Finally, in Table 5 we repeat our baseline 3SLS regressions using an alternative source for the institutional data, the *ICRG* indicators for expropriation risk and

Table 4 Institutions and resource extraction: alternative specifications

	exprop_risk(hf)	nr_extract	Corruption
Tax	2.958*	−0.183	
	(0.091)	(0.503)	
nr_extract	2.440**		0.173***
	(0.030)		(0.000)
exprop_risk(hf)		−0.031*	
		(0.062)	
Openness	−3.633*		
	(0.051)		
extract_cost		−0.693***	
		(0.002)	
Transparency		0.357**	−0.133***
		(0.032)	(0.004)
Exconst	−1.942***		
	(0.008)		
Hydrocarbon		2.656***	
		(0.000)	
gpdpc(t−1)	−10.120***		−0.518***
	(0.000)		(0.000)
Constant	92.533***	18.586***	1.903***
	(0.653)	(0.000)	(0.002)
N	46	46	46
R-sq.	0.709	0.587	0.710

Final stage of 3SLS estimations. *p* values in parentheses
* $p<0.1$; ** $p<0.05$; *** $p<0.01$

corruption. Compared to the results in Table 2, there is only one qualitative change: the positive relationship between resource extraction and expropriation risk in column (1) is no longer statistically significant at conventional levels. All our other findings still hold.

Summarizing, we can state that the empirical results generally confirm the predicted relationship between ex ante expropriation risk and resource extraction, which has been derived from the theoretical model: Higher resource extraction makes expropriation more attractive from the perspective of national governments, resulting in a higher expropriation risk. However, a low expropriation risk in turn is seen as an important factor for international resource producers and is therefore associated with a high level of extraction. With regard to corruption, we also obtain a negative influence on the level of natural resource extraction.

4 Conclusion

In this paper, we have looked at and endogenized three interrelated variables: extraction activities of foreign investors in a country's natural resource sector, the level of corruption in this country, and the government's decision to expropriate

Table 5 ICRG institutions and resource extraction

	exprop_risk(icrg)	nr_extract	Corruption(icrg)
Tax	−0.352	−0.024	
	(0.363)	(0.965)	
nr_extract	0.226		0.114*
	(0.183)		(0.086)
exprop_risk(icrg)		−0.386**	
		(0.037)	
Openness	−0.471*		
	(0.074)		
extraction_cost		−1.243***	
		(0.000)	
Transparency		0.430***	−0.158**
		(0.008)	(0.011)
gpdpc	−0.957***		−0.244***
	(0.000)		(0.002)
Constant	11.307***	23.123***	4.378*
	(0.000)	(0.000)	(0.072)
N	42	42	42
R-sq.	0.602	0.487	0.317

Final stage of 3SLS estimations. p values in parentheses * $p<0.1$; ** $p<0.05$; *** $p<0.01$

foreign investments. Our theoretical analysis shows that resource extraction is a decreasing function of taxation, corruption and the perceived risk of expropriation. The risk of expropriation in turn increases in the output level, and declines in expropriation costs and taxation. The level of corruption is determined by a bureaucracy that is independent from the government and depends on natural resources output and the costs of corruption. One implication of this finding is that by controlling bureaucrats more intensively and thereby making corruption more "expensive", the government of the host country can push back corruption and increase investment and resource extraction.

Our main contribution to the debate on the relationship between institutional quality and natural resources is to endogenize all relevant variables in one approach, and to test the resulting system of equations for a sample of resource-rich countries. Our theory and evidence support the view that foreign investment, risk of expropriation, and corruption are mutually interdependent and should be considered jointly. This also implies that policy measures to raise a countries' attractiveness for foreign investment, to improve property rights, or to reduce corruption should take this interdependence into account. In particular, one should be aware that a reduction of expropriation risk can increase investment and thus extraction, but at the same time may also stimulate corruption. It is therefore important that policy reform proposals look at all institutional dimensions simultaneously.

5 Appendix

See Tables 6, 7, 8, 9 and 10.

