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# *Profit Sharing under the Threat of Nationalization*

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# Profit Sharing under the Threat of Nationalization\*

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## Abstract

A multinational corporation engages in foreign direct investment for the extraction of a natural resource in a developing country. The corporation bears the initial investment and earns as a return a share of the profits. The host country provides access and guarantees conditions of operation. Since the investment is totally sunk, the corporation must account in its plan not only for uncertainty in market conditions but also for the threat of nationalization. In a real options framework, where the government holds an American call option on nationalization, we show under which conditions a Nash bargaining leads to a profit distribution maximizing the joint venture surplus. We find that the threat of nationalization does not affect the investment threshold but only the Nash bargaining solution set. Finally, we show that the optimal sharing rule results from the way the two parties may differently trade off rents with option values.

KEYWORDS: REAL OPTIONS, NASH BARGAINING, EXPROPRIATION, NATURAL RESOURCES, FOREIGN DIRECT INVESTMENT.

JEL CLASSIFICATION: C7, D8, K3, F2, O1.

## 1 Introduction

Many developing countries are rich in natural resources such as oil, natural gas and minerals. Such endowments may be crucial for funding their economic growth and welfare.<sup>1</sup> However, developing countries may often lack the needed technological and managerial knowledge and/or they must cope with limited funds for exploring the resource fields and building the infrastructures required for extraction. Foreign direct investments (hereafter, FDI) may overcome these difficulties. In fact, a multinational corporation may be willing to undertake

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<sup>1</sup>The relationship between natural resource and economic growth is still a controversial issue. See e.g. Brunnschweiler and Bulte (2008) on the "resource curse" debate.

the initial investment costs and extract the resource if an adequate return is paid. A multinational corporation may engage in FDI by forming a joint venture with a local firm which is usually owned by the government. The agreement between the two parties entitles the foreign investor to a property right on the infrastructure installed and to a compensation for the investment. The compensation may be represented by a share of the profit flow accruing from extraction.<sup>2</sup>

Once the investment has been undertaken, matching the economic interests of both parties may be problematic. In fact, given the sunk nature of the investment,<sup>3</sup> the local government may expropriate the enterprise's investment and run the project on its own. In this case, since the host is a sovereign country, no court may impose the respect of contract's terms or a compensation for the assets expropriated.<sup>4</sup> Although not on legal ground, the expropriation may however be punished by imposing international sanctions such as a limited access to world capital markets and restrictions on international trade. In addition, a cost due to the loss of reputation must be accounted. Nevertheless, even if a punishment may be triggered, high profits from extraction and/or populist pressure on governments for rents' distribution may justify this opportunistic move on the basis of benefits covering the costs.

Nationalizations<sup>5</sup> were an important issue over the 1960's and the 1970's when many colonies became independent countries. Later, during the 1980's and the 1990's, their frequency<sup>6</sup> declined as reported by Minor (1994). Despite this evidence, a bunch of examples in the last few years seems to support a new trend. For instance, let us refer to Bolivia whose leader Morales announced in 2006 a plan to nationalize the local natural gas industry; to Venezuela where over the last three years the president Chavez ordered the nationalization of foreign firms in several extractive industries; to Ecuador where a contract with the oil company Occidental Petroleum was cancelled on 2006.<sup>7</sup>

The relationship between multinational corporations and host countries is characterized not only by such conflicts but also by mutual economic interests. The activation of the extractive project requires a mutually convenient agreement inducing the initial investment. Needless to say, both parties are worse off without the investment. Mutuality may then lead to a joint venture where the profit distribution accounts and compensates for the threat of nationalization.

The aim of this paper is to account for conflicting and convergent economic interests

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<sup>2</sup>Schnitzer (2002) suggests the parties to engage in joint ventures to reduce the impact of sovereign risk on FDI.

<sup>3</sup>See Barham et al. (1998) for an analysis of investment in extractive industries and Guasch et al. (2003) for investment on infrastructures.

<sup>4</sup>As Schnitzer (1999) points out as long as on legal ground only a light penalty or no penalty at all may be imposed for the violation of the agreement's terms it is hard to have a host country credibly committed to their respect.

<sup>5</sup>Following Duncan (2006) by expropriation we mean a partial confiscation of the foreign investor's assets. Instead, the term nationalization will be used for total confiscation.

<sup>6</sup>Data on expropriations have been collected and presented in several studies. See e.g. Tomz and Wright (2008), Kobrin (1984) and Hajzler (2007).

<sup>7</sup>See [http://www.nytimes.com/2006/05/17/business/worldbusiness/17oil.html?\\_r=1](http://www.nytimes.com/2006/05/17/business/worldbusiness/17oil.html?_r=1) and <http://en.wikipedia.org/wiki/Nationalization> for further details.

and determine such a distribution.<sup>8</sup> This will be done setting up a model of cooperative bargaining where the foreign investor and the local government are viewed as holding an American call option, respectively on investment and nationalization. The analysis will be developed in a real options framework where both investment and nationalization are economic decisions characterized by uncertain pay-offs and irreversibility. Both parties are equally exposed to profit fluctuations following a geometric Brownian motion. Uncertain profits and irreversibility makes information on future prospects valuable and regret may be reduced keeping an option open and collecting such information (see Dixit and Pindyck, 1994). Finally, differently from the host, the investor must also account for the threat of nationalization.

Three closely related applications of this approach are Brennan and Schwartz (1985), Mahajan (1990) and Clark (2003). Brennan and Schwartz (1985) applies stochastic optimal control to evaluate natural resource extractive projects under uncertainty on output prices and define the optimal policies for investing, running and shutting down such projects. They model uncompensated expropriation as a Poisson process with a constant exogenous intensity parameter and account for its impact on the proceeds from the project. In Mahajan (1990) the government holds an option to expropriate and a contingent claims approach is taken to assess the expropriation risk. In Clark (2003) the cost of expropriation risk for a foreign investor corresponds to the value of an insurance contract covering the losses due to expropriation<sup>9</sup> and it is determined by the government maximizing the value of its option to expropriate.

Our proposal to merge cooperative bargaining and real options analysis is an innovative attempt in the literature on expropriation risk. We contribute considering explicitly both parties and modelling the impact on investment of conflicting and mutual economic interests. Three main features characterize our set-up. First, the lack of a credible commitment on the respect of the initial contract. Second, the foreign investor is aware that "almost from the moment that the signatures have dried on the document, powerful forces go to work that quickly render the agreements obsolete in the eyes of the government" (Vernon, 1993, p. 82). Last, differently from Clark (2003) where investment is taken as given, our approach involves a mutual interest in the initial investment. In this frame, we let the parties bargain to set up an agreement inducing investment.

By applying the Nash bargaining solution concept to the underlying game we can determine a Pareto efficient sharing rule and fully characterize a cooperative agreement. We find that to induce investment the profit distribution must trade off the probability of nationalization with the share paid to the foreign investor. Another interesting finding is represented by the invariance of the investment threshold. That is, with or without a threat of nationalization the investment occurs at the same time. On the contrary, the threat of nationalization does impact on the set of the distributive equilibria over which a Nash bargaining solution can be defined. In fact, as the threat becomes more severe we show how the extent of this set shrinks and bargaining failure may occur. We also find that, as expected, the multinational corporation's share must be higher than without the threat of nationalization. This

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<sup>8</sup>See Kobrin (1987) for a review of literature on bargaining paradigm in the extractive sector.

