5 Optimal Resource Extraction Contracts under Threat of Expropriation

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We have nationalized copper by unanimous decision of Parliament, where the parties supporting the government are in the minority. We want the whole world to understand that we have not confiscated the large foreign mining companies. In keeping with a constitutional amendment, we have redressed an historical iniquity by subtracting from the compensation due to the firms, the profits accrued since 1956 that are in excess of a 12% annual rate.

The profits of some of the nationalized firms were so outrageous that when applying the reasonable annual profit rate of 12%, their compensations were subject to substantial deductions.

—Salvador Allende, speech to the United Nations, December 4, 1972

5.1 Introduction

Natural resource–rich countries are prone to expropriating investors in those sectors in good times, when prices of resources are considerably above the long-run average price. The temptation for governments is large, because in the future prices will be lower, and thus any punishment by investors in terms of reduced future investment is low relative to the immediate gains of expropriation. Moreover, the short time frame of democratic governments also leads to high discounting of future losses of investment. Apart from these considerations, profits under a bonanza may be so high that populist pressures for redistribution can compel governments to act. Hence in recent years, high commodity prices have led to outright expropriation or to sectoral tax increases, which also amount to a form of expropriation.[1]

This type of behavior is especially common in industries with large sunk investments, such as oil and mining. These plants normally operate at capacity, except when prices are so low that they shut down. Therefore, it is especially galling for the public when profits rise substantially, without change in output, solely because of higher international prices. If the investors are foreign and have little political support, it seems to the public that they are exploiting the generous conditions offered them.[2] In addition, the investments are sunk, so it appears to be a case of there being little or no cost to the government from expropriation.

We therefore observe a cycle in which, when prices are high, investors receive less than the amounts stipulated in their contracts, and when prices are low, they are offered especially favorable conditions to induce them to invest. These special conditions are not credible, since investors realize that they will be expropriated—or at least receive smaller profits than would have existed under the original contracts—when times are good again. The resulting policies lead to lower investment than under certainty, and of a stop-go variety, which is inefficient.[3]

The boom in natural resources that continued in 2007 is an example: Venezuela, Ecuador, and Bolivia have expropriated investors, Peru imposed "voluntary contributions" worth US$757 million, and Chile (before the rise in prices) imposed a small royalty. Even developed countries have used windfall taxes (the United States imposed an oil windfall tax post-1973) or increasing royalties (Australia, Canada, and the United Kingdom) after perceived increases in profits in the natural resource sector.

The standard mining contract does not provide for the possibility of expropriation. From the point of view of the foreign investor, it is an additional risk of investment. Attempts have been made to introduce profit-sharing mechanisms to reduce the temptation to expropriate, but in practice they are often abused by transfer pricing, creating a negative effect on public opinion, which in turn increases the probability of expropriation.

Hence it appears that the appropriate contracts for this type of environment are different from those currently in use. It is possible to describe hypothetical scenarios where all parties, including the foreign investor, are better off if the contract is such that taxes paid by the firm are highly progressive, since this may lower the probability of expropriation in high price scenarios (by reducing the gains from expropriation), while increasing the expected profits of the firm, because of the reduced risk of expropriation. And even if firm's rents are dissipated through some competitive mechanism, the deadweight loss associated with expropriations may be reduced through such a contract.

The object of this chapter is to present a family of models that formalize this intuition by proposing an environment in which expropriations cannot be ruled out, because of ex post political pressures. We derive general conditions that characterize the optimal ex ante contract, in the sense that the government maximizes social welfare under the threat of expropriation. We also show how the optimal contract can be implemented using a competitive auction.

In our model, the government has a natural resource project that requires up-front sunk investment, as in the case of a mining or oil extraction project. Since the problem of expropriation usually arises with foreign investment, profits are not included (or have a lower weight) in the welfare function of the planner, and because the good is not consumed at home but exported, the government only cares about the revenues it can obtain from the project.

The present value of raw profits of the project (i.e., if we disregard the possibility of expropriation) depends on the price, which is random, so profits are described by a probability density.[4] In a dynamic model, governments are replaced by newer governments that do not necessarily respect the commitments of previous governments, or they may be subject to political pressures that make them renege on previous agreements to not expropriate, or to renegotiate natural resource contracts. We deal with these sources of dynamic inconsistency in our model via a reduced form: we assume that there is a predefined function, known to all parties, of the probability of expropriation, which depends on the firm's present discounted profits.[5]

We assume that the expected value of profits in each state (i.e., given the possibility of expropriation) increases with raw profits, but at a decreasing rate. Furthermore, we assume that expropriations cause a deadweight loss that is proportional to the firm's loss—that is, to the difference between contractual and effective profits. This deadweight loss can be interpreted as a measure of the country's respect for property and contract law. In a country in which contracts are broken continually, there is little trust in them and firms cannot impose a large cost on government when they are expropriated. On the other hand, countries where contract and property rights are respected are those where firms can impose a large cost on the government when they are expropriated.

