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Environmental Aspects of Resource Extraction Contracts

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Abstract

This paper analyzes resource partnerships and their influence on the environmental quality in a resource-rich country by introducing incomplete contracts, imperfect property rights protection, and a lack of valuation for the environment by the government in the South. Employing numerical simulations, I determine the equilibrium extraction rate, the applied extraction technology, and the environmental quality in dependence of the state of democracy in the resource-rich country. In contrast to what one might expect, under certain circumstances it can be environmentally beneficial to have incomplete contracts that induce the utilization of a suboptimal technology for resource extraction. Further, reducing the holdup problem by shifting bargaining power to the North, is only desirable if the environmental quality increases with a better extraction technology.

JEL classification: F18, Q37, Q56
Keywords: Resource Extraction, Environment, North-South Trade

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1 Introduction

Natural resources, such as rare earth elements or platinum, are an essential input in the production of high technology goods. Firms in industrialized countries (from now on: the North) producing these high-tech products depend on imports of natural resources due to highly limited domestic reserves. The North relies heavily on the supply from resource-rich countries, which can often be classified as developing or emerging countries (the South). The South, for its part, lacks appropriate technology needed for the extraction of natural resources which could be provided by the North. A resource partnership presents one solution to this bilateral problem. Within a resource partnership, a multinational corporation and the government from a resource-rich country negotiate a resource extraction contract. In this contract the partners agree on extracting natural resources from the South's territory by applying an extraction technology which is provided by the North. The extracted resources can be used by the North as an input in the production of high-technology goods. Hence, a resource extraction contract[1] seems to be a win-win situation for both partners. One example of such a partnership is the engagement of the AngloAmerican corporation in Chile with regard to the extraction of copper. The multinational contributes the extraction technology to this co-operation and also exhibits the mining and final processing of the natural resource (AngloAmerican, 2013). Through taxation the Chilean government receives a share of the revenue generated by AngloAmerican.

The process of resource extraction is, however, polluting and detrimental to the environment in the resource-rich country. The extent of pollution caused by extracting resources depends on the quality of the technological equipment used for the extraction process (from now on: extraction technology or simply technology) and the amount of resources extracted. The provision of the optimal extraction technology cannot be guaranteed due to the incomplete nature of resource extraction contracts, and consequently the non-cooperative determination of the extraction technology by the North. A technology producing less waste or relying on less chemicals during the extraction process is referred to as being "cleaner". The cleaner the quality of the extraction technology, the lesser the harm caused by the extraction process on the local environment. However, in correspondence with the Porter hypothesis (Porter, 1991; Porter and van der Linde, 1995) I assume that applying a better extraction technology does not only mean reducing the pollution caused by resource extraction but also enhancing cost efficiency in

[1] The terms "resource extraction contract" and "resource partnership" are used interchangeably in this analysis.

the extraction process.

I apply a game-theoretic approach to show how forming a resource partnership affects the environment in the resource-rich country. Within this setting, the quality of the extraction technology applied as well as the amount of resources extracted are determined. I identify the conditions under which an improvement in the extraction technology is beneficial or harmful for the environment. I point out two externalities that influence the North's decision on the extraction technology it wants to provide. In particular, for one, the resource partnership is based on a contract which cannot be fully enforced ex post due to its incomplete nature.[2] Since the investment undertaken by the North is contract-specific, a holdup problem as defined by Williamson (1985) and Grossmann and Hart (1986) arises. Consequently, a lack of incentives results for the North regarding the investment in the optimal extraction technology. As a second issue, the model developed in this paper accounts for the lack of environmental consciousness in developing countries. This limited degree of environmental awareness by the ruling government results in a negligence towards the environmental quality when negotiating on the resource extraction contract. The activities of Royal Dutch Shell in Nigeria, for example, demonstrate the consequences of a lack in environmental awareness of a resource-rich country in combination with resource extraction conducted by a multinational company. The oil recovery in the Niger Delta has caused substantial ecological damage to the vulnerable ecosystem, for example through oil spills, drilling sludge, and road construction (The Guardian, 2013). While the damage is neglected by the government, the consequences for the rural population and the environment are dramatic. I investigate upon the impact of both externalities on the provision of the extraction technology, the consequences for the resource extraction rate, and the resulting level of environmental quality in the resource-rich country.

The degree of democratization in the South influences to some extent both externalities. I therefore define democracy, or the degree of democratization, to mirror the quality of property rights protection as well as the degree of environmental awareness of the government. This assumption about the two dimensions of democracy is supported by two areas of research. In the first approach, a positive correlation of democracy and property rights protection has been theoretically suggested and empirically confirmed (Knutsen, 2011).[3]

[2]Examples, such as the Ecuadorean President Rafael Correa raising the share of oil windfall taxes from 50% to 99% in 2007, portray the risk of expropriation for foreign investors in the extractive sector in developing countries (The Economist, 2013).

[3]Additional work on the positive correlation between democracy and property rights can, e.g., be found in North and Weingast (1989), Adsera et al. (2000), Leblang (1996), and Clague et al. (1996).

Li (2009) shows that the risk of expropriation is lower in democracies than in autocracies. Correspondingly, I assume that a more advanced democratic state of the South implies a higher quality in property rights protection and therewith a reduction in the risk of expropriation. According to the second approach, the degree of environmental consciousness in a country depends to a large degree on the state of its democratic institutions. Based on empirical findings of, among others, Arvin and Lew (2011), I assume that regimes of less developed countries have a lower valuation of the environment. Hence, a less democratic government puts less emphasis on the preservation of the local environment when negotiating upon the terms and conditions of a resource extraction contract.[4] In the following, the equilibrium quality of the extraction technology, the amount of resources extracted, and the resulting environmental quality are therefore determined in dependence on the condition of the democratic institutions in the South. Throughout this paper, I refer to (the state or level of) democracy or (the condition of) democratic institutions to characterize the state of the government in the resource-rich country with regard to both externalities. The process of democratization describes an improvement in this state.

The research question about the environmental impact of a resource partnership is answered in two sequences. First, how does a chosen extraction technology affect the environment? And second, which technological quality is applied in a resource partnership and what are the consequences for the environment in dependence on the democratic condition of the host country? Two main results can be emphasized. For one, an improvement in the quality of the extraction technology does not necessarily lead to a better quality of the environment. In analogy to Smulders and Di Maria (2012), I classify an extraction technology whose improvement leads to a higher degree of environmental destruction as "brown". If the improvement is environmentally beneficial, I consider the technology as "green". For the second finding, two channels through which democracy in the South has an impact on the North's decision on the quality of the extraction technology are defined. It is shown that no clear-cut relationship between the degree of democratization and the quality of the applied extraction technology can be found. Correspondingly, the impact of democratization on the South's environmental state is also ambiguous. Finally, a numerical simulation substantiates the analytical results.