<sup>9</sup>See also Clark (1997) where expropriation is modelled as a Poisson process with a constant exogenous intensity parameter.

makes economic sense and two possible interpretations are provided. On the one hand, this wedge can be simply seen as the way the investor is compensated for the additional risk, while on the other hand it may be viewed as balancing for the local government being compensated not only through the share on profits but also indirectly through the option to expropriate. Developing the last interpretation, we contribute also by proposing the cooperative bargaining frame for pricing the option to expropriate. Finally, studying the impact of market volatility on the investor's share, we can observe two different scenarios. On the first, as uncertainty rises, the foreign corporation accepts a lower share to delay investment. Such loss is compensated by a high profit level when investing and a less acute threat of expropriation. On the second, as uncertainty soars up, to encourage earlier investment the local government accepts a lower share. A more valuable option to expropriate and a lower threshold for its exercise will balance the loss.

The remainder of the paper is organized as follows. In Section 2 the basic set-up for the model is presented. In Section 3 we study the investment and nationalization decisions. In Section 4, we define the efficient bargaining set, and then we derive the cooperative game outcome. In Section 5 we discuss results using comparative statics and illustrate the model by a numerical solution. Section 6 concludes.

## 2 The Basic Set-up

Consider a joint investment project for the extraction of a natural resource in a developing country. The extraction of this resource is lucrative and generates a flow of non-negative<sup>10</sup> profits,  $\pi_t$ , which randomly fluctuates over time following a geometric Brownian motion with instantaneous growth rate  $\alpha$  and instantaneous volatility  $\sigma$ :

$$\frac{d\pi_t}{\pi_t} = \alpha dt + \sigma dZ_t, \quad (1)$$

where  $Z_t$  is a Wiener process with  $E[dZ_t] = 0$  and  $E[dZ_t^2] = dt$ .

The two parties forming the joint venture, a multinational corporation (hereafter, MNC) and the government of the host country (hereafter, HC), are both risk-neutral. The project to be activated requires a sunk investment  $I > 0$ . For simplicity we assume that the extractive project has a term sufficiently long that it can be approximated by infinity. Suppose that HC is fund-constrained and cannot finance the project while MNC can undertake it. The parties agree on sharing each unit of profit in two parts, respectively  $\theta$  to MNC and  $1 - \theta$  to HC, where  $\theta \in (0, 1)$ . Assume also that once the project is activated, the parties have joint control on the extractive process and that the plant runs at capacity.<sup>11</sup>

Once the agreement has been signed MNC holds an option to invest in the extractive project. Since MNC faces uncertainty about market conditions, delaying the investment to

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<sup>10</sup>The simple form for  $\pi_t$  may be thought of as a reduced form of the more complex  $\pi_t = \pi(v_t)$ , where  $v_t$  is a vector representing the variables (market prices, technology, regulation, etc.) which may affect such a flow in the reality.

<sup>11</sup>See Long (1975) for resource extraction patterns and Engel and Fischer (2008) for optimal resource extraction contracts under the threat of nationalization.

gather information on future profit realizations may be valuable. However, market conditions are not the only sources of uncertainty on MNC's profit flows. In fact, once the investment is undertaken HC holds an option to nationalize it. Since HC cannot credibly commit not to exercise this option, MNC's must account for such a threat when bargaining for the distribution of profits. HC is a sovereign country and no legal court may oblige it to pay a compensation for assets and returns expropriated. Nevertheless, we assume that HC's opportunistic behaviour may be realized at a known and constant sunk cost<sup>12</sup>  $N > 0$ . Let  $N$  include the losses due to international sanctions, such as limited access to capital markets and restrictions on trade, to the ruined reputation<sup>13</sup> and to the lack of technological and managerial competences to run the project on its own. Given that nationalization is a costly and irreversible move, also HC may want to postpone it to benefit from information on fluctuating future profits. Finally, note that if the option to nationalize is kept open, a dividend, i.e. the profit share  $1 - \theta$ , is paid to HC.<sup>14</sup>

### 3 Nationalization and Investment

Since MNC is a foreign firm, the value of the project for HC accounts only for the profits accruing to the local government. That is, its share of profits as long as the project is jointly run plus the share expropriated minus the cost of expropriation once nationalization takes place. Hence, before investment has been undertaken the expected net present value for HC at the general initial  $\pi \leq \pi_I < \pi_N$  is

$$\begin{aligned} H(\pi, \theta) &= E \left[ e^{-\rho T^I} \mid \pi_0 = \pi \right] \cdot E \left[ \int_{T^I}^{T^N} (1 - \theta) \pi_t e^{-\rho(t - T^I)} dt + \right. \\ &\quad \left. + \int_{T^N}^{\infty} \pi_t e^{-\rho(t - T^N)} dt - N e^{-\rho T^N} \right] \\ &= E \left[ e^{-\rho T^I} \mid \pi_0 = \pi \right] \cdot G(\pi_I, \theta), \end{aligned} \quad (2)$$

where  $\rho > \alpha$  is the riskless interest rate<sup>15</sup> and  $T^k = \inf(t > 0 \mid \pi_t = \pi_k)$  for  $k = I, N$  is the random first time the process (1) hits respectively the investment threshold,  $\pi_I$ , and the nationalization threshold,  $\pi_N$ .<sup>16</sup> By  $G(\pi_I, \theta)$ , we will denote the value accruing to HC at the investment time,  $T^I$ .

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<sup>12</sup>Such cost may be also seen as a flow over time. In this case, the analysis would not change in that one may consider  $N$  as their discounted present value at the time of nationalization. Our frame may also be easily modified to let, as in Clark (2003),  $N$  follow a geometric Brownian motion.

<sup>13</sup>Changing perspective  $N$  may be equivalently interpreted as HC's respect for property and contract law.

<sup>14</sup>This is technically the main difference between the two American call options.

<sup>15</sup>To account for an appropriate adjustment for risk, we should have taken the expectation with respect to a distribution of  $\pi$  adjusted for risk neutrality. See Cox and Ross (1976) for further details. Finally, note that if  $\rho \leq \alpha$  investing would never be optimal for MNC.

<sup>16</sup>See Harrison (1985, p. 42) for the computation of expected present values.



Similarly, MNC's expected net present value at  $\pi \leq \pi_I < \pi_N$  is given by

$$\begin{aligned} M(\pi, \theta) &= E \left[ e^{-\rho T^I} \mid \pi_0 = \pi \right] \cdot E \left[ \int_{T^I}^{T^N} \theta \pi_t e^{-\rho(t-T^I)} dt - I \right] \\ &= E \left[ e^{-\rho T^I} \mid \pi_0 = \pi \right] \cdot F(\pi_I, \theta), \end{aligned} \quad (3)$$

where  $F(\pi_I, \theta)$  represents the expected value of the profit flow gained from  $T^I$  to  $T^N$  minus the investment cost,  $I$ , discounted at  $T^I$ . So far we have assumed that  $T^N > T^I$  ( $\pi_I < \pi_N$ ). This is clearly the only case where bargaining makes economic sense. Otherwise, as we will show later, once undertaken the investment would be simultaneously expropriated.

### 3.1 The Nationalization Decision

Once the investment is undertaken, HC holds the option to nationalize and earns the share  $1 - \theta$  of the profit flow if the option is kept open. HC must decide when it is optimal to exercise this option. This is an optimal stopping problem where  $G(\pi, \theta)$  must be maximized with respect to  $T^N$ .<sup>17</sup>

Let  $V(\pi)$  be the expected present value of total revenues from extraction once the project has been activated. That is<sup>18</sup>

$$\begin{aligned} V(\pi) &= E \left[ \int_0^\infty \pi_t e^{-\rho t} dt \mid \pi_0 = \pi \right] \\ &= \int_0^\infty \pi e^{-(\rho-\alpha)t} dt \\ &= \frac{\pi}{\rho - \alpha}. \end{aligned} \quad (4)$$

Since  $\pi_N$  is the nationalization threshold, the option to nationalize is unexercised over the continuation region,  $\pi < \pi_N$ . In this region, the Bellman equation for  $G(\pi, \theta)$  is

$$\rho G(\pi, \theta) = E[dG(\pi, \theta)] + (1 - \theta)\pi. \quad (5)$$

Expanding the middle term by Ito's lemma and rearranging

$$\frac{1}{2}\sigma^2\pi^2 G''(\pi, \theta) + \alpha\pi G'(\pi, \theta) - \rho G(\pi, \theta) = -(1 - \theta)\pi. \quad (6)$$

The solution for the differential equation in (6) is<sup>19</sup>

$$G(\pi, \theta) = A_N \pi^\beta + (1 - \theta)V(\pi), \quad (7)$$

where  $\beta > 1$  is the positive root of  $\Psi(\beta) = \frac{1}{2}\sigma^2\beta(\beta - 1) + \alpha\beta - \rho = 0$ .