The question for the planner is to determine a contractual profit schedule for the firm that depends on the present value of raw profits and the expropriation function, subject to a participation constraint: given the known expropriation probability, the investor must at least break even on its investment. Initially, we assume that there is no unobservable effort the firm can exert to increase profits (i.e., there is no moral hazard in effort), or to reduce the probability of expropriation (no political moral hazard).

In the simple setup without moral hazard, we show that a contract that eliminates all risk for the firm, while granting it no rents, is optimal in the case in which operating profits cover investment costs in all states of demand in finite time (*high-demand* scenario). The optimal contract then entails no expropriation. On the other hand, if the project cannot be financed using a transfer schedule that avoids expropriations, a case we refer to as an *intermediate-demand* scenario, the optimal contract is characterized by a cap on the firm's present discounted revenues. This cap is not binding in low-demand states, and the firm collects all revenue in those states. By contrast, in high-demand states all revenues above the cap accrue to the government. The threshold is chosen so that ex ante expected profits, net of expropriation, are zero.[6] In an ordinary natural resource contract, the firm would receive all of the upside in the good states, making it prone to expropriation. In the optimal contract, there is an upper bound to the operating profits of the firm, and this reduces, by the optimal amount, the probability of expropriation in high-demand states. Note that this is equivalent to a windfall tax, because in the good states, the residual revenues go to the government.[7] In both the high- and intermediate-demand cases the optimal contract can be implemented via an auction where firms bid on the maximum present value of operating profits they would obtain in the good states of the world, and the minimum bid wins the auction. The planner does not need to know the expropriation probability or the firm's sunk investment cost in order to implement this auction.[8]

We extend the model in several directions. First we consider the possibility that the government provides subsidies in the bad states of the world. Second, we extend the model to the case of moral hazard in effort—that is, when the firm can exert costly effort that increases the probability of the good states of the world (the price distribution mentioned above now becomes a distribution of net revenue where marginal costs depend on effort exerted by the investor up front). Finally, we consider the possibility that the firm can exert effort to reduce the probability of expropriation (by lobbying, targeted social expenditures, and so on) and consider the optimal contract in that case.[9]

Subsidies in bad states are not unusual in countries characterized by a probability of expropriation in the good states of the world. These subsidies usually cost society more than they benefit the firm, as in the case in which they involve relaxing environmental or labor regulations in bad states of the world.[10] We find that the optimal contract with distortionary subsidies involves a minimum operating profit guarantee coupled to a maximum bound to profits: the government subsidizes the firm in the worst states (in which there is no expropriation), sets a maximum value to operating profits in the good states of the world, and has an intermediate range of states where the firm receives all the revenue generated by the project, but is not subsidized.

In the case of moral hazard in effort, effort influences the results of the project, by reducing marginal costs throughout the life of the project. In a mining project, for example, as the grade of the ore declines, marginal costs tend to increase until they become higher than operating costs, and the mine closes down. By reducing marginal costs, the amount of minerals extracted before the mine has to close down is higher, and this is more valuable when prices are high. Here the optimal contract does not set a fixed cap on the operating profits of the firm, since that would lead to insufficient effort. Nevertheless, as in the benchmark model, the optimal contract lowers the firm's profits, as compared to the standard contract in high-demand scenarios. In this case it does so by imposing a schedule similar to progressive taxation when operating profits exceed predetermined values. Thus, the government trades off the deadweight cost associated with expropriation in high-revenue scenarios, while providing incentives that increase their likelihood.[11]

We also consider the case in which the firm faces political moral hazard and can exert costly effort to reduce the probability of expropriation. The optimal contract is similar to that in the simpler case with no political moral hazard. It stipulates that in bad states the firm operates the franchise forever, while in better states the contract lasts until a fixed amount of operating profits, common to all these states, is collected. The reason is that, in contrast to the case of moral hazard in effort, here effort affects the probability of expropriation across states, but does not increase the probability of higher-income states. Hence there is no conflict between reducing the probability of expropriation by limiting contracted profits and providing incentives in order to increase the probability of higher-income states.

Finally, we come to the issue of implementation. It would be politically infeasible to have a contract in which the government collects nothing while accumulated profits are lower than the limiting amount of profits, and receives all the residual afterward, with all the attendant complications for the government of operating the mine. Consider then the following schematic proposal to determine the windfall tax in a given period. Each period, an independent agency makes the best estimate of future discounted profits given current information. This estimate plus the profits accrued and taxes already paid leads to an estimate of the present value of taxes that needs to be paid in the future so as to comply with the contract. The firm then pays a tax proportional to this amount—for example, the fraction that, if paid indefinitely, would lead, in expectation, to paying the windfall tax stipulated in the contract. In the absence of uncertainty about future profits, this tax rate leads to a tax burden that remains constant over time. Given the existence of uncertainty, it may be desirable to have a lower tax rate, set so that the probability of the firm earning less than the contracted amount is a predetermined and small value.