Table 6 Additional instruments for institutions and resource extraction

	exprop_risk(hf)	nr_extract	Corruption
Tax	2.244	−0.281	−0.018
	(0.195)	(0.254)	(0.798)
Openness	−6.220**	−0.033	−0.231***
	(0.029)	(0.907)	(0.007)
gpdpc	−7.332***	0.458**	−0.358***
	(0.001)	(0.026)	(0.000)
Exconst	−1.845	−0.014	−0.018
	(0.122)	(0.903)	(0.653)
extract_cost	−1.181	−0.656**	0.019
	(0.485)	(0.035)	(0.764)
Transparency	0.076	0.356**	−0.051
	(0.962)	(0.037)	(0.335)
Hydrocarbon	4.824	2.109**	0.519***
	(0.262)	(0.017)	(0.001)
Consstant	116.313***	14.201***	2.948***
	(0.000)	(0.000)	(0.000)
N	46	46	46
Adj.R-squared	0.644	0.615	0.722

First stage results; OLS estimations. p values in parentheses * $p<0.1$; ** $p<0.05$; *** $p<0.01$. By country clustered standard errors are used

Table 7 Institutions and resource extraction: alternative specifications

	exprop_risk(hf)	nr_extract	Corruption
nr_extract	1.831		0.175***
	(0.130)		(0.000)
tax	2.781**	−0.200	
	(0.048)	(0.400)	
Openness	−6.313***		
	(0.004)		
gpdpc(t−1)	−8.260***		−0.515***
	(0.000)		(0.000)
Exconst	−2.089***		
	(0.008)		
exprop_risk(hf)		−0.037**	
		(0.011)	
extract_cost		−0.788***	
		(0.002)	

Table 7 continued

	exprop_risk(hf)	nr_extract	Corruption
Hydrocarbon		2.499***	
		(0.001)	
Transparency		0.299	−0.149***
		(0.105)	(0.004)
Constant	90.280***	20.052***	1.927***
	(0.000)	(0.000)	(0.001)
N	46	46	46
Adj.R-squared	0.684	0.519	0.689
p value Hansen's J	0.908	0.526	0.108

Final stage of 2SLS estimations. *p* values in parentheses * $p<0.1$; ** $p<0.05$; *** $p<0.01$. By country clustered standard errors are used

Table 8 Summary statistics

Variable	Obs	Mean	SD	Min.	Max.
exprop_risk(hf)	46	62.854	18.373	10	90
nr_extract	46	16.902	2.07	11.494	20.667
Corruption	46	0.487	0.783	−2.065	1.531
Tax	46	3.401	0.807	0.358	4.478
Openness	46	−0.045	0.930	−1.804	1.595
extraction_cost	46	4.267	1.195	2.608	7.498
Transparency	46	4.25	1.388	1.5	7
Exconst	46	3.737	2.03	1	7
Hydrocarbon	46	0.783	0.417	0	1
gdppc(t−1)	46	7.302	1.303	5.286	10.368
exprop_risk(icrg)	42	6.748	1.968	3.815	11.216
corruption (icrg)	42	3.791	0.695	1	5

Table 9 List of countries

Country	Resource type	Country	Resource type
High income			
Bahrain	Hydrocarbons	Qatar	Hydrocarbons
Equatorial Guinea	Hydrocarbons	Saudi Arabia	Hydrocarbons
Kuwait	Hydrocarbons	Trinidad and Tobago	Hydrocarbons
Norway	Hydrocarbons	United Arab Emirates	Hydrocarbons
Oman	Hydrocarbons		
Low and middle income			
Algeria	Hydrocarbons		
Angola	Hydrocarbons	Mauritania	Minerals, hydrocarbons

Table 9 continued

Country	Resource type	Country	Resource type
Azerbaijan	Hydrocarbons	Mexico	Hydrocarbons
Bolivia	Gas	Mongolia	Copper
Cameroon	Hydrocarbons	Namibia	Minerals
Chad	Hydrocarbons	Nigeria	Hydrocarbons
Chile	Copper	Papua New Guinea	Hydrocarbons, copper, gold
Colombia	Hydrocarbons	Peru	Minerals
Congo	Hydrocarbons	Russia	Hydrocarbons
Ecuador	Hydrocarbons	Sierra Leone	Minerals
Gabon	Hydrocarbons	South Africa	Minerals
Ghana	Minerals	Sudan	Hydrocarbons
Guinea	Mining	Syria	Hydrocarbons
Guyana	Gold, bauxite	Turkmenistan	Hydrocarbons
Indonesia	Hydrocarbons	Uzbekistan	Hydrocarbons
Iran	Hydrocarbons	Venezuela	Hydrocarbons
Iraq	Hydrocarbons	Vietnam	Hydrocarbons
Kazakhstan	Hydrocarbons	Yemen	Hydrocarbons
Libya	Hydrocarbons	Zambia	Copper