This paper relates to three different strands of literature. The literature on resource extraction contracts analyzes the formation of international co-

[4]Similar findings are presented, a.o., in Bhattarai and Hammig (2004) and Fredriksson and Wollscheid (2007).

operations for the joint exploitation of natural resources. The focus here lies on the North's investment decision in light of the risk of expropriation due to an insecure investment environment in resource-rich countries (see e.g. Di Corato 2013, Engel and Fischer 2008, and Hajzler 2014). Hajzler (2012) identifies the extractive sector as being especially prone to expropriation. Deacon and Bohn (2000) reflect upon the relevance of political instability causing insecure investment in the extractive sector. The impact of democracy on foreign direct investment (FDI) is debated in the literature. On the one hand, a.o., Jensen (2003), Li (2009) and North and Weingast (1989) argue that due to strengthened property rights protection, countries with democratic institutions attract FDI. I adopt this approach due to my focus on the property rights aspect of democracy. On the other hand, Li and Resnick (2003) show that when correcting for the positive impact of property rights protection, democratic institutions hinder the investment of multinational corporations. It is argued that multinational enterprises can better exploit the profits from their investment if an autocratic regime rules the host country. Asiedu and Lien (2011) find that for countries with an exceptionally high share of exports from the extractive industries democracy may reduce investments. To my knowledge, the aspect of environmental destruction has neither been considered in the research on resource extraction contracts nor in the research on the relationship between democracy and FDI in the extractive sector. In the field of environmental economics, Smulders and Di Maria (2012) classify abatement technologies into green versus brown technologies. I apply this concept to the setting of resource partnerships and determine the quality of the extraction technology applied in dependence to the state of democracy in the resource-rich country.

In the following, I start off by introducing the model that describes a resource partnership and presents the equilibrium level of technological quality provided by the North. The impacts of an improvement in the technology as well as of the process of democratization on the environmental quality are described in section 3. I distinguish three channels through which democratization in the South influences the environmental quality. The numerical simulations presented in the subsequent section 4 substantiate the analytical findings. Finally, the last section sums up the results.

2 The Model

The environmental quality E in a resource-rich country is a function of the quantity of resources extracted R and the quality of the technology T applied in the extraction process, i.e. $E = f(R, T)$. I consider a resource partnership within which both of these variables are determined. This partnership is modeled as a two-stage game with two actors $i \in \{N, S\}$: A firm in an industrialized country, the North (N), which provides the extraction technology and produces high-technology goods on the basis of natural resources, and a developing country, the South (S), which is rich in natural resources. In the first stage of the game, the North decides upon its provision of a resource extraction technology of quality T. For the construction of this technology, sunk investment costs of $s(T) = \frac{1}{2}\chi T^2$ occur, which are solely born by the North. It is assumed that the marginal investment costs are increasing with the quality of the extraction technology. In the second stage, the North and the South form a cooperation and decide jointly on the extraction of the resource R. The Nash-bargaining solution determines the amount of resources to extract, such that both parties' surplus from entering the partnership is maximized. The respective utility levels in case of a failure of the partnership give the outside options and therewith the bargaining power of both partners.

During the extraction process two types of costs emerge whose extent depends on the provided extraction technology: the extraction costs $a(T)$ and the environmental damage $d(T)$ per extracted resource unit. It is assumed that the extraction costs $a(T)$ are born by the North while the South is affected by the environmental damage $d(T)$.[5] The marginal costs resulting from resource extraction, $a(T) = A - \alpha T$, depend negatively on the quality of the extraction technology applied in the extraction process. Analogously, the marginal environmental damage also decreases with an improvement in the extraction technology, giving $d(T) = D - \delta T$. Hence, the quality of the extraction technology has two dimensions: efficiency and cleanliness. In correspondence to Porter's hypothesis claiming "that a reduction in pollution may lead to an improvement in [...] productivity" (Ambec et al., 2011), I thereby assume a positive relationship between cost efficiency and environment-friendliness resulting from an increase in the quality of the extraction technology.[6] The extracted resource is then shipped to the North,

[5]This is a convenient assumption. An alteration of the cost allocation does not, however, alter the outcomes for the equilibrium level of resource extraction and the quality of the extraction technology. Hence, the equilibrium environmental quality is also not affected by this assumption.

[6]This assumption is based on Porter (1991) and Porter and van der Linde (1995), who argue that innovations resulting from well-designed environmental regulations can enhance competitiveness. Ambec et al. (2011) provide a survey of the theoretical and empirical support for the Porter hypothesis. Additional empirical support for Porter's hypothesis can be found in the Business Risk Report for the Mining and Metals Industry for 2012 - 2013 (Ernst&Young, 2012) and in the mining sector, which promotes the application of clean technology (CleanMiningAlliance, 2012).

which produces and sells a final good Q based on this resource. For the sake of simplicity, a linear production function for the final good with $Q = R$ is assumed. Part of the revenue earned by the North from selling the final good, i.e. a side payment Z, is used to reimburse the South for the costs from environmental pollution and to share revenues. It is assumed that the North has market power on the final goods market, facing a linear demand function $p(Q) = v - bQ$. Subtracting the extraction costs $a(T)$ as well as the side payment Z for the South from the return yields the North's payoff function

$$G_N = p(R)R - a(T)R - Z \tag{1}$$

in dependence on the amount of resource extraction. For the South, the side payment Z marks the revenues while it has to bear the environmental damage $d(T)$ caused by resource extraction. It is assumed that the South's government lacks environmental consciousness to a certain degree and therefore does not fully internalize the environmental harm caused by resource extraction, which, however, is fully perceived by the society of the South. One example for this assumption is the Peruvian government which approved the expansion plans of the Camisea gas project despite its threatening the lives of the indigenous people (Feather, 2014). Another example is the Bijola Mining Area in Rajasthan, India, where various minerals are extracted. The case study by Chauhan (2010) describes the consequences of mining with regard to deforestation, habit destruction, biodiversity erosion and air and water pollution for workers and inhabitants. Licenses for mining are nevertheless distributed by the government. Based on the argumentation of, a.o., Arvin and Lew (2011), the degree of environmental consciousness is assumed to behave in a proportional manner to the development of democratic institutions of a country. Hence, the internalization of the environmental damage depends on the degree of democratization ω in the South with $\omega \in (0, 1)$. Thus, the government of the South aims at maximizing its payoff function

$$G_S = Z - \omega d(T)R.$$

I assume that the partners engage in Nash-bargaining to determine the size of the side payment Z^* as well as of the amount of resources to extract R^*, such that the Nash-product

$$N = (G_N - OO_N)(G_S - OO_S) \tag{2}$$

is maximized. The countries' excess utilities consist of their respective payoff functions G_i minus the outside options OO_i. By finding the Nash-bargaining solution, the joint payoff $G = G_N + G_S$ with

$$G(T, \omega) = p(R)R - a(T)R - \omega d(T)R \tag{3}$$

is simultaneously maximized.