The remainder of the chapter is organized as follows. In the next section, which can be skipped without loss of continuity, we relate this chapter to the literature. Section 5.3 describes the basic model and derives the main results, including how to implement the optimal contract with a competitive auction with realistic informational assumptions. Section 5.4 considers various extensions. The last section concludes.

5.2 Relation to the Literature

There is an extensive literature on optimal taxation of exhaustible natural resources to which this chapter is related (see Heaps and Helliwell 1985, Gillis 1982, and Boadway and Flatters 1993 for classical references).[12] Also related to this chapter is Bohn and Deacon 2000, which explores both theoretically and empirically the effects of insecure ownership on investment and natural resource use. They show that investment falls with insecure ownership and therefore the net effect on depletion of natural resources is ambiguous. Finally, Fraser and Kingwell 1997 compares the performance of resource rent taxes and ad valorem royalties on investment levels, but the effects the authors describe are due to risk aversion, whereas in our case the investors are risk neutral.

There are two justifications to tax resource rents over and above the levies implicit in general income taxes. One is the efficiency-based argument that resource rents are not distorting (but note that this argument requires positive ex ante and not ex post rents). The other reason is an equity-based argument that suggests that natural resource rents should accrue to the population at large, not to a few private individuals. We assume that the private firm is paid no rent at all when solving the planner's problem (i.e., rents receive no weight in the social welfare function), which is consistent with the assumption that the firm is foreign. However, the characteristics of the optimal contract remain unchanged when the planner weighs firm's profits in the objective function, as long as this weight is not too large (see Result 3 for a formal statement).

Our contribution to this literature is to incorporate, in admittedly reduced reform, the probability of expropriation and the deadweight loss associated with this event into the planner's objective function. Also, in contrast to most of that literature, the taxes that are implicit in our contract are on the present value of firm's profits, and not on flow profits—that is, we assume away the dynamic issues. This simplifies our analysis considerably and explains why we can implement the planner's optimal contract via a competitive auction with realistic informational requirements.

As noted by Boadway and Flatters (1993), there are three "ideal" approaches for government to divert rents to the public sector. One approach is a full-fledged cash flow tax, which implies that tax liabilities will be negative at initial stages of exploitation of the natural resource, making governments reluctant to adopt this option. A second approach is that the government takes a share of equity in the firm. The third approach is for governments to capture rents by having firms bid for the rights to exploit the resource. The winning firm provides an up-front payment in exchange for the perpetual right to extract the resource. This option is not credible, precisely because of the time inconsistency in government policy—that is, because of ex post expropriation. The policy proposals that emerge from this chapter lie within this third group, even though the bidding variable that implements the planner's optimal contract is the firm's present discounted profit. This has the advantage that no up-front payments by the firm to the government are needed, but motivates extending our model to incorporate moral hazard, since the firm's incentives to extract the resource efficiently are reduced by the fact that under our contract it is not the residual claimant of revenues generated by the contract.[13]

The planner's problem considered in this chapter has much in common with the problem facing the planner who designs the optimal public-private partnership contract in Engel, Fischer, and Galetovic 2007, and therefore the results we obtain share the flavor of the results obtained in that paper as well. Interestingly, we do not need to assume a risk-averse firm here, since the possibility of expropriation combined with a deadweight loss associated with expropriations leads the planner to view a risk-neutral firm's behavior as if it were risk averse, at least for high-demand realizations.

5.3 The Main Model

A natural resource project ("mining project" in what follows) requires a fixed amount of up-front investment I common across firms. The present value of operational profits generated by the project are described by a probability density $f(v)$, with support $[v_{\min}, v_{\max}]$ and c.d.f. $F(v)$. Operational profits are equal to revenue minus operating costs minus standard income taxes; in what follows we refer indistinctly to *revenues* and *operational profits*. The density f summarizes exogenous price uncertainty—that is, the project sells its product in a large world market over which it has no influence.[14]

A contract is characterized by a schedule $R_c(v)$ that defines the firm's present discounted remuneration as a function of discounted revenues generated by the project, v; the subscript c emphasizes that this is the remuneration stipulated in the contract, thereby ignoring the possibility that the contract will be cut short by expropriation and realized revenues may be lower. The only source of remuneration for the firm are revenues generated by the project, therefore $0 \leq R_c(v) \leq v$. The government is the residual claimant of revenues generated by the project, so that, according to the contract, in state v it receives $v - R_c(v)$.[15]

At the time of contracting, expropriations are random events, both as to when they happen and as to the amount expropriated. Because of this, in state v, the firm may end up receiving present discounted profits that can lie anywhere between $-I$ (when the government expropriates all its revenue) and $R_c(v) - I$ (when no expropriation takes place). Since the government and the firm are risk neutral, all we need to know about expropriations is expected profits that accrue to the firm in state v *after* expropriation. We denote this function by $\Pi_e(R_c(v) - I)$, and refer to it as the *effective profit* function. In general, $\Pi_e(x)$ denotes the present value of the firm's expected ex post discounted profits, when the contract entitles it to profits equal to x. This function summarizes, admittedly in reduced form, all the (common) knowledge available to the planner and the firm about future expropriation scenarios when signing the resource extraction contract. Will the next president be market friendly or a diehard nationalist? And if she turns out to be a diehard nationalist, will the firm be successful bribing the upcoming administration to avoid expropriation?