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<sup>17</sup>This is equivalent to the maximization of (2). However, since  $T^I$  is determined by MNC we can reduce the problem to the maximization of  $G(\pi, \theta)$ .

<sup>18</sup>See Harrison (1985, p. 44) for the calculation of this expected present value.

<sup>19</sup>See e.g. Dixit and Pindyck (1994, p. 143 and p. 180).

The constant  $A_H$  and the threshold  $\pi_N$  can be determined attaching the following value-matching and smooth-pasting conditions to (7)

$$G(\pi_N, \theta) = V(\pi_N) - N, \quad (8)$$

$$G'(\pi_N, \theta) = V'(\pi_N). \quad (9)$$

Note that (8) can be rearranged as follows:

$$A_N \pi_N^\beta = V(\pi_N) - [(1 - \theta)V(\pi_N) + N].$$

That is, at  $\pi_N$  the value of keeping the option (LHS) must be equal to the net benefit of nationalization (RHS). The first term on RHS is the expected present value of the entire flow of profits while the term into square brackets stands for the cost associated to the expropriation. This cost is given by the expected present value of the share of the joint project revenues implicitly given up when nationalizing, plus the nationalization cost.

Solving (8) and (9) for  $\pi_N$  and  $A_H$  yields

$$\pi_N = \frac{\beta}{\beta - 1} \frac{(\rho - \alpha)}{\theta} N, \quad (10)$$

$$A_N = [\theta V(\pi_N) - N] \pi_N^{-\beta}. \quad (11)$$

Note that  $\pi_N$  is decreasing in  $\theta$ . This implies that, as  $\theta \rightarrow 1$ , the expropriation becomes in expected terms more likely. The higher  $N$ , the further must profit rise before nationalization is triggered.

Finally, plugging (11) into (7) gives

$$G(\pi, \theta) = \begin{cases} [\theta V(\pi_N) - N] \left(\frac{\pi}{\pi_N}\right)^\beta + (1 - \theta) V(\pi) & \text{for } \pi < \pi_N \\ V(\pi) - N & \text{for } \pi \geq \pi_N. \end{cases} \quad (12)$$

In (12) on the first line, the first term represents the value of the option to expropriate while the second is the perpetuity paid if HC does not nationalize. On the second line, we have the discounted net pay-off of nationalization.

### 3.2 The Investment Decision

MNC maximizes (3) with respect to  $T^I$  taking  $T^N$  as given. Let  $F(\pi, \theta)$  represent the expected present value of the stream of profits gained by MNC once invested

$$\begin{aligned} F(\pi, \theta) &= E \left[ \int_0^{T^N} \theta \pi_t e^{-\rho t} dt \mid \pi_0 = \pi \right] \\ &= \frac{\theta}{\rho - \alpha} \left[ \pi - \pi_N \left( \frac{\pi}{\pi_N} \right)^\beta \right] \\ &= \theta \left[ V(\pi) - V(\pi_N) \left( \frac{\pi}{\pi_N} \right)^\beta \right]. \end{aligned} \quad (13)$$

From (13) one can easily see that MNC is accounting for a flow of profits stopping at  $T^N$  due to nationalization.<sup>20</sup>

In the continuation region,  $\pi < \pi_I$ , the Bellman equation for  $M(\pi, \theta)$  is:

$$\rho M(\pi, \theta) = E[dM(\pi, \theta)]. \quad (14)$$

Expanding the RHS in (14) it follows that

$$\frac{1}{2} \sigma^2 \pi^2 M''(\pi, \theta) + \alpha \pi M'(\pi, \theta) - \rho M(\pi, \theta) = 0. \quad (15)$$

The guessed form for the solution to (15) is

$$M(\pi, \theta) = A_I \pi^\beta. \quad (16)$$

Imposing the value-matching and smooth-pasting conditions at  $\pi_I$

$$M(\pi_I, \theta) = F(\pi_I, \theta) - I, \quad (17)$$

$$M'(\pi_I, \theta) = F'(\pi_I, \theta), \quad (18)$$

and solving for  $\pi_I$  and  $A_I$  we obtain

$$\pi_I = \frac{\beta}{\beta - 1} \frac{(\rho - \alpha)}{\theta} I, \quad (19)$$

$$A_I = \left\{ \theta \left[ V(\pi_I) - V(\pi_N) \left( \frac{\pi_I}{\pi_N} \right)^\beta \right] - I \right\} \pi_I^{-\beta}. \quad (20)$$

Note that  $\pi_I$  is not affected by  $\pi_N$ .<sup>21</sup> This means that with or without threat of nationalization the expected investment timing is the same. This result is consistent with the dynamic programming principle of optimality used to solve the problem: if  $\pi_I$  is the optimal investment threshold at  $t = 0$  then it should remain optimal for every  $t > 0$ . In other words,

<sup>20</sup>From MNC's perspective  $\pi_N$  represents an absorbing barrier for (1).

<sup>21</sup>This can also be seen solving the MNC's problem with  $\pi_N \rightarrow \infty$ .

no possible event occurring after  $\pi_I$  has been hit has any impact on the optimal threshold.<sup>22</sup> Since  $\frac{\partial \pi_I}{\partial \theta} < 0$ , the higher is MNC's share, the earlier the investment takes place. More interestingly, note that  $\frac{\partial(\pi_N - \pi_I)}{\partial \theta} = -\frac{\pi_N - \pi_I}{\theta} < 0$ . This result implies that to induce earlier investment a higher share must be paid to compensate for the option value given up and for the rising threat of nationalization ( $\frac{\partial \pi_N}{\partial \theta} < 0$ ).

Substituting (20) into (16) gives

$$M(\pi, \theta) = \begin{cases} \left\{ \theta \left[ V(\pi_I) - V(\pi_N) \left( \frac{\pi_I}{\pi_N} \right)^\beta \right] - I \right\} \left( \frac{\pi}{\pi_I} \right)^\beta & \text{for } \pi < \pi_I \\ \theta \left[ V(\pi) - V(\pi_N) \left( \frac{\pi}{\pi_N} \right)^\beta \right] - I & \text{for } \pi_I \leq \pi < \pi_N \\ -I & \text{for } \pi \geq \pi_N. \end{cases} \quad (21)$$

MNC is aware that investment implicitly provides HC with the option to expropriate. This is accounted for in (21) through the term  $\theta V(\pi_N) \left( \frac{\pi_I}{\pi_N} \right)^\beta = \theta V(\pi_N) \cdot E[e^{-\rho T^N} | \pi_0 = \pi_I]$ . This term discounts the profits expropriated for the random time period  $T^N - T^I$  and corrects the perpetuity  $\theta V(\pi_I)$ .

From (21) it follows that the only case to matter in our analysis is  $\pi_I < \pi_N$ . Otherwise, for  $\pi_I \geq \pi_N$ , investment makes no sense in that HC nationalizes it as soon as it is undertaken. We thus state the following proposition

**Proposition 1** *If the investment is undertaken then the following inequality must hold*

$$\gamma^{\beta-1} > \beta, \quad (22)$$

where  $\frac{\pi_N}{\pi_I} = \frac{N}{I} = \gamma$ .