Table 10 Variable description

Variable	Description & Source
Corruption	Reversed value of the index on *control of corruption* that captures "perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as capture of the state by elites and private interests". The original index is constructed by Kaufmann et al. (2010); the reversed values range between −2.5 (high control, i.e., low corruption) and +2.5 (low/high control/corruption). *Source*: World Bank (2013a)
Corruption(icrg)	"Assessment of corruption within the political system. The measure captures financial corruption in the form of demands for special payments and bribes connected with import and export licenses, exchange controls, tax assessments, police protection. It also takes into account actual or potential corruption in the form of excessive patronage, nepotism, job reservations, and suspiciously close ties between politics and business." The reversed index ranges between 1 and 6 with maximum points indicating high levels of corruption. *Source*: Political Risk Services Group (2012)
Exconst	"Extent of institutionalized constraints on the decision making powers of chief executives, whether individual or collective" with a scale ranging from 1 (low constraints) to 7 (high constraints). *Source*: Marshall et al. (2013)
exprop_risk (hf)	An indicator of expropriation risk measured by the *property right* index of the Heritage Foundation. The original index scores the degree to which a country's laws protect private property rights and the degree to which its government enforces those laws. It also accounts for the possibility that private property will be expropriated. We use the reversed range of the scores from 0 and 100, where 100 represents the minimum/maximum degree of protection of property rights/risk of expropriation. *Source*: Heritage Foundation (2013)

Table 10 continued

Variable	Description & Source
exprop_risk (icrg)	Another indicator of expropriation risk measured by the index on *investment profile* which is "an assessment of factors affecting the risk to investment that are not covered by other political, economic and financial risk components. The risk rating assigned is the sum of three equally weighted subcomponents: contract viability/expropriation, profits repatriation, payment delays." The reversed index ranges between 1 and 12 with a maximum score indicating high risk. *Source*: Political Risk Services Group (2012)
extract_cost	Natural logarithm of unit costs (in metric tons) of natural resource production. Production costs depend on the resource type. If the type is hydrocarbon, unit costs of producing one ton of oil are used. In the case in which a country produces more than one type of resources, weighted averaged unit costs are calculated using the share of the specific resource output in aggregate resource production as the respective weights. *Source*: Own calculation. Data for resource production and unit costs are from the World Bank, Wealth of Nations Database. Information on the type of resources stems from IMF (2010, 2012)
gpdpc(t−1)	Natural logarithm of GDP per capita at 2005 constant prices, average values over 1990–2000. *Source*: Own calculation; World Bank (2013b)
Hydrocarbon	Dummy that takes a value of 1 if a country is hydrocarbon (i.e., oil and/or gas) producer. *Source*: Own calculation; information on type of resources stems from IMF (2010, 2012)
nr_extract	Natural logarithm of natural resource extraction quantities in metric tons (mt). Depending on the country-specific type of natural resources, the volume is either the sum of oil and gas production for hydrocarbon producers or the corresponding value for specific minerals. In the case that a country produces more than one type of resources or the type is simply characterized by "minerals", production quantities are the sum of the respective resources. *Source*: Own calculation. The data for resource production is from the World Bank's Wealth of Nations database. Information on type of resources stems from IMF (2010, 2012)
Openness	An indicator of de jure economic openness of an economy. It combines the values of the *kaopen* index created by Chinn and Ito (2008), the *restriction* sub-component of the KOF Index of Globalization by Dreher (2006) and the *trade freedom* index by the Heritage Foundation (2013). The original values of the three indices are standardized and the unweighted mean is then taken. High values imply high degrees of openness. *Source*: Own calculation
Tax	Natural logarithm of the ratio of government's resource revenues to total resource revenues. *Source*: Own calculation. Data on government's resource revenues as a share of GDP stems from IMF (2010, 2012). Values for total resource revenues are calculated by multiplying the resource prices with the respective quantities. See description of the variable *nr_extract*. Data on GDP at current prices stems from World Bank (2013b)
Transparency	*T1 index* of transparency created by Islam (2006), which is based on the availability of a list of economic data in international and national official sources and a country's regulation regarding Freedom of Information Act. The index ranges between 1 and 7 (most transparent). *Source*: Islam (2006)

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