In this section Π_e is determined exogenously—that is, the current planner and firm's actions have no effect on this function.[16] We make the following assumptions regarding this function:

Assumption 1 (Effective Profit Functions) The effective profit function, $\Pi_e(x)$, has a continuous second derivative, and there exists an $x_E \geq 0$, referred to as the *expropriation threshold*, that satisfies

1. $\Pi_e(x) = x$ for $x \leq x_E$.
2. $\Pi_e'(x) > 0$ and $\Pi_e''(x) < 0$, for all $x > x_E$.

The first property says that there exists a threshold for effective profits below which expropriation cannot take place: expropriations are possible only when discounted profits are positive, larger than x_E.[17] The second property implies that, beyond this threshold, the firm's effective profit increases with the discounted profits it is entitled to according to the contract, albeit at a decreasing rate.

The above properties assume that expropriation depends on the profit rate—that is, on $(R_c(v) - I)/I$, which is linear in $R_c(v)$. The quote at the beginning of this chapter, from Salvador Allende's 1972 speech at United Nations, is consistent with this assumption. If the firm earns five times its investment, so that its profit rate is 400 percent, it expects to lose a much larger fraction of its profit because of expropriation than if its profit rate is only 20 percent. This is captured by the first assumption. Furthermore, if the firm expects to lose half of every additional dollar generated by the project when the profit rate increases from 200 to 210 percent due to expropriation, then the second assumption implies that it will grab more than half of every additional dollar of profit when the profit rate goes from 210 to 220 percent.

Our final assumption relates to the cost of expropriations. We assume that when a mining project is expropriated, the firm challenges the decision in (possibly international) court, thereby imposing a cost on the government of defending itself. This deadweight loss is a fraction μ of the expropriated value of the project, where $0 < \mu < 1$.[18]

5.3.1 Planner's Problem

In the benchmark model there is no moral hazard, and therefore no need to provide incentives for performance. In order for firms to be willing participants in the project, the contract offered by the planner must satisfy the firm's participation constraint:

$$\int \Pi_e(R_c(v) - I) f(v)\, dv > 0.$$

Since the government is the residual claimant of revenues generated by the mining project, in state v its expected revenue is the difference between net (of investment) revenues generated by the project, $v - I$, and profits accrued to the firm, $\Pi_e(R_c(v) - I)$:

$$\text{Expected government revenue} = v - I - \Pi_e(R_c(v) - I),$$

while the average loss to the firm due to expropriation is the difference between profits it was entitled to in the contract and actual profits:

$$\text{Revenue loss for the firm due to expropriation}$$
$$= R_c(v) - I - \Pi_e(R_c(v) - I).$$

Because of the deadweight loss mentioned above, only a fraction $(1 - \mu)$ of the revenue lost by the firm due to expropriation is received by the government, hence the planner maximizes

$$\int [v - I - \Pi_e(R_c(v) - I) - \mu\{R_c(v) - I - \Pi_e(R_c(v) - I)\}] f(v)\, dv.$$

And because the term $\int (v - I) f(v)\, dv$ is independent of the actions of the government, the planner's problem is equivalent to solving

$$\min_{R_c(v)} (1 - \mu) \int \Pi_e(R_c(v) - I) f(v)\, dv + \mu \int R_c(v) f(v)\, dv, \tag{1a}$$

$$\text{s.t.} \quad \int \Pi_e(R_c(v) - I) f(v)\, dv \geq 0, \tag{1b}$$

$$0 \leq R_c(v) \leq v. \tag{1c}$$

As mentioned above, the effective profit function, Π_e, is exogenous, while the firm's contractual revenue function, R_c, is the planner's decision variable.

It follows from (1a) that the government's objective is to minimize a weighted average of the operating profits effectively received by the firm and those profits it had contracted to pay according to the original contract. The former enters for obvious reasons, since less money for the firm means more money for the government. The latter is more interesting, and reflects the fact that, other things being equal, a contract that promises higher returns to the firm leads to larger losses when the firm is expropriated and therefore larger losses for the government as well.

Note that there is another interpretation, mentioned in the introduction: the higher the cost the firm can impose on the government by challenging the expropriation decision (via a higher μ), the more weight the government gives to the terms of the original contract in the objective function—that is, to $R_c(v)$. In other words, the more secure the property rights of the foreign firm, the more the government concentrates on reducing the contractual profits, while if property rights are insecure (small μ), the government is willing to offer more generous terms in the original contract, since it knows that the costs of expropriation are lower.