The inequality in (22) is a necessary but not sufficient condition for investment. In fact, an investment requires that  $M(\pi, \theta) > 0$  for  $\pi < \pi_I$ . Note that this in turn implies  $M(\pi_I, \theta) > 0$ . The parameter  $\gamma$  represents the magnitude of the punishment with respect to the scale of the investment expropriated. By  $\gamma$  we can capture the impact that international sanctions, loss of reputation and other costs have on the likelihood of nationalization and implicitly on the investment decision. In particular, note from (22) that given  $\gamma^{\beta-1} > \beta$ , since  $\beta > 1$  then  $\gamma > 1$ . This means that the punishment,  $N$ , must be greater than the investment cost,  $I$ .<sup>23</sup> As  $\gamma$  increases the distance between the two thresholds,  $\pi_N - \pi_I$ , becomes larger, and in expected terms the flow of MNC's profits has a longer duration. In Figure 1, we analyse some possible scenarios. It is interesting to compare plots (a) and (b): condition (22) does not hold for some  $\gamma$  in (a) while it may hold for the same  $\gamma$  over some range of  $\sigma$  in (b). This is due to the profit growth rate,  $\alpha$ . In fact, if  $\alpha > 0$ , profits increases at a faster rate and in expected terms the threshold  $\pi_N$  is met earlier. This in turn reduces

<sup>22</sup>See chapters 8 and 9 in Dixit and Pindyck (1994) discussing a similar result.

<sup>23</sup>As suggested by a referee, MNC may be seen as an agent acting on behalf of HC. To appropriate the total profit flow two steps are necessary: first, MNC must invest and second, HC must nationalize the investment. Since MNC cannot gain more than HC, MNC will find convenient to activate the project only if the cost of doing it is not greater than the cost to HC of nationalization.

MNC's gain from joining HC. In (b) for  $\gamma = 1.5$ , the zero growth effect holds for levels of volatility up to  $\sigma = 0.3$ . Above this value, the punishment is too mild and  $\gamma$  must increase for condition (22) to hold.

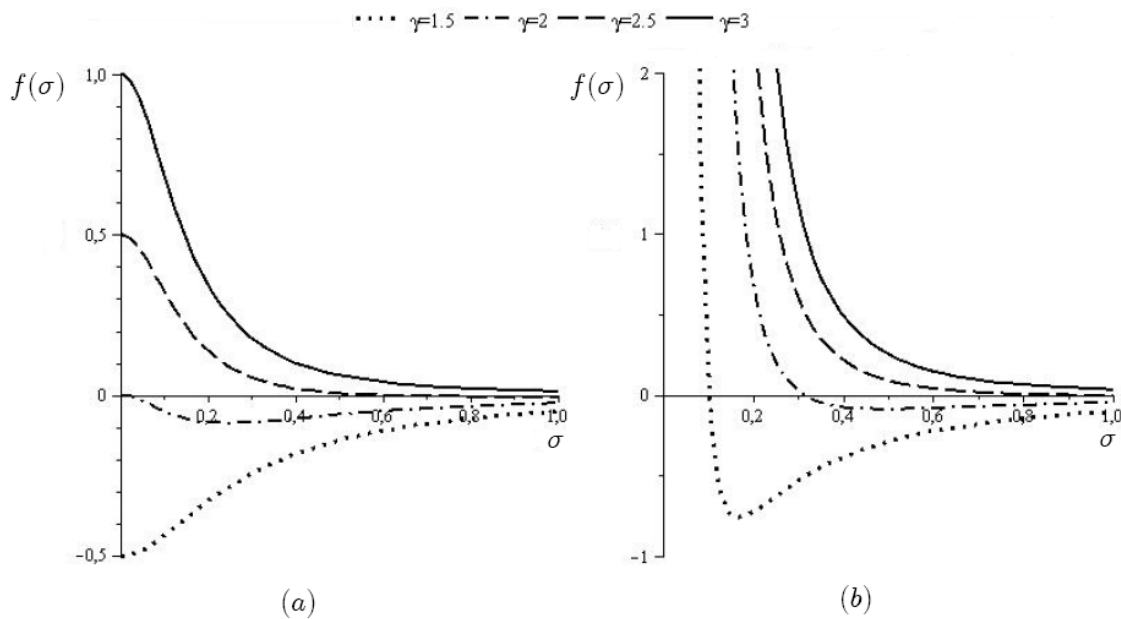


FIGURE 1:  $f(\sigma) = \gamma^{\beta-1} - \beta$  for  $\rho = 0.1$ , (a)  $\alpha = 0.05$ , (b)  $\alpha = 0$

## 4 Nash Bargaining under Uncertainty and Irreversibility

The relationship between MNC and HC is characterized by conflicting but also convergent economic interests. Both parties are interested in the activation of the extractive project. Before the project starts, an agreement on the distribution of the profits must be reached. The parties must agree on a distributional parameter,  $\theta$ , which maximizes their joint interests. This situation can be framed as a cooperative game, the outcome of which may be determined by applying the Nash bargaining<sup>24</sup> solution concept (see Nash, 1950; Harsanyi, 1977).

HC and MNC gather the same information on the future prospects for  $\pi_t$  and are averse to the risk of internal conflict.<sup>25</sup> This allows us to represent both parties by the concave Von Neumann-Morgenstern functions,  $W(H)$  and  $U(M)$  respectively, defined on the set of HC's and MNC's expected net discounted values.<sup>26</sup> A Nash bargaining solution,<sup>27</sup>  $0 < \theta^* < 1$ , maximizes the following joint objective function

$$\nabla = \log[W(H) - \hat{w}] + \log[U(M) - \hat{u}], \quad (23)$$

where  $H(\pi, \theta)$  and  $M(\pi, \theta)$  are defined in (21) and (2) and  $\hat{w}$  and  $\hat{u}$  are disagreement pay-offs. However, note that in our problem  $\hat{w} = \hat{u} = 0$  since the resource is not extracted if the bargaining fails.

The bargaining on the profit sharing rule  $\theta$  must take place before the project activation, i.e. for  $\pi < \pi_I < \pi_N$ . Note that if, as it should for bargaining to make economic sense, condition (22) holds then both derivatives,  $\frac{\partial H(\pi, \theta)}{\partial \pi}$  and  $\frac{\partial M(\pi, \theta)}{\partial \pi}$ , are positive for  $\pi < \pi_I$ . This means that the bargaining should occur an infinitely small time period before the investment threshold is reached. By the continuity of the two value functions, it follows that the objective function in (23) must be maximized at  $\pi_I$ .<sup>28</sup> Waiting up to  $\pi_I$  both parties are better off in that they may collect more information on future prospects.

### 4.1 Cooperative Equilibrium

Denote by  $W(H) = H^p$  and  $U(M) = M^q$  respectively HC's and MNC's utility functions. Their degrees of relative risk aversion are thus measured by  $0 < p \leq 1$  and  $0 < q \leq 1$ ,

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<sup>24</sup>The basic situation behind a Nash bargaining is very simple. Two agents demand a share of some good. Each of them simultaneously and without knowing the other agent's proposal presents to a referee her request. If the two requests sum to no more than the total good, an agreement is reached and the pie is divided accordingly. Otherwise, the game ends and the two agents obtain the disagreement pay-off.

<sup>25</sup>This is not in conflict with previously assumed risk neutrality. In fact, the parties may be neutral when assessing a more general and differentiated set of ventures opportunities. On the contrary, when involved in the bilateral setting HC-MNC, due to the specificity of the bargaining, the parties may show risk adversity.