Solving the model backwards, the partners jointly determine the level of R in the second stage of the game, such that the joint payoff function in equation (3) is maximized. The equilibrium resource level R^* with

$$R^*(T,\omega) = \frac{v - a(T) - \omega d(T)}{2b} \tag{4}$$

leads to a joint payoff of

$$G^*(T,\omega) = \frac{(v - a(T) - \omega d(T))^2}{4b} = bR^{*2}. \tag{5}$$

Both functions depend on the quality of the extraction technology T provided by the North and the degree of democratization ω in the South. The extraction technology is to be determined endogenously in the first stage of the game while the state of the democracy is taken as exogenous to the setting of the resource partnership.

In the first stage of the game, the North determines its investment level for the provision of the extraction technology T in the partnership. In equilibrium, the North supplies the quality of extraction technology that maximizes its profit function. Implementing Z^* as the level of the side payment that maximizes the Nash-Product in equation (2) into the North's payoff function G_N (1) and subtracting the investment costs $s(T)$ gives the North's profit function π_N with

$$\pi_N(T,\omega) = \frac{G^*(T,\omega)}{2} + \frac{OO_N(T,\omega) - OO_S(T,\omega)}{2} - s(T). \tag{6}$$

The outside options for the two partners are defined as $OO_N = \omega MT$ and $OO_S = (1-\omega)MT$, where M is the market price per quality unit of technology. They describe the respective alternative payoffs for the North and the South in case of a breakdown of the resource partnership. That is, if no bargaining solution is reached in the second stage of the game and hence no resources are being extracted, the only option to earn revenue is to sell the extraction technology that has been provided by the North. Depending on the quality of the property rights protection in the South, the North faces a risk of expropriation concerning its investment. Hence, the quality of the property rights determines which of the partners owns the extraction technology and is able to earn revenues in the case of a failure of the partnership. In correspondence to the argumentation of Knutsen (2011), ω, the state of democracy, serves as an indicator for the quality of property rights protection in the South. Therewith, $(1-\omega)$ gives the probability of expropriation for the North. The risk of expropriation is higher in less democratic host countries, i.e. for a lower value of ω. Thereby, an inversely proportional relationship between the risk of expropriation and democratic institutions is assumed. In the end, the degree of democratization in the South determines the size of the bargaining power of both partners.

The North's decision on the quality of the extraction technology supplied depends on the risk of expropriation and its expected profit. Hypothetically, if contracts were complete and hence the risk of expropriation eliminated, the North would provide an extraction technology of quality

$$T^{CC}(\omega) = \frac{(v - A - \omega D)(\alpha + \omega\delta)}{2b\chi - (\alpha + \omega\delta)^2}, \tag{7}$$

such that the joint profit function $\pi = G^* - s(T)$ was maximized (I call this the "Complete Contracts" Case). In equilibrium, however, the North provides an extraction technology of quality T^{eq}, depicted below, which maximizes its own profit function, stated in equation (6).

$$T^{eq}(\omega) = \frac{(v - A - \omega D)(\alpha + \omega\delta)}{4b\chi - (\alpha + \omega\delta)^2} + \frac{(\omega - \frac{1}{2})M}{\chi - \frac{1}{4b}(\alpha + \omega\delta)^2} \tag{8}$$

When comparing the first term of the equilibrium quality level of the extraction technology in equation (8) with the higher level given in equation (7) the occurrence of a holdup problem becomes obvious.[7] With a better property rights protection and a larger outside option of the North, the holdup problem can be reduced, i.e. the second term of equation (8) increases.

In the subsequent analysis, I start my investigation of the environmental outcome of the resource partnership with a simplified version of the model, notated as "Benchmark", in which the outside options are assumed to be equal to zero ($M = 0$), giving the North a profit function of $\pi_N = \frac{1}{2}G^*(\omega, T) - s(T)$. In equilibrium a "Benchmark" technological quality of

$$\tilde{T}^{eq}(\omega) = \frac{(v - A - \omega D)(\alpha + \omega\delta)}{4b\chi - (\alpha + \omega\delta)^2} \tag{9}$$

is obtained. In the later part of section 3, the scenario "Outside Options" extends upon the "Benchmark" case by including the bargaining power of both partners. Then the simplifying assumption of zero outside options is

[7] Only in the case of perfect democracy, i.e. with $\omega = 1$, and when $OO_N = G^*$, will the North choose the T^{CC} as equilibrium level of technological quality.

relaxed leading to the equilibrium outcome with $T = T^{eq}$, as defined in equation (8). Distinguishing between these three cases allows us to identify the separate effects and mechanisms occurring in the model. For one, the "Complete Contracts" case gives the optimal outcome such as a social planner would arrange it and serves as a point of reference. In the "Benchmark" scenario the consequences of the lack of environmental consciousness on behalf of the South's government can be observed. Finally, the inclusion of outside options in the third scenario allows illustrating the consequences of poor property rights protection for the environment.

3 The Environment in Resource Partnerships

The quality of the extraction technology applied in the resource partnership crucially affects the resulting state of the South's environment. As indicated above, the environmental quality is a function of the quantity of resources extracted and the technology applied, with the former also being a function of the latter and both variables depending on the democracy level ω, i.e

$$E = f\left(R(T(\omega), \omega); T(\omega)\right).$$

The function can be specified as

$$E = \bar{e} - d(T(\omega))R(T(\omega), \omega), \tag{10}$$

with $\bar{e}$ being the initial endowment of environmental quality available in the South. Equation (10) reflects the influence of resource extraction on the environment. Figure (1) illustrates this relationship . First, we focus on panel a). In the graph at the top with the downward-sloping demand function for the final good, $p(Q)$, with the corresponding marginal revenue, MR, the amount of resource extraction is determined. Since the production of the final good solely depends on its input R, I stay with the notation for natural resources, R, in the figure. In the figure I assume that the resource-extracting monopolist not only accounts for the marginal extraction costs $a(T)$, but also fully internalizes the marginal environmental damage $d(T)$ occurring from resource extraction when determining the resource extraction rate. In correspondence to the Hotelling rule (1931), both types of marginal costs are considered to be independent of the size of the stock of reserves remaining in the ground. That is, given for a certain quality of the extraction technology, both types of extraction costs are constant. The marginal social costs $\mu(T)$, i.e. the sum of marginal extraction costs and marginal environmental damage, decrease with the application of a better technology. Let us assume that extraction technology of quality T_0, depicted by the black lines,