5.3.2 Optimal Contract

We first consider projects that can be financed with operating profits below the expropriation threshold (so that, if desired, they could be financed avoiding any risk of expropriation) and show that the optimal contract indeed considers no expropriation. When the firm's participation constraint can be satisfied without incurring an expropriation risk, any contract that avoids expropriation altogether and for which the firm's participation constraint is satisfied with equality is optimal (these are the *high-demand* projects we referred to in the introduction). Expropriation *should* be avoided when it *can* be avoided.

Result 1 (Projects Where Expropriation Can Be Avoided) Denote by x_E the expropriation threshold defined in Assumption 1 above and assume that

$$\int_0^{x_E} vf(v)\,dv + x_E(1 - F(x_E)) \geq I. \tag{2}$$

Then any contract that satisfies the firm's participation constraint with equality and for which $R_c(v) \leq I + x_E$ for all v, is optimal. In particular, the contract with $R_c(v) \equiv I$ is optimal.

Proof The following string of equalities and inequalities shows that the planner's objective function is bounded from below by μI for any schedule $R_c(v)$ that satisfies the firm's participation constraint:

$$
\begin{aligned}
\int R_c(v) f(v)\, dv &= I + \int [R_c(v) - I] f(v)\, dv \\
&= I + \int \Pi_e^{-1}(\Pi_e(R_c(v) - I)) f(v)\, dv \\
&\geq I + \Pi_e^{-1}\left(\int \Pi_e(R_c(v) - I) f(v)\, dv \right) \\
&\geq I + \Pi_e^{-1}(0) \\
&= I.
\end{aligned}
$$

The first and second equalities are trivial. The first inequality follows from Jensen's inequality (Assumption 1 implies that Π_e^{-1} is convex), while the second inequality is justified by the firm's participation constraint. Finally, the last equality follows from the assumption that $\Pi_e(0) = 0$ (which follows from Assumption 1).

Next note that any schedule with $R_c(v) \leq I + x_E$ that satisfies the firm's participation constraint with equality attains a value of μI for the planner's objective function (1a) and therefore is optimal.

Finally, note that the first inequality is strict unless the function $\Pi_e(x)$ is linear in the range of values taken by $R_c(v) \leq I + x_E$. Thus the set of optimal policies derived above is the set of all optimal policies.

■

The intuition for this result is the following: When the planner can design a contract that avoids expropriations and satisfies the firm's participation constraint with equality, this contract is optimal, since it avoids the deadweight loss associated with expropriations altogether. Even though the firm is indifferent between this and a wide variety of contracts where its expected profits, net of expropriation risk, are zero, the planner prefers the contract without expropriations.

The next result analyzes the case in which the expropriation risk is unavoidable (*intermediate-demand* projects according to the introduction). It confirms the intuition that the planner wants this risk to be as small as possible.

Result 2 (Projects with Unavoidable Expropriation) Assume that there exists no contract that avoids expropriation risk altogether—that is,

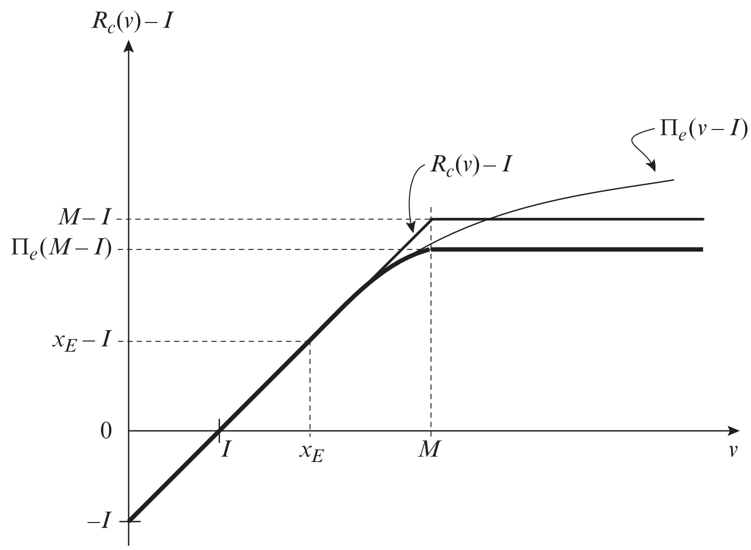

Figure 5.1
The optimal contract in the case where expropriation is unavoidable

$$\int_0^{x_E} vf(v)\,dv + x_E(1 - F(x_E)) < I. \tag{3}$$

Also assume that the firm's participation constraint can be satisfied:

$$\int_0^{\infty} \Pi_e(v - I)f(v)\,dv > 0.$$

Then M defined via

$$\int \Pi_e(\min(M, v) - I)f(v)\,dv = 0, \tag{4}$$

is finite and larger than x_E. More important, $R_c(v) = \min(v, M)$ characterizes the optimal contract (see figure 5.1). That is, operational profits of the firm in the optimal contract are limited to a cap M defined in (4).

Proof Even though a proof based on the problem's Lagrangian and complementary slackness conditions is straightforward, we believe the following informal argument provides more insight.