<sup>26</sup>See Breccia and Salgado-Banda (2005) and Moretto and Rossini (1995,1996) for bargaining games over a Nash product driven by a geometric Brownian motion.

<sup>27</sup>A Nash bargaining solution is a Pareto efficient solution of the game. Both parties have a positive share and their sum is equal to 1.

<sup>28</sup>More realistically, MNC and HC may agree before on a sharing rule conditional on  $\pi_I$ .

respectively. Let the two parties play the cooperative game at  $T^I$ . The equilibrium agreement will be represented by the level of  $\theta^*$  maximizing (23).

Differentiating (23) with respect to  $\theta$ , the following condition must hold in equilibrium:<sup>29</sup>

$$p \frac{\frac{\partial H(\pi_I, \theta^*)}{\partial \theta}}{H(\pi_I, \theta^*)} + q \frac{\frac{\partial M(\pi_I, \theta^*)}{\partial \theta}}{M(\pi_I, \theta^*)} = 0. \quad (24)$$

Rearranging (24), and using (2) and (21), we get

$$-\frac{\beta - \theta^* (\beta - \gamma^{1-\beta})}{\beta - \theta^* (\beta - \gamma^{1-\beta}) - 1} = \eta, \quad (25)$$

where  $\eta = \frac{p}{q}$ .

Solving for  $\theta^*$ , we have the following proposition

**Proposition 2** *Under the threat of nationalization the optimal sharing rule is given by*

$$\theta^* = \frac{\beta - \frac{\eta}{\eta+1}}{\beta - \gamma^{1-\beta}}. \quad (26)$$

The solution in (26) makes sense if  $\theta^* > \frac{\beta-1}{\beta-\gamma^{1-\beta}}$ . By Proposition (1) and since  $\beta > 1$ , it follows that  $\beta - 1 < \beta - \gamma^{1-\beta}$ . This means that over  $\frac{\beta-1}{\beta-\gamma^{1-\beta}} < \theta^* < 1$  a Nash bargaining solution can be reached. Note that, as  $\gamma \rightarrow \infty$  ( $\pi_N \rightarrow \infty$ ), the lower bound tends to  $1 - \frac{1}{\beta} < \frac{\beta-1}{\beta-\gamma^{1-\beta}}$  and the set enlarges. In other words, the threat of nationalization makes it more difficult to attain a Pareto efficient bargaining outcome. Finally, while  $\theta^* > \frac{\beta-1}{\beta-\gamma^{1-\beta}}$  can be easily shown to hold, a restriction is needed to have  $\theta^* < 1$ . That is

$$\eta > \frac{\gamma^{1-\beta}}{1 - \gamma^{1-\beta}}. \quad (27)$$

Since  $\frac{\partial(\frac{\gamma^{1-\beta}}{1-\gamma^{1-\beta}})}{\partial \gamma} = (1-\beta) \frac{\gamma^{-\beta}}{(1-\gamma^{1-\beta})^2} < 0$ , as the magnitude of the punishment,  $\gamma$ , increases, the restriction on relative risk aversions loosens ( $\frac{\gamma^{1-\beta}}{1-\gamma^{1-\beta}} \rightarrow 0$ ).

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<sup>29</sup>The second order condition always holds. See appendix A.1.

## 5 Some Comparative Statics and a Numerical Solution

In this section we derive and discuss some properties of the cooperative agreement. We will show how interest rate,  $\rho$ , profit growth,  $\alpha$ , volatility,  $\sigma$ , the relative magnitude of nationalization cost,  $\gamma$ , and the relative risk aversion ratio,  $\eta$ , impact on the bargaining outcome. Finally, to complete this analysis a numerical illustration will be provided.

### 5.1 On the Impact of Interest rate, Profit Growth and Volatility

The value of  $\theta^*$  is affected by  $\rho$ ,  $\alpha$  and  $\sigma$  through  $\beta$ . Using equation  $\frac{1}{2}\sigma^2\beta(\beta-1)+\alpha\beta-\rho=0$ , it is easy to show that  $\frac{\partial\beta}{\partial\rho}>0$ ,  $\frac{\partial\beta}{\partial\sigma}<0$  and  $\frac{\partial\beta}{\partial\alpha}<0$ . Taking the derivative of (26) with respect to  $\beta$  we obtain (see figure 2)

$$\frac{\partial\theta^*}{\partial\beta} = \frac{1 - \theta^*(1 + \ln \gamma \cdot \gamma^{1-\beta})}{\beta - \gamma^{1-\beta}} \begin{matrix} \geq \\ \leq \end{matrix} 0 \text{ for } \theta^* \begin{matrix} \leq \\ \geq \end{matrix} \tilde{\theta}. \quad (28)$$

where  $\tilde{\theta} = (1 + \ln \gamma \cdot \gamma^{1-\beta})^{-1}$ .

The non-monotonicity of  $\theta^*$  in  $\beta$  reflects how the parties may differently trade off option value and profit share. For instance, studying the impact of volatility, since  $\frac{\partial\beta}{\partial\sigma}<0$ , an increase in  $\sigma$  implies, by (10) and (19), that both investment and nationalization occur later in expected terms. By (28) two possible scenarios may take place. If  $\theta^* < \tilde{\theta}$ , as volatility soars up, MNC prefers to invest later when profits are high enough and may accept a lower share. This in turn lightens the nationalization threat. In this case, HC is compensated with a larger share for the postponed investment and thereby have a less valuable option to expropriate. Instead, when  $\theta^* \geq \tilde{\theta}$ , to encourage earlier investment the local government agrees on a larger  $\theta^*$  to MNC. However, note that a larger share makes the option to nationalize more tempting and lowers the threshold for its exercise.

On the contrary, as  $\alpha$  rises both  $\pi_N$  and  $\pi_I$  decrease, implying respectively earlier nationalization and investment. In the bargaining room the parties may have different deals. Since  $\frac{\partial\beta}{\partial\alpha}<0$ , if  $\theta^* < \tilde{\theta}$ , MNC relying on a faster profit growth prefers to wait and agree on taking a smaller share. Instead, if  $\theta^* \geq \tilde{\theta}$  HC wants to push the investment and would accept a lower share to induce it. This is needed to compensate MNC for the option value given up and for the more severe threat of nationalization. However, this loss is balanced by the higher profit growth and a more valuable option to nationalize.

Finally, discounting at a higher interest rate  $\rho$  induces earlier nationalization and investment. Again the parties must trade off option value and profit share. Since  $\frac{\partial\beta}{\partial\rho}>0$ , if  $\theta^* < \tilde{\theta}$ , HC is more impatient and accept a lower share to induce investment. Even if nationalization takes place earlier in expected terms, the attached pay off is discounted at an higher rate and has less weight when compared with profits from the joint venture. On the contrary, if  $\theta^* \geq \tilde{\theta}$ , MNC takes a smaller share to postpone investment and increase the value of keeping



open the option to expropriate once the investment is undertaken.