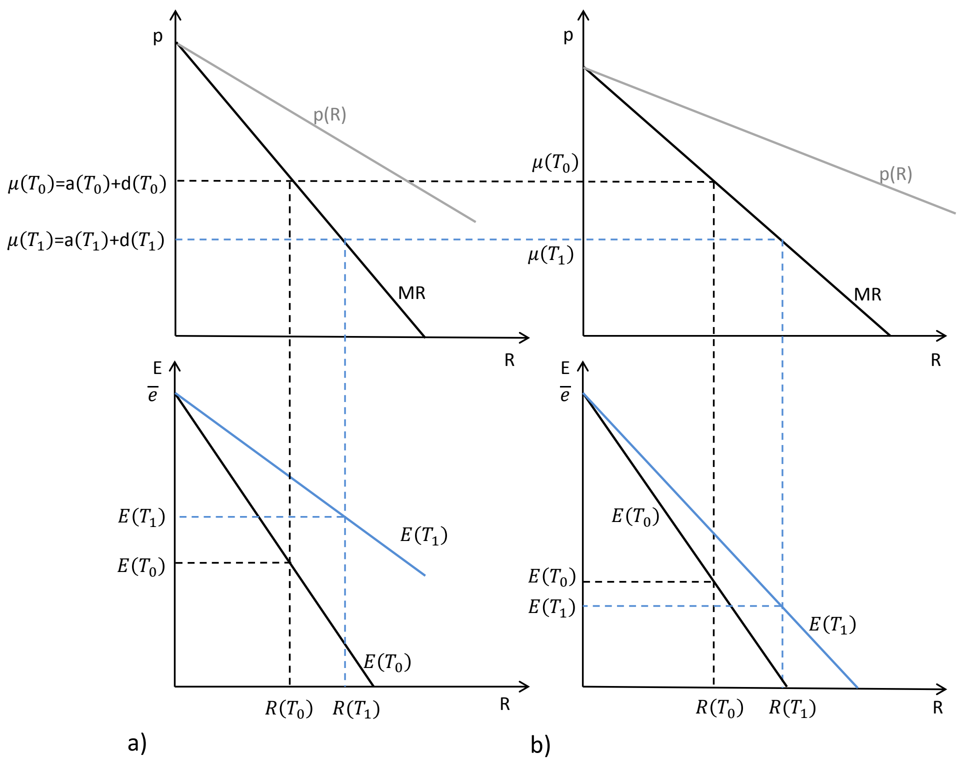

Figure 1: The environmental impact of resource extraction

is applied, giving the equilibirum extraction level of $R(T_0)$. The lower graph illustrates the negative relationship between resource extraction and the environmental quality, as defined in equation (10). An increase in the quantity of resources extracted raises pollution and hence diminishes the environmental quality. With the full consideration of the marginal social costs $\mu(T)$, an environmental level of $E(T_0)$ is obtained. The combination of both graphs in panel a) depicts the resource extraction level with the corresponding environmental quality for a given extraction technology under full internalization of the environmental damage. Now, let us assume in a second step that an improved technology T_1 is applied. The cleaner and more efficient new extraction technology T_1, illustrated by the blue lines, reduces the marginal social costs $\mu(T)$. The absolute size of the slope of the environmental quality function $E(T)$ decreases due to the reduction in $d(T)$. The introduction of the cleaner technology T_1 raises environmental quality. Despite the higher extraction rate, the absolute amount of pollution emitted is reduced, leading to an overall higher environmental quality. However, in panel b) of Figure 1, a case in which the environment is harmed by the introduction of an improved extraction technology is presented. If the improved technology initiates a relatively larger reduction in $a(T)$ compared to the reduction in $d(T)$ or if the demand for resources is fairly elastic, the new situation proves to be environmentally detrimental. The higher extraction rate emerging from the improved extraction technology eliminates the environmental gains from the cleaner technology. In correspondence to Smulders and Di Maria (2012), such a technology can be defined as a brown technology, or pollution-using instead of pollution-saving.

The Relevance of the Technological Quality

The intuition graphically depicted in Figure 1 is supported by the comparative statics analyzing the effect of an improvement in the extraction technology on the environment. We start with the comparative statics of the second stage equilibrium, taking the quality of the extraction technology as exogenous for now. It can be shown that the impact of an improvement in the applied extraction technology on the environment is twofold. On the one hand, per definition, a cleaner technology reduces the marginal damage per resource extracted by

$$\frac{\partial d(T)}{\partial T} = -\delta < 0,$$

as can be seen in the flattening of the environment function in the lower graph of Figure (1). On the other hand, partially differentiating equation (4) shows that the extraction rate is raised with an improved extraction technology by

$$\frac{\partial R}{\partial T} = \frac{\alpha + \omega\delta}{2b} > 0. \tag{11}$$

The extraction rate is increased by the amount of the reduction in marginal social costs initiated from the raise in technological quality $(\alpha + \omega\delta)$. A less elastic demand function for the final high-technology good, i.e. a large value of b and consequently more market power for the North, reduces the impact of a rise in technological quality on the extraction rate.

As a consequence of these contradicting effects, the partial derivative $\frac{\partial E}{\partial T}$ shows that the impact of an improved technology on the environmental quality is ambiguous:

$$\frac{\partial E}{\partial T} = -\left(\frac{\partial d(T)}{\partial T} R + d(T)\frac{\partial R}{\partial T}\right) \tag{12}$$

$$= \frac{\delta(v - A - \omega D) + (\alpha + \omega\delta)(2\delta T - D)}{2b}. \tag{13}$$

While the first term in the brackets of (12) is negative, the second term is positive. The size of $d(T)$ determines whether an improvement in the extraction technology is environmentally beneficial. Specifically, rearranging equation (13) shows that the environment only benefits from an improved extraction technology if the marginal damage from resource extraction is sufficiently low, i.e.

$$\frac{\partial E}{\partial T} > 0 \text{ if } D < \frac{\delta(v - A - 2T(\alpha + \omega\delta))}{2\omega\delta + \alpha}. \tag{14}$$

If the amount of environmental destruction caused in the extraction process is rather small, i.e. if D is small or δ is large, an improvement in the extraction technology is beneficial in terms of environmental quality. The improved quality of the extraction technology not only reduces the marginal environmental damage from resource extraction but also increases the extraction rate due to reduced marginal extraction costs. If the aggregated amount of pollution rises since the reduction in marginal damage is small compared to the increase in the amount of resources extracted, the application of an improved extraction technology is overall harmful for the environment. This phenomenon can be compared to the so-called rebound effect described, a.o., by Sorrell and Dimitropoulos (2008). Transferred to the situation at hand, the concept of the rebound-effect describes that the gain from the improvement in cleanliness is at least partially offset by the higher extraction rate resulting from cost reduction. If the improvement in the extraction technology improves productivity relatively more than it advances the cleanliness of the extraction process, the overall impact on the environment is negative. In other words, the rebound effect is the result of the application of a brown technology. In summary, an improvement in the extraction technology can be beneficial or detrimental to the environment. When applying a brown technology a rebound effect occurs since the improvement of the extraction technology leads to an increase in the extraction rate, which absorbs the reduction in marginal pollution.