It is obvious that the firm's participation constraint will hold with equality in the optimal contract. Also, increasing by one dollar the firm's revenues stipulated in the contract in state v increases the firm's expected revenue by $\Pi_e'(R_c(v)-I)f(v)$, while it increases the objective function the planner wishes to minimize by $[(1-\mu)\Pi_e'(R_c(v)-I)+\mu]f(v)$. It follows that the rate at which the objective function increases with the money being collected by the firm is

$$\rho(v, R_c(v)) \equiv (1-\mu) + \frac{\mu}{\Pi_e'(R_c(v)-I)}. \tag{5}$$

The smallest value $\rho(v, R_c(v))$ can take is one, and it takes this value if and only if $R_c(v) \le x_E$ (and $R_c(v)$ is feasible, i.e., $0 \le R_c(v) < v$). The planner first uses up socially cheaper dollars to satisfy the firm's participation constraint—that is, dollars with $\rho(v, R_c(v)) = 1$. If the firm's participation constraint can be satisfied this way, the optimal contract belongs to the family described in the previous proposition.

In the case we are considering here, however, the planner falls short of satisfying the firm's participation constraint after exhausting all transfers from schedules with $\rho(v, R_c(v)) = 1$, and must resort to socially more expensive revenues with $\rho(v, R_c(v)) > 1$. Since Assumption 1 implies that $\rho(v, R_c(v))$ is increasing in $R_c(v)$ for given v, it follows that in the optimal contract

$$\rho(v, R_c(v)) = \begin{cases} \rho_0, & \text{if } \rho(v,v) \ge \rho_0, \\ (1-\mu) + \frac{\mu}{\Pi_e'(v-I)}, & \text{if } \rho(v,v) < \rho_0, \end{cases}$$

where ρ_0 is chosen to satisfy the firm's participation constraint with equality. The optimal contract now follows immediately, with M defined via $\rho_0 = (1-\mu) + \mu/\Pi_e'(M-I)$. ■

The optimal contract, depicted in figure 5.1, caps the firm's upside risk. In doing so, the planner minimizes the deadweight loss associated with expropriation. The social cost of transferring an additional dollar to the firm increases with the amount already transferred, hence the planner has incentives to keep the firm's profits as low as possible. The planner keeps away from high values of $R_c(v)$ because they entail higher expropriation probabilities, and therefore larger gaps between expected (under the contract) and realized profits for the firm. Large "disappointments" by the firm are costly, since they imply larger losses for the planner.

Two extensions follow immediately for both results above. First, if the planner gives weight α to the firm's profits, the optimal contract remains unchanged, as long as $\alpha \leq 1 - \mu$, for in this case the planner minimizes

$$(1 - \mu - \alpha) \int \Pi_e(R_c(v) - I) f(v)\, dv + \mu \int R_c(v) f(v)\, dv$$

and the above proofs go through without change as long as $1 - \mu - \alpha \geq 0$.

Second, if the firm's participation constraint requires a predetermined level of rents, so that

$$\int \Pi_e(R_c(v) - I) f(v)\, dv \geq \Pi_0 > 0,$$

the proofs of both results above continue holding with only minor modifications.

Result 3 (Optimal Contract for the Main Model) If the planner gives weight $\alpha \leq 1 - \mu$ to the firm's profit, the firm's participation constraint is

$$\int \Pi_e(R_c(v) - I) f(v)\, dv \geq \Pi_0,$$

with $\Pi_0 \geq 0$, and the firm's participation constraint can be satisfied:

$$\int \Pi_e(v - I) f(v)\, dv \geq \Pi_0.$$

Define M via

$$\int \Pi_e(\min(M, v) - I) f(v)\, dv = \Pi_0.$$

Then the contract $R_c(v) = \min(M, v)$ solves the planner's problem, and this is the only optimal contract if $M \geq x_E$. By contrast, if $M < x_E$, any contract with $R_c(v) = \min(M, v)$ in states with $v \geq x_E$ that collects $\int_0^{x_E} \Pi_e(\min(M, v) - I) f(v)\, dv$ in states with $v \leq x_E$ is optimal.

5.3.3 Implementation

We have shown that a threshold contract that specifies a particular cap on discounted profits for the firm is the optimal contract when expropriation is possible. We show next how this contract can be implemented via a competitive auction. Following this result, we discuss some practical implementation issues that are ignored by our framework.

Result 4 (Implementation) Many identical firms exist for which

$$\int \Pi_e(v - I) f(v)\, dv \geq \Pi_0, \tag{6}$$

with Π_0, $\Pi_e(x)$, $f(v)$ and Π_0 defined earlier.

The following auction then implements the optimal contract: Firms bid on the present value of revenue they are entitled to by the contract; the firm that bids the lowest value, β, wins. The contract stipulates that the winning firm collects β if $v > \beta$ and v otherwise.[19] The firm bears demand (i.e., price) and expropriation risk under the ensuing contract.