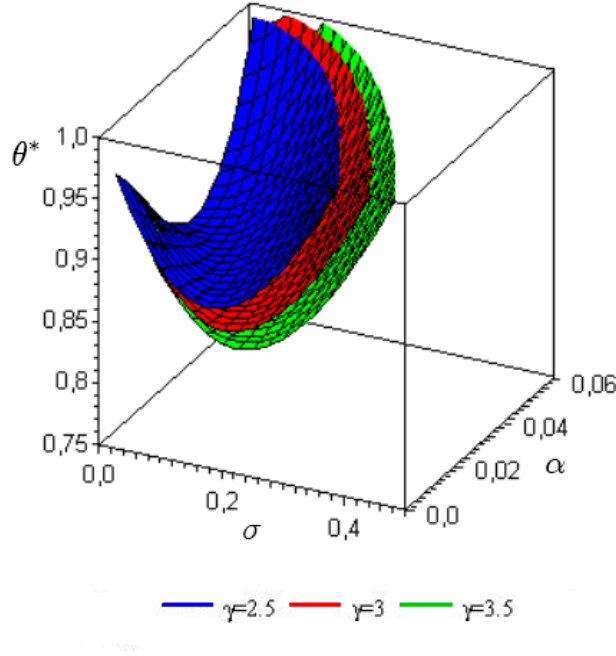


FIGURE 2:  $\rho = 0.1, \eta = 1$

To conclude, let us state some limit results

- (a) as  $\sigma \rightarrow \infty$  then  $\beta \rightarrow 1$  and thus both  $\pi_N \rightarrow \infty$  and  $\pi_I \rightarrow \infty$ . Due to high uncertainty on future profit prospects the threat of nationalization vanishes. However, high uncertainty affects also the timing of investment which is never undertaken;
- (b) if  $\alpha > 0$  and  $\sigma \rightarrow 0$  then  $\beta \rightarrow \rho/\alpha$ ,  $\pi_I \rightarrow \frac{\rho}{\theta}I$ ,  $\pi_N \rightarrow \frac{\rho}{\theta}N$  and

$$\theta^* = 1 - \alpha \frac{\frac{\eta}{\eta+1} + \gamma^{-\frac{\rho-\alpha}{\alpha}}}{\rho - \alpha \gamma^{-\frac{\rho-\alpha}{\alpha}}};$$

- (c) if  $\alpha \leq 0$  and  $\sigma \rightarrow 0$  then  $\beta \rightarrow \infty$ ,  $\pi_I \rightarrow \frac{\rho-\alpha}{\theta}I$ ,  $\pi_N \rightarrow \frac{\rho-\alpha}{\theta}N$  and  $\theta^* = 1$ . Since as  $\beta \rightarrow \infty$  then  $\gamma^{1-\beta} \rightarrow 0$ , the domain,  $\frac{\beta-1}{\beta-\gamma^{1-\beta}} < \theta^* < 1$ , collapses and the bargaining fails. The two value functions in (12) and (21) become linear and this implies that MNC and HC propose only not conciliable requests.

## 5.2 On the Impact of Risk Aversion

Taking the derivative of (26) with respect to  $\eta$  we obtain  $\frac{\partial \theta^*}{\partial \eta} = -\frac{1}{(\beta - \gamma^{1-\beta})(\eta+1)^2} < 0$ . It follows that  $\frac{\partial \theta^*}{\partial p} = \frac{1}{q} \frac{\partial \theta^*}{\partial \eta} < 0$ ,  $\frac{\partial \theta^*}{\partial q} = -\frac{\eta}{q} \frac{\partial \theta^*}{\partial \eta} > 0$  and  $\frac{\partial^2 \theta^*}{\partial p \partial q} = \frac{\partial^2 \theta^*}{\partial q \partial p} = -\frac{p-q}{(\beta - \gamma^{1-\beta})(p+q)^3}$  (see figure 3). This result can be explained by the disadvantage that the more risk adverse party has in bargaining (see e.g. Roth, 1989). In fact, keeping  $q$  constant and letting  $p \rightarrow 1$ , HC becomes less risk averse and a higher share  $1 - \theta^*$  is required to have a deal. The same effect applies as  $q \rightarrow 1$ .

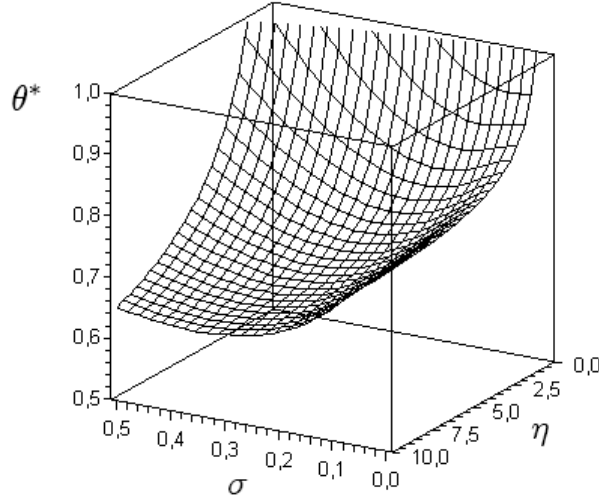


FIGURE 3:  $\rho = 0.1$ ,  $\gamma = 3$ ,  $\alpha = 0.025$

## 5.3 On the Impact of Nationalization Cost

An increase in  $\gamma$  makes nationalization more costly in relative terms and as expected  $\frac{\partial \theta^*}{\partial \gamma} = -\theta^* \frac{\beta-1}{\beta-\gamma^{1-\beta}} \gamma^{-\beta} < 0$ . Hence, if the threat of nationalization is less severe MNC accepts a lower share.

Taking the limit for  $\gamma \rightarrow \infty$ ,  $\theta^*$  decreases and tends to

$$\hat{\theta} = 1 - \frac{1}{\beta} \frac{\eta}{\eta + 1}. \quad (28)$$

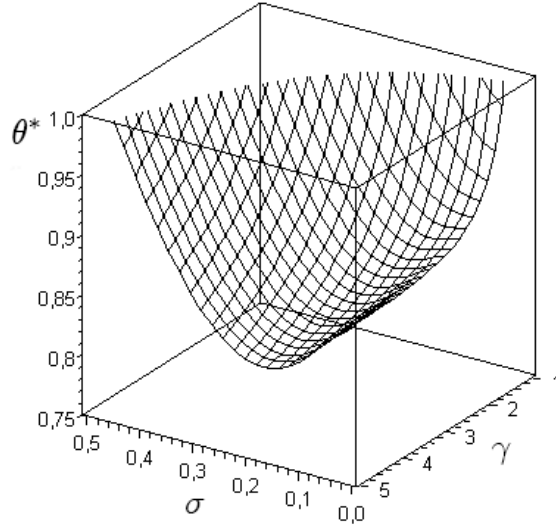


FIGURE 4:  $\rho = 0.1$ ,  $\eta = 1$ ,  $\alpha = 0.025$

Comparing (28) with (26), we note

$$\theta^* - \hat{\theta} = \frac{\gamma^{1-\beta}}{\beta - \gamma^{1-\beta}} \hat{\theta}, \quad (29)$$

and we can state that

**Proposition 3** *Under the threat of nationalization the share of profits accruing to MNC is always higher than under no threat.*

HC must pay a premium to induce investment under the threat of nationalization. However, changing perspective another interesting explanation could be given to the wedge in (29). MNC is aware that by investing an option to expropriate is open. This is kept into account during the bargaining process. Once agreed on the shares the two parties have implicitly priced the option to expropriate. Hence, one can view such an option as a part of the compensation paid to HC in addition to the share  $1 - \theta^*$ . In figure 5, we show that the wedge increases as volatility soars up. This can be explained by a more valuable option to expropriate held by HC at the investment timing.<sup>30</sup> The wedge reduces as  $\eta$  increases. As anticipated above, this is due to the advantage that less risk adverse parties have in bargaining.

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<sup>30</sup>See appendix A.2.