The Relevance of Democracy in the South

Having analyzed the impact of an improvement in the extraction technology on the environment, the consequences of a change in democratic institutions is now examined. Hereby, three channels through which an improvement in democratic institutions influences the environmental quality are distinguished. First, a resource partnership under better democratic conditions is less prone to the holdup problem. Since the North's outside option OO_N positively depends on the quality of property rights protection, an imporvement in the state of democracy ω mitigates the holdup problem. The lower risk of expropriation grants a higher technology level in equilibrium. The consequences of such an improvement in the extraction technology have been shown in the section above.

The second and third channels act through the rise in environmental consciousness of the government in the resource-rich country coming along with an improvement in the degree of democracy. To start with the second channel, I concentrate on the direct effect from an increase in environmental awareness on the environmental quality. A higher environmental awareness increases the degree to which the environmental damage caused by the extraction process is internalized to the profit maximization considerations of the South's government. Since the resource partnership aims at maximizing the joint payoff determined in the Nash bargaining solution, the higher degree of pollution internalization also influences the joint decision on the level of resource extraction. For the analysis of this direct effect, I take the quality of the extraction technology T as exogenously given, i.e. I analyze the comparative statics of the second stage equilibrium of the game. The partial derivative of the resource extraction function given in equation (4) with respect to ω shows that an increase in the environmental awareness reduces the amount of resources extracted by

$$\frac{\partial R}{\partial \omega} = -\frac{d(T)}{2b} < 0.$$

The marginal pollution rate and the degree of the North's market power on the final goods market indicated by the slope of the demand function determine the size of the impact of a rising democracy index on the level of resource extraction. Inserting the equilibrium extraction level derived in equation (4) into the environment function (10) and taking the partial derivative with respect to ω gives

$$\frac{\partial E}{\partial \omega} = \frac{(d(T))^2}{2b} > 0,$$

which shows the improvement in the environmental quality resulting from a raise in environmental awareness. The larger the marginal pollution $d(T)$ caused by resource extraction, the larger the effects on both variables. Similar to the analysis of the impact of an improvement in the extraction technology, more market power resulting from a relatively inelastic demand curve leads to less of a reduction in the extraction rate initiated by the increase in ω. Consequently, the absolute effect of democratization on the environmental quality is also reduced. Hence, if the extraction technology were independent of the environmental consciousness of the government in the resource-rich country, the process of democratization would clearly lead to a lower equilibrium level of extracted resources resulting in a higher environmental quality.

However, the degree of environmental consciousness in the South also affects the North's investment decision for the extraction technology. This is the third channel portrayed. When including the first stage of the modeled game, with the endogenously determined level of the extraction technology, it can be observed that the environmental awareness also has an "indirect" impact on the environment through the channel of the equilibrium extraction technology. In order to focus on the effect from a rise in environmental consciousness on the North's technology choice, I continue with the "Benchmark" case without outside options to exclude the property rights impact from democratization. Hence, the extraction technology of quality $\tilde{T}^{eq}$, as defined in equation (9), is applied as equilibrium technology. The total impact of an improvement in the South's environmental awareness on the North's investment choice can be seen when totally differentiating the North's profit function with respect to ω. I.e. $\frac{\partial \pi_N}{\partial \omega}$ gives

$$\frac{d\tilde{T}^{eq}}{d\omega} = -\frac{\frac{\partial x}{\partial \omega}}{\frac{\partial x}{\partial T}} \text{ with}$$
$$x \equiv \frac{\partial \pi_N}{\partial T} = bR^*(T, \omega)\frac{\partial R^*}{\partial T} - \frac{\partial s}{\partial T} \quad \text{for } OO_N = OO_S = 0, \tag{15}$$

where the asterisk denotes the equilibrium level of a variable. The denominator of (15) gives the second order condition, which is negative by assumption. The derivative with respect to ω,

$$\frac{\partial x}{\partial \omega} = b\frac{\partial R^*}{\partial \omega}\frac{\partial R^*}{\partial T} + bR^*\frac{\partial^2 R^*}{\partial T \partial \omega} \lesseqgtr 0, \tag{16}$$

consists of a negative first term and a positive second term. Hence, the impact of democratization on the extraction technology given in equation (15) is ambiguous. In equation (17) it is shown that, as a consequence, the total impact of democratization on the extraction level is also ambiguous since it depends directly on the relationship between T and ω:

$$\frac{\partial R(T^*)}{\partial \omega} = \frac{\partial R}{\partial T^*}\frac{\partial T^*}{\partial \omega} + \frac{\partial R^*}{\partial \omega} \lesseqgtr 0. \tag{17}$$

The impact of democratization on the environment depends on both of these effects: that of democratization on the extraction technology as well as on resource extraction. As a result, the effect of democratization on the environment, depicted in equation (18),

$$\frac{\partial E(T^*)}{\partial \omega} = -\delta\frac{\partial T^*}{\partial \omega}R^* - d(T)\frac{\partial R(T^*)}{\partial \omega} \lesseqgtr 0, \tag{18}$$

can also not be uniquely determined. Intuitively, the internalization of the environmental damage, on the one hand, induces the investment into a cleaner technology for cost reduction. On the other hand, however, having a cleaner and simultaneously more productive technology leads to a higher extraction rate, which might increase the absolute level of pollution. Due to the higher environmental awareness, this pollution level is included to a larger degree as a cost into the profit function of the resource partnership. Hence, a lower investment in the extraction technology should be expected.

When having a look at the specified model including the outside options, the result of not having a clear-cut relationship between the extraction technology T^{eq} and democratization ω can be confirmed. As in equation (15), totally differentiating π_N of equation (6) with respect to ω, i.e. taking the derivative of T^{eq} with respect to ω shows the full impact of democratization on the North's profit function determining its investment decision. Analytically, the derivative in equation (19) cannot be uniquely determined to be positive or negative:

$$\begin{aligned}\frac{\partial T^{eq}}{\partial \omega} =& \frac{2\delta(v - A - \omega D)(\alpha + \omega\delta)^2 + 8\delta b^2 M(\omega - \frac{1}{2})(\alpha + \omega\delta)}{(4b\chi - (\alpha + \omega\delta)^2)^2} \\ &+ \frac{4bM - D(\alpha + \omega\delta) + \delta(v - A - \omega D)}{(4b\chi - (\alpha + \omega\delta)^2)}. \end{aligned} \tag{19}$$

An improvement in the South's democratic institutions is accompanied by an increase in the North's investment into the extraction technology only if the environmental damage of resource extraction is small, i.e. for

$$D < 2\delta T^{eq} \frac{(\alpha + \omega\delta) + 2b\delta(\alpha + \omega\delta)}{\alpha + 2\omega\delta} + \frac{4bM + \delta(v - A)}{\alpha + 2\omega\delta}. \tag{20}$$

Hence, I call this inequality the North's "investment condition". The size of the environmental damage is again the decisive factor. After having been identified as the factor that tips the scales in favor of or against a green technology, the environmental damage is now the crucial factor shaping the investment behavior of the North in regard of democratization.