The planner does not need to know the ex ante probability density $f(v)$, the expropriation probabilities (and therefore the effective profit function $\Pi_e(x)$), the up-front investment I, or the outside option Π_0 to implement the optimal contract via a competitive auction. The planner needs to observe operating profits, since it needs this information to enforce the contract (in high-demand scenarios it must determine when the firm has collected M). Finally, no firm will bid in the auction if the project is not privately profitable—that is, if (6) does not hold.

Proof Given a winning bid β, the firm's profit in state v is $\beta - I$ if $v \geq \beta$ and $v - I$ otherwise. Thus the winning firm's expected profits are

$$\int \Pi_e(\min(\beta, v) - I) f(v)\, dv.$$

This expression is continuous, negative for low values of β, positive for large values of β (because of (6)), and strictly increasing in β. Hence a unique $\bar{\beta}$ exists for which

$$\int \Pi_e(\min(\bar{\beta}, v) - I) f(v)\, dv = \Pi_0.$$

This bid wins the auction (in the sense that it defines the Nash equilibrium), and it is trivial to see that $\bar{\beta}$ is equal to the threshold M that characterizes the optimal contract in Result 3 (note that $M = I$ in the case of a project with avoidable expropriation, as in Result 1). ∎

Working with discounted revenues has provided tractability, at the expense of avoiding dynamic issues. There are many revenue trajectories for the firm and government that will implement the optimal contract, in that they satisfy the condition that their present values are those stipulated in the contract. This motivates discussing, at least informally, which of this multitude of trajectories are more attractive in practice.

One possibility is to allow the firm to collect all revenues from the project until their discounted value adds up to M or it is expropriated. There are several problems with this approach. First, the government collects windfall taxes only late in the contract. Contracts with long gestation periods before the government collects any windfall tax, even in high-demand scenarios, are likely to lead to a higher expropriation risk, thus lowering the effective profit function, $\Pi_e(v)$, and therefore are unattractive. Second, the government has to operate the project once the threshold of the firm's profits is attained, which is not appealing.

An alternative implementation, which we believe to be more attractive, is to define by contract a windfall tax schedule that increases with the firm's accumulated discounted profits at the date of taxation and decreases with the amount of windfall taxes paid. We present a simple example of such a schedule.

Example 1 Production is constant over time (and equal to one), production costs are zero, and the price of the natural resource follows a random walk:[20]

$$P_t = P_{t-1} + \epsilon_t,$$

where the ϵ_t are i.i.d. with zero mean and variance σ^2. The discount rate is constant over time and denoted by r.

Unless indicated otherwise, all discounted values are expressed as of time zero. Denoting expected discounted revenues between period s and u by R_s^u, and by $E_t R_s^u$ the corresponding expected value conditional on information available in period t (given the random walk assumption, this is equivalent to conditioning on P_t), we have:

$$\begin{aligned} E_t R_t^\infty &= (1+r)^{-t} \sum_{k \geq 0} (1+r)^{-k} E_t P_{t+k} \\ &= (1+r)^{-t} \sum_{k \geq 0} (1+r)^{-k} P_t = \frac{1}{r(1+r)^{t-1}} P_t. \end{aligned}$$

Hence

$$E_t R_0^{\infty} = R_0^t + \frac{1}{r(1+r)^{t-1}} P_t.$$

Denote by T_s^u discounted windfall taxes paid by the firm between periods s and u and by M the revenue threshold that characterizes the optimal contract. If $\sigma = 0$—that is, if there is no price uncertainty—we have that the windfall tax schedule in period t dollars defined by

$$T_t = \frac{r}{1+r}[E_t R_0^{\infty} - T_0^{t-1} - M]$$

implements the optimal contract with a constant tax payment in all periods.

In general, when $\sigma > 0$ and we have uncertainty, defining

$$T_t = \frac{\delta r}{1+r}[E_t R_0^{\infty} - T_0^{t-1} - M],$$

with $\delta \in (0, 1]$, provides a family of plausible windfall tax schedules. The parameter δ should decrease as σ increases, to ensure that the probability that the firm's discounted payment of windfall taxes exceeds $v - M$ is small. ■

The auction that implements the optimal contract differs in important ways from the standard auction considered in the literature to dissipate rents of natural resource projects. While the standard auction involves an up-front payment to the government by the firm, the auction derived in this chapter does not. In the case of this auction, the firm's bid is linked to the degree of progressivity of the windfall tax faced by the firm. More aggressive bids are associated with higher expected profits and lead to more progressive taxation.

5.3.4 Welfare Gain

As noted in section 5.2, the standard auction proposed in the literature to dissipate rents of an exhaustible natural resource project, has firms bid for the perpetual right to extract the resource. Next we compare the welfare implications of this auction ("standard auction" in what follows) with those of the optimal auction under threat of expropriation derived above.