Finally, some limit results from (28) are:<sup>31</sup>

(i) as  $\sigma \rightarrow \infty$  then  $\beta \rightarrow 1$  and  $\pi_I \rightarrow \infty$ . The investment is not undertaken due to high uncertainty on  $\pi_t$ ;

(ii) if  $\alpha > 0$  and  $\sigma \rightarrow 0$  then  $\beta \rightarrow \frac{\rho}{\alpha}$ ,  $\pi_I \rightarrow \frac{\rho}{\theta} I$ . This implies that

$$\hat{\theta} = 1 - \frac{\alpha}{\rho} \frac{\eta}{\eta + 1}.$$

As  $\sigma \rightarrow 0$  the frame becomes deterministic. The sharing rule is shaped by the profit drift rate,  $\alpha$ , the discount rate,  $\rho$ , and by relative risk aversions. In this case, the following results hold

$$\frac{\partial \hat{\theta}}{\partial \alpha} < 0, \quad \frac{\partial \hat{\theta}}{\partial \rho} > 0, \quad \frac{\partial \hat{\theta}}{\partial p} < 0, \quad \frac{\partial \hat{\theta}}{\partial q} > 0;$$

(iii) if  $\alpha \leq 0$  and  $\sigma \rightarrow 0$  then  $\beta \rightarrow \infty$ ,  $\pi_I \rightarrow \frac{\rho - \alpha}{\theta} I$  and  $\hat{\theta} = 1$ . Here, the same interpretation as in (c) applies.

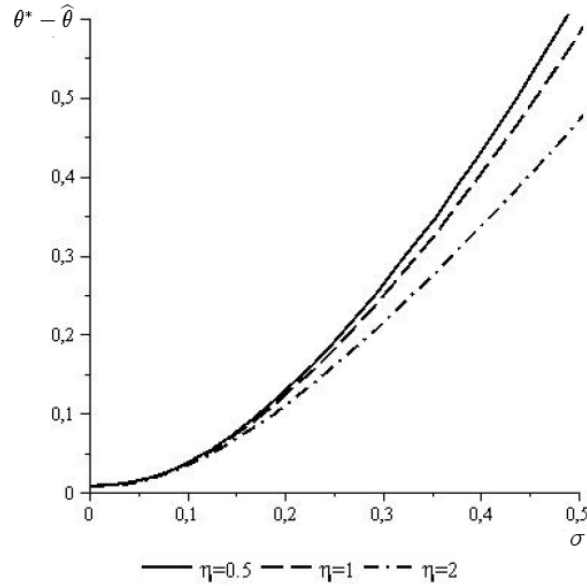


FIGURE 5:  $\rho = 0.1$ ,  $\gamma = 3$ ,  $\alpha = 0.025$

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<sup>31</sup>Note that the bargaining outcome would lead to  $\hat{\theta}$  in two other cases. First, if the local government was able to credibly commit not to nationalize, second if HC totally compensates MNC for the value expropriated.

## 5.4 Numerical Solution

We now illustrate the results above through a numerical solution. Let us normalize the investment cost to  $I = 1$ , and set the cost of nationalization  $N = 3$ , and the discount rate  $\rho = 0.1$ . In figures 6a and 6b, for profit growth rates  $\alpha = 0.025$  and  $\alpha = 0$ , we plot the sharing rule  $\theta^*$  for different values of profit volatility ( $\sigma$ ). In addition, to stress again on the role of relative risk aversion in bargaining, we show its impact on  $\theta^*$  for three different scenarios. As  $\eta$  increases, HC is becoming less risk averse than MNC, and is therefore entitled to a larger share,  $1 - \theta^*$ , of the profit flow. Note, that for  $\eta = 1$ , any asymmetry is present being either parties equally risk averse or both risk neutral. In this case the profit share is only affected by the asymmetrical charge in terms of risk-taking. Focusing on  $\sigma$ , the duality marked in (28) is straightforward.

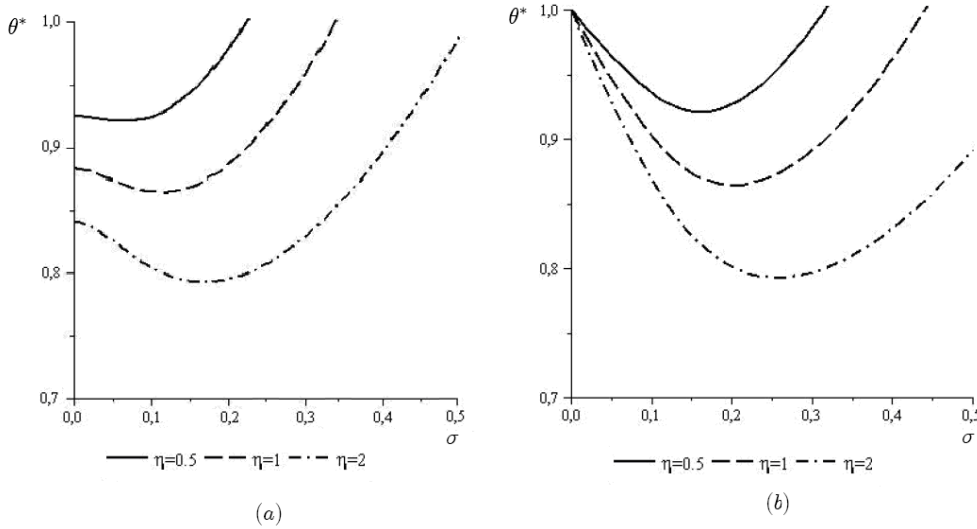


FIGURE 6:  $\rho = 0.1$ ,  $\gamma = 3$ , (a)  $\alpha = 0.025$ , (b)  $\alpha = 0$

Let us run (26) for  $\alpha = 0.025$ ,  $\sigma = 0.2$  and  $\eta = 1$ . Under these assumptions, MNC takes approximately the 89% of each unit of profit and leaves the rest to HC. Plugging the assumed parameters into (10) and (19) we respectively determine the thresholds for investment,  $\pi_I \simeq 0.16$ , and nationalization,  $\pi_N \simeq 0.43$ .

In figure 7, the value function,  $H(\pi, \theta^*)$ , and the net present value of nationalization,  $NPV(\pi, \theta^*) = V(\pi) - N$ , are plotted. Holding the option to nationalize up to  $\pi_N$  is valuable as shown by the gap between the two functions. Note also that even if continuous,  $H(\pi, \theta^*)$  is not differentiable at  $\pi_I$ . This is due to the option to nationalize being conditional on the investment.

To complete our illustration we draw in figure 8 the value function,  $M(\pi, \theta^*)$ , and the net present value of investment,  $NPV(\pi, \theta^*) = \theta^* \left[ V(\pi) - V(\pi_N) \left( \frac{\pi}{\pi_N} \right)^\beta \right] - I$ . Again, to keep the option open up to  $\pi_I$  is valuable. Let analyse the impact of nationalization on the net present value. This impact is absolutely clear for  $\pi \geq \pi_N$  where the investment would

be instantaneously expropriated and result in a loss equal to  $-1$ . Now, note that under no threat  $NPV(\pi, \theta^*) = \theta^* V(\pi) - I$  which is linear and increasing in  $\pi$ . The effect of the threat of nationalization is then shown by the curvature of  $NPV(\pi, \theta^*)$ . As  $\pi$  approaches  $\pi_N$ , a more likely nationalization lowers the net present value from investment. This results in a negative  $NPV(\pi, \theta^*)$  for some  $\pi_I < \pi < \pi_N$ .