In a nutshell, it was shown in section 3 that the effect from extracting natural resources on the environment depends on whether a green or a brown extraction technology is being applied. Equations (13) and (14) show that the classification into a green versus a brown technology mainly depends on the size of the marginal environmental damage caused by resource extraction. I continued by showing that in the setting of the resource partnership, the degree of democratization influences the size of the investment in the extraction technology and therewith the quality of technology applied in the extraction process. A clear-cut relationship between the environmental quality and the democratic condition of a resource-rich country cannot, however, be determined in the analytical analysis.

4 Numerical Simulation

A numerical simulation, based on the specified model, helps with visualizing the possible outcomes from democratization in the resource partnership setting in order to substantiate the analytical findings. In analogy to the analytical analysis, I start by classifying an extraction technology as either green or brown. Then, I continue by visualizing the quality of the extraction technology and its impact on the environment. All results are portrayed in dependence on the South's state of democracy. Based on the findings of the theoretical model presented above, three distinctive cases are constructed, for which the numerical simulations are conducted. These cases serve as examples to illustrate the effects of a resource partnership but do not claim to capture the whole range of possible outcomes. The values for the parameters in all three cases are chosen such that the conditions derived from the analytical model, which are listed in the Appendix, are satisfied. The chosen parametric values are also depicted in the Appendix.

The three cases simulated in the following differ in two aspects. First, the three possible relationships between democratization and the quality of the extraction technology are covered, which are either increasing, decreasing, or inversely U-shaped. In the analytical part it was shown that the condition stated in inequality (20) determines the sign of this relationship. The finding in equation (18) reveals the importance of this relationship since it also determines the impact of ω on the environment. Secondly, the analytical part exposes the size of the marginal environmental damage as a decisive factor for the development of the environmental quality. Hence, the relative size of environmental damage to extraction costs is also addressed in these three cases. Case (1) is considered as the "symmetric" case, where both extraction costs and environmental damage contribute to equal parts to the size of marginal social costs. In this case the process of democratization always gives an incentive to the North to invest more into the extraction technology. Hence, the condition of inequality (20) is satisfied, guaranteeing a positive relationship between ω and T. Case (2) puts additional emphasis on the environmental damage by increasing the marginal environmental destruction costs D, and also the marginal damage reduction δ, over the marginal extraction costs of $a(T)$. In this case the investment condition stated in inequality (20) is only met for small values of ω. An inversely U-shaped relationship between T and ω can be observed. In Case (3) the values are chosen such that a negative relationship between technological quality and democratization appears. As in Case (2), the marginal environmental damage also constitutes the main share of the marginal social costs. While in both cases the emphasis is laid upon large environmental damage, in contrast to Case (2), the marginal reduction in the environmental destruction, δ, through the improvement in the extraction technology is relatively small in Case (3).

The three graphs displayed in Figure (2) classify the equilibrium extraction technology for Cases (1) through (3) (from top to bottom) in the "Benchmark" scenario as a green versus a brown technology. In dependence on the progress of democratization, the impact of an improvement in the applied extraction technology on the environment is pictured. On the vertical axis the marginal change in the environmental quality resulting from a marginal improvement in the quality of the extraction technology $\frac{\partial E}{\partial T}$ is plotted. The independent variable on the horizontal axis gives the degree of democratization. The dotted line at zero represents the border between a green and a brown technology. Hence, above this line, an improvement in T is beneficial for the environment, below it is detrimental. As defined in equation (13), if the impact of an improvement in the extraction technology is positive for the environment, the new technology is classified as green, otherwise it is brown. It can be seen that in Case (1), a green technology is applied. In Case (3) the technology is practically always brown, independent of the state of democracy in the South. In Case (2) the technology turns brown as democratization proceeds. The larger the size of environmental damage relative to the extraction costs of resource extraction, the more likely it is that an improvement in the extraction technology will harm the environment. It is striking that an improvement in the state of democracy always worsens the effect of an improvement in technology on the environment. The larger the degree of internalizing the environmental damage, the worse the impact of an improvement in the extraction technology on the environment. Intuitively, the marginal environmental benefit of an improvement in the quality of the extraction technology decreases when the level of democracy rises since democratization has simultaneously a negative effect on the extraction rate.

Figure (3) presents the relationships between the quality of the extraction technology, the environment, and democracy for the three cases introduced above. In each of the graphs of Figure (3), three lines depict the development of the dependent variables, the extraction technology (in the upper row) and the environmental quality (in the bottom row), during the process of democratization in the South. The "Complete Contracts" and "Benchmark" scenarios are depicted with the light and dark solid lines, respectively. The

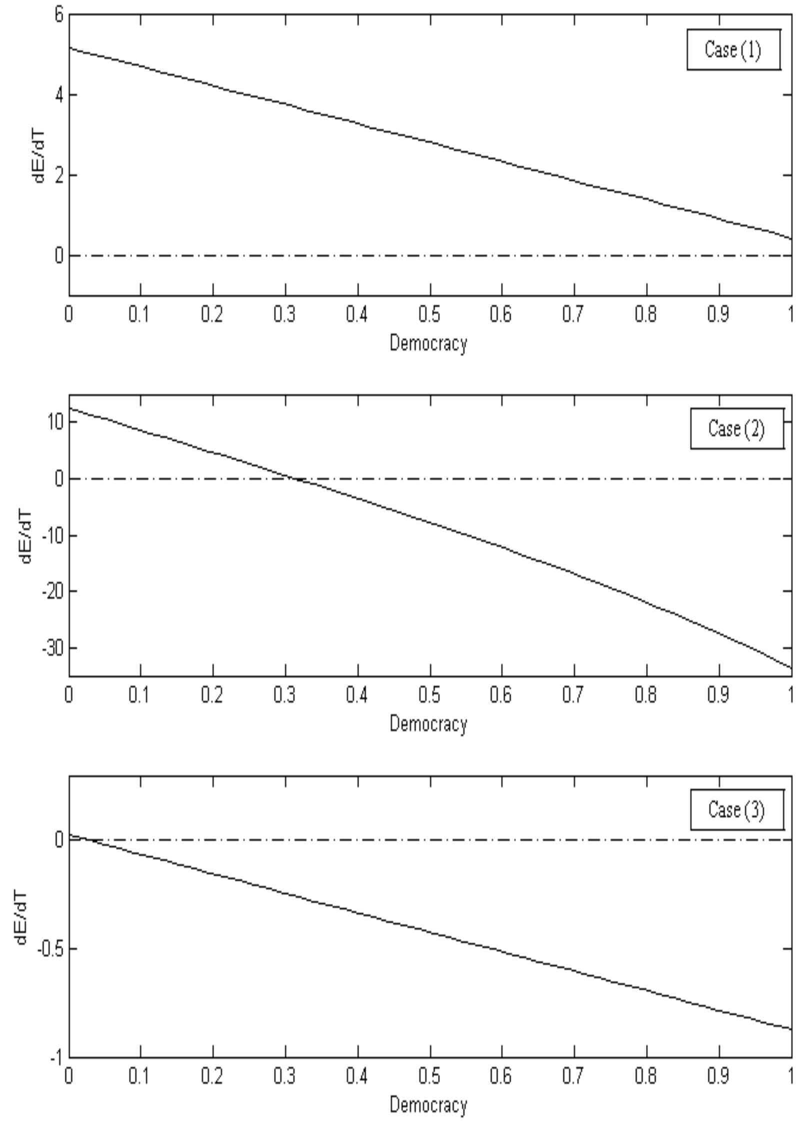

Figure 2: Quality of Extraction Technology

gap between these solid lines reflects the holdup problem. The inclusion of "Outside Options", illustrated with the black dashed lines, allows for bridging this gap by increasing property rights protection.

The simulations of Case (1) are illustrated in the first column (after rotating the page) of Figure (3) and paint the picture as intuitively expected. Democratization increases the environmental awareness and thus provides incentives to invest into a cleaner technology. Democratization has decreasing marginal effects in that respect. The holdup problem, visualized by the gap between the "Complete Contacts" versus the "Benchmark" lines, leads to a less productive and dirtier technology. The dashed line, which depicts the inclusion of outside options in comparison to the "Benchmark" case, shows that the improvement in democratization reallocates bargaining power from the South to the North. The improvement in property rights protection reduces the risk of expropriation for the North. The outside option of the North is consequently enhanced, bridging the investment gap. The degree to which this gap is bridged depends on the size of the outside option. In the lower graph, it can be seen that the environment benefits enormously from democratization. With the light solid line lying above the dark solid line, the holdup problem is transferred to the resulting environmental quality. Overall, the initiation of a cleaner extraction technology from the mitigation of the holdup problem combined with the internalization of pollution elevates the level of the environmental quality.

In the second column, the second combination of parametric values demonstrates that the situation is generally not as straightforward as the picture painted in Case (1) suggests. In this intermediate case, an increase in the democracy index ω first leads to an improvement in the equilibrium quality of the extraction technology. However, after a certain degree of democratization the impact turns negative. This inverse-U-shaped relationship results from not strictly meeting one side of the investment condition of inequality (20) for the full range of $\omega \in (0, 1)$. After a certain threshold and due to the large marginal environmental damage, the internalization of pollution more than offsets the gains from higher revenues with the higher extraction level resulting in a reduced investment into T. The impact of democratization on the environmental quality is again clearly positive. It can, however, be observed that the application of a better, i.e. also cleaner, extraction technology resulting from the mitigation of the holdup problem, does not necessarily lead to a higher level of environmental quality. The crossing of the lines in the lower graph of column two pictures the rebound effect, which is caused by the application of a brown resource extraction technology (see Figure (2)). In this case, under a relatively large marginal environmental burden from the resource extraction process, the higher extraction level coming

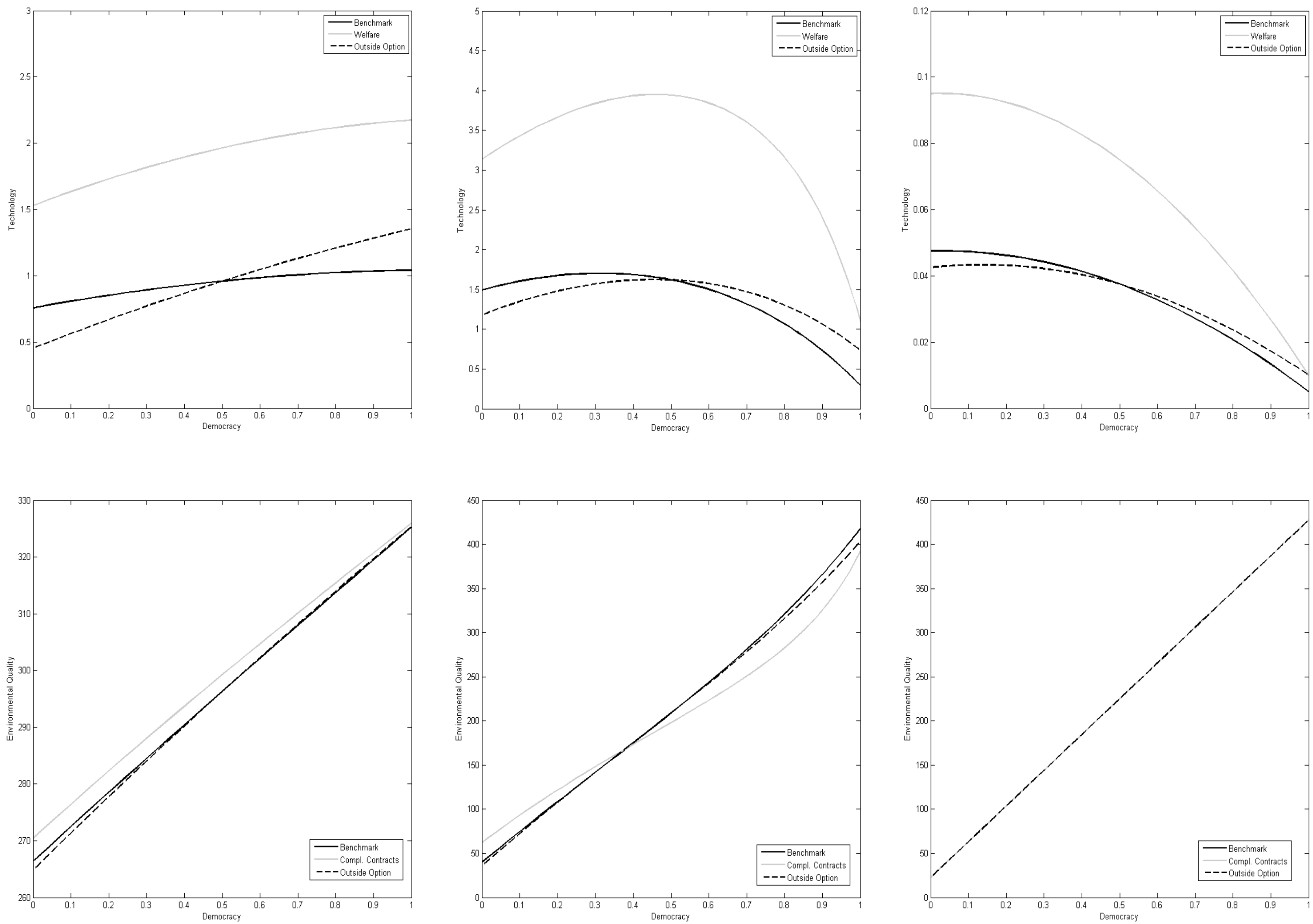

Figure 3: Numerical Simulations

along with the cleaner extraction procedure under "Complete Contracts" harms the environment more than the comparably dirtier technology in the "Benchmark" model does. That is, the reduction in marginal environmental destruction is more than offset from the higher extraction level initiated by the simultaneously more productive extraction technology.