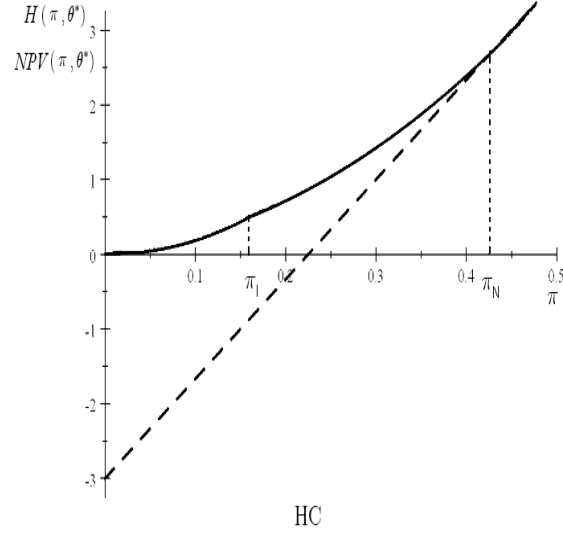


FIGURE 7:  $\theta^* = 0.8868060187$ ,  $\pi_I = 0.1604535594$ ,  $\pi_N = 0.4269609891$   
 $\rho = 0.1$ ,  $\alpha = 0.025$ ,  $\gamma = 3$ ,  $\eta = 1$ ,  $\sigma = 0.2$ ,  $I = 1$

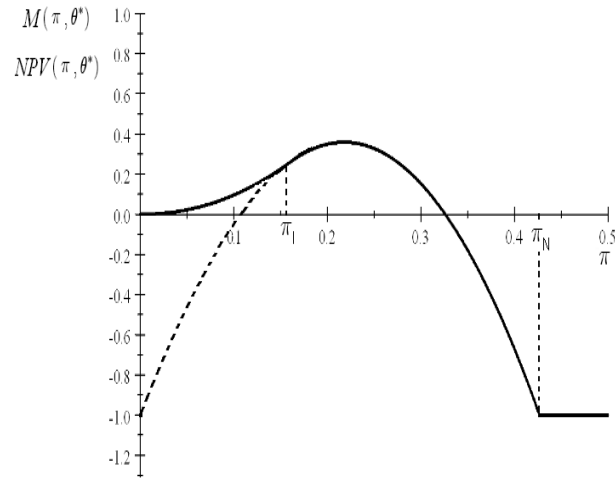


FIGURE 8:  $\theta^* = 0.8868060187$ ,  $\pi_I = 0.1604535594$ ,  $\pi_N = 0.4269609891$   
 $\rho = 0.1$ ,  $\alpha = 0.025$ ,  $\gamma = 3$ ,  $\eta = 1$ ,  $\sigma = 0.2$ ,  $I = 1$

## 6 Conclusions

The exploitation of natural resources in developing countries can support their economic growth and fund social welfare improvements. Often, in the presence of funding constraints and lack of technological skills the activation of extractive projects may be problematic. In this case, local governments can benefit from joint ventures with multinational corporations offering capital and technology.

Unfortunately, high political hazard may limit joint venture formation. The abuse of national sovereignty concept to support the existence of a right to expropriate or nationalize foreign investment weakens the legal frame regulating contractual agreements. In the lack of a credible commitment, expropriation and nationalization may be a temptation hard to resist when profits are high and local governments are under populist pressure for profit redistribution. International sanctions and the fall of future FDI may limit but not deter this opportunistic behaviour.

In this paper these conflicting and mutual economic interests have been considered. We have proposed a model where cooperative bargaining meets the real option approach. Both parties hold an option, respectively on investment and nationalization. Both decisions are characterized by uncertain pay-offs and irreversibility. Hence, accounting for market uncertainty and additional political risk we shape and fully characterize a Nash bargaining solution inducing foreign investment.

We believe that this framework should be extended at least in two respects. First, we have considered only the case where the government takes all the "cake". It would be interesting to apply our frame to analyse the more subtle threat of "creeping expropriation".<sup>32</sup> That is, the increasingly common practice by which, after an agreement has been signed, governments violate its terms imposing a change in MNC's profit taxation, import or export duties, stricter environmental and labour regulations. As one can easily see, the main issue with creeping expropriation is to distinguish between the legitimate exercise of government prerogatives and a clear act of expropriation.

Second, the analysis can be extended to account for government time inconsistency. Time inconsistency may be due to changing time preferences (see Strotz, 1956). This can be a consequence of short political cycles for democratic governments.<sup>33</sup> Each government in power to magnify the probability of re-election needs to please the currently living political body. This consideration modifies the time preferences which may show a certain bias for the present and induce rush on decisions which entails present benefits in front of future costs. A similar issue may arise also when dictatorship are considered. In this case the point becomes to maximize the probability of conserving the power feeding populism to deter political opposition.

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<sup>32</sup>On the impact of creeping expropriation on FDI see Schnitzer (1999) and (2002).

<sup>33</sup>See Amador (2004) where political turnover can induce hyperbolic preferences for governments.

## A Appendix

### A.1 Optimality of $\theta^*$

The second order condition for the optimality of  $\theta^*$  requires  $\frac{\partial^2 \nabla}{\partial \theta^2} |_{\theta^*} < 0$ . Using (25) and rearranging this is equivalent to

$$-\left[ \frac{\left( \frac{dH(\pi_I, \theta^*)}{d\theta} \right)^2}{H(\pi_I, \theta^*)} - \frac{dH^2(\pi_I, \theta^*)}{d\theta^2} \right] < -\frac{\frac{dH(\pi_I, \theta^*)}{d\theta}}{\frac{dM(\pi_I, \theta^*)}{d\theta}} \left[ \frac{\left( \frac{dM(\pi_I, \theta^*)}{d\theta} \right)^2}{M(\pi_I, \theta^*)} - \frac{dM^2(\pi_I, \theta^*)}{d\theta^2} \right]. \quad (\text{A.1.1})$$

Since  $\theta^* > \frac{\beta-1}{\beta-\gamma^{1-\beta}}$  it follows

$$\frac{\frac{dH(\pi_I, \theta^*)}{d\theta}}{\frac{dM(\pi_I, \theta^*)}{d\theta}} = \frac{\beta - \theta^* (\beta - \gamma^{1-\beta}) - 1}{\theta^* (\beta - \gamma^{1-\beta})} < 0.$$

Finally, to prove that (A.1.1) holds it suffices to show that

$$\frac{dH^2(\pi_I, \theta^*)}{d\theta^2} < 0 \text{ and } \left( \frac{dM(\pi_I, \theta^*)}{d\theta} \right)^2 > M(\pi_I, \theta^*) \frac{dM^2(\pi_I, \theta^*)}{d\theta^2}.$$

Proposition (1) implies  $1 - \theta^* \gamma^{1-\beta} > 0$ . In addition, since  $\theta^* > 1 - \frac{1}{\beta}$  then  $\beta(1 - \theta^*) - 1 < 0$ . Using these results the first inequality is verified being

$$\frac{\beta}{I} \left( \frac{\pi}{\pi_N} \right)^\beta \left[ \frac{\beta(1 - \theta^*) - 1}{\theta^*} - \left( \frac{1}{\theta^*} - \gamma^{1-\beta} \right) \right] \left( \frac{1}{\theta^*} \right)^2 < 0.$$

Rearranging on both sides the second inequality it follows

$$\begin{aligned} \left( \frac{\beta}{\beta-1} \right)^2 \frac{1 - \beta\gamma^{1-\beta}}{I} &> \frac{\beta}{\beta-1} \frac{1 - \beta\gamma^{1-\beta}}{I} \\ \frac{\beta}{\beta-1} &> 1. \end{aligned}$$

### A.2 Impact of Volatility on the Option to Nationalize

According to (12) the option to nationalize at  $\pi = \pi_I$  is worth  $[\theta V(\pi_N) - N] \left( \frac{\pi_I}{\pi_N} \right)^\beta = \frac{N}{\beta-1} \left( \frac{I}{N} \right)^\beta$ . The derivative of its value with respect to  $\sigma$  is given by

$$\frac{\partial \left[ \frac{N}{\beta-1} \left( \frac{I}{N} \right)^\beta \right]}{\partial \sigma} = -\frac{N \left[ 1 - \frac{\ln(I/N)}{\beta-1} \right] \left( \frac{I}{N} \right)^\beta}{(\beta-1)^2} \frac{\partial \beta}{\partial \sigma} > 0.$$



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