A distinction between the application of a "Benchmark" versus the "Complete Contracts" technology is barely visible in the third case depicted in the third column. In order to fulfill the reverse condition of inequality (20), the level of technological quality is so low that the holdup problem for the outcome of environmental quality becomes practically irrelevant. Especially in the simulation for environmental quality, all three lines almost completely overlap. Nevertheless, an interesting finding can be stated. Despite the negative relationship between the quality of the extraction technology and democratization, the relationship between environmental quality and democracy remains positive. In the numerical simulation no proof for an ambiguous relationship between democratization and the environment can be found. This contradicts the apparent ambiguity found in the analytical analysis of equation (18). Combining the findings from the numerical simulations in Figures (2) and (3) one can observe that the North reduces its investment into the extraction technology when the process of democratization leads to the application of a brown technology. This mechanism ensures a positive relationship between the state of democracy and the environment. The driver for both developments is the large environmental damage caused by resource extraction. Apparently, an increase in the South's environmental awareness always benefits the environment, even if it leads to a lower quality in the extraction technology. The gain from improving environmental awareness initiated by the process of democratization dominates the enhanced investment incentive resulting from the mitigation of the holdup problem.

5 Conclusion

The formation of a resource partnership between a resource-dependent firm and a resource-rich country may solve the input shortage in natural resources for companies in industrialized nations and enable developing countries to earn revenue from their wealth in natural resources. However, the process of resource extraction may destruct the local environment. The degree of environmental damage depends on the quantity of resources extracted and the quality of the extraction technology applied for the extraction process. The incomplete nature of resource extraction contracts as well as the lack of environmental consciousness by the South's government cause the application of a suboptimal extraction technology. Based on the endogenously determined extraction technology, the environmental quality is identified in dependence of the state of democracy in the resource-rich country. The paper answers two successive questions in order to determine the impact from forming a resource partnership on the environment. For one (i), how does an improvement in the extraction technology affect the environment of a resource-rich country? And (ii), what extraction technology is provided and applied in dependence of the degree of democratization in the resource-rich country? Combining these questions, the equilibrium level of environmental quality is determined. The following summarizes the answers found in my analysis:

(i) The application of an improved resource extraction technology is only beneficial to the environment if the new technology can be qualified as a green technology. The distinction between a green and a brown technology depends on the relationship of the marginal reduction in extraction costs versus the marginal reduction in environmental damage resulting from the improvement in the extraction technology. A rebound effect occurs when a brown technology is applied and, consequently, the gains for the environmental quality earned from the cleaner extraction technology are more than offset by the higher resource extraction level resulting from the higher productivity of the new technology.

(ii) In a resource partnership, the quality of the applied extraction technology is determined by the size of the North's investment. Two externalities, the imperfect property rights protection and the lack of environmental valuation in the South, influence the North's incentive regarding its investment into the extraction technology. Both externalities, influencing the equilibrium extraction technology, are mitigated by an improvement in the democracy of the resource-rich country. Since the equilibrium extraction technology applied in the resource partnership depends on the South's democracy, so does the environmental level. In the analysis, the total impact of the democratization process is divided into its components. First, the rise in environmental consciousness has a direct effect which leads to a lower extraction rate and a consequently higher level of environmental quality. Second, the environmental consciousness also influences the North's decision on the quality of the supplied extraction technology. On the one hand, the internalization of the environmental damage induces the firm to invest into a cleaner technology reducing the marginal damage of resource extraction. On the other hand, a cleaner technology increases the extraction level due to the gains in efficiency. The overall effect from democratization on the environment is ambiguous. Third, a raise in democratization mitigates the holdup problem through improved property rights protection and therewith causes the application of a better extraction technology. Hence, the findings stated in result

(i) are also rooted in the process of democratization. Overall, the full impact of democratization on the investment incentive is found to be ambiguous and mainly depends on the size of the marginal environmental destruction caused during the extraction process. However, the numerical simulation conducted in section 4 confirmed the intuitive assumption of a positive relationship between the process of democratization and environmental quality. That is, even in the case in which democratization leads to the application of a brown technology due to a large marginal environmental damage from resource extraction, the rise in environmental valuation excels the increase in the investment incentive, such that the North's investment in the extraction technology is reduced if the extraction technology turns brown. Hence, the gains from the improvement in environmental awareness due to democratization virtually outperform the rise in investment incentive resulting from the mitigation of the holdup problem.

The main finding of this paper states that, at least for the cases covered in the numerical simulations, an improvement in the state of the South's democracy is always beneficial in terms of environment protection in a North-South investment relationship in the extractive sector. This finding suggests itself to be applied to an assessment of the different development cooperation objectives of traditional investors in comparison to China as a new investor, e.g. in Africa. Arguing in line with the findings of this paper, conditioning investments on improvements in the institutional setting of host countries, in fact, has a positive impact on the protection of the local environment and can be regarded as beneficial, especially to the rural population.

6 Appendix

Analytical Conditions:

$$a(T) = A - \alpha T > 0$$
$$d(T) = D - \delta T > 0$$
$$p(Q) = v - bQ > 0$$
$$s(T) = \frac{1}{2}\chi T^2 > 0$$

$T(\omega) > 0:$

$$(v - A - \omega D) > 0$$
$$2b\chi - (\alpha + \omega\delta)^2 > 0$$
$$\frac{(\alpha + \omega\delta)^2}{4b} < \chi \text{ (s.o.c.)}$$

$E > 0:$

$$\bar{e} > d(T^*)R^*$$

Description	**Parameter**	**Case 1**	**Case 2**	**Case 3**
Demand curve	v	100	100	100
	b	5	10	10
Production costs	A	25	5	5
	α	1	3	0.1
Environmental costs	D	25	90	90
	δ	1	5	0.1
Sunk costs	χ	5	5	5
Environmental stock	$\bar{e}$	450	450	450
Outside options	M	3	3	0.05

Table 1: Values of Parameters for the Numerical Simulation

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