Since both auctions dissipate the firm's rents (we assume that the firm's outside option, Π_0, does not depend on the auction), in both cases the project's rents accrue exclusively to the government. It follows that the auction that is most attractive for the government is the one that leads to the smallest average deadweight loss from expropriation. With the standard auction, the deadweight loss is given by

$$\mathcal{L}_{\text{st}} = \mu \int [v - I - \Pi_e(v - I)] f(v)\, dv,$$

while for the optimal auction derived in this section the loss is

$$\mathcal{L}_{\text{opt}} = \mu \int [R_c(v) - I - \Pi_e(R_c(v) - I)] f(v)\, dv.$$

Since $R_c(v) = \min(M, v)$ for the optimal contract,[21] we have

$$\mathcal{L}_{\text{opt}} = \mu \int_0^M [v - I - \Pi_e(v - I)] f(v)\, dv + \mu \int_M^\infty [M - I - \Pi_e(M - I)] f(v)\, dv.$$

Subtracting $\mathcal{L}_{\text{opt}}$ from $\mathcal{L}_{\text{st}}$ leads to the following expression for the government's gain from using the optimal auction:

$$\text{Gain} = \mu \int_M^\infty [v - I - \Pi_e(v - I) - \{M - I - \Pi_e(M - I)\}] f(v)\, dv. \tag{7}$$

Note that the Gain is positive only for states where prices are sufficiently high that revenues are larger than M. The optimal contract provides no gain in relatively low demand states. Define the "grab function" $G(x) \equiv x - \Pi_e(x)$.[22] We have that $G(x) = 0$ for $x \leq x_E$, while $G(x)$ is strictly increasing for $x > x_E$, with $G'(x) = 1 - \Pi_e'(x) > 0$ in this range. It then follows that

$$\text{Gain} = \mu \int_M^\infty [G(v - I) - G(M - I)] f(v)\, dv$$

and since the integrand is strictly positive, the gain from using the optimal contract is strictly positive as well.

The intuition for why the contract derived above is better than the standard contract is the following: The optimal contract avoids, to the extent allowed by the firm's participation constraint, scenarios where expropriations are more costly, in terms of deadweight loss, thereby leading to higher welfare than the standard auction. Welfare gains are larger when the threshold M is lower—that is, for example, when the firm's outside option Π_0 is lower.

Even in the case where the distribution of revenue from the project is highly skewed, welfare gains from the optimal auction can be significant. Consider, for instance, an exploratory prospect where the probability of success is π and I corresponds to investment in exploration. Conditional on successful exploration, the distribution of revenue is described by a probability density $f(w)$ (with c.d.f. $F(w)$) that takes values between w_m and w_M. The revenue threshold that characterizes the optimal contract, M, then solves

$$\int_{w_m}^{M} \Pi_e(w - I) f(w)\, dw + \Pi_e(M - I)(1 - F(M)) = \frac{(1 - \pi)}{\pi} I. \tag{8}$$

Revenue uncertainty is usually large in such a project, even conditional on successful exploration, which amounts to a large variance of $f(w)$. It then follows that the threshold M will be much smaller than w_M if the project is highly profitable ex ante; and welfare gains associated with moving from the standard to the optimal contract can be expected to be considerable. For example, if $\pi = 0.1$, the r.h.s. of (8) suggests that return on investment will average 900 percent when exploration is successful, yet realized profit rates may still vary substantially, say between 500 and 2000 percent, as is likely to be the case for most natural resource projects. Gains from the optimal contract are negligible only for a project where the firm's participation constraint holds for a value of M close to w_M.

The following result summarizes our result on the welfare gain from the optimal contract:

Result 5 Welfare under the optimal auction derived in this section is higher than under the standard auction where firms bid on the right to extract the resource indefinitely. The welfare gain from the optimal auction is equal to

$$\text{Gain} = \mu \int_{M}^{\infty} [v - I - \Pi_e(v - I) - \{M - I - \Pi_e(M - I)\}] f(v)\, dv > 0.$$

5.4 Extensions

In this section we examine two extensions of practical importance. First, we study the case in which the government provides subsidies to the firm in bad states of the world. In the context of this chapter, subsidies usually translate into laxer application of environmental or labor regulations and sometimes into direct cash transfers. The second extension incorporates moral hazard—for example, it could be that by exerting costly effort, the foreign investor can reduce unobservable costs and increase revenues. The question is how to design a contract that provides optimal incentives.

5.4.1 Subsidies

The main problem of subsidies is that they cost governments more than the benefit they provide to firms. If labor and environmental regulations are meant to correct externalities, the social cost of the laxer regulations is higher than the private benefit perceived by the foreign investor.

Hence we assume that a subsidy $S(v)$ has a social cost of $\zeta S(v)$, $\zeta > 1$, so that the objective function maximized by the planner now is

$$\int [v - I - \Pi_e(R_c(v) + S(v) - I) - (\zeta - 1)S(v) \\ - \mu\{R_c(v) + S(v) - I - \Pi_e(R_c(v) + S(v) - I)\}] f(v)\, dv, \tag{9}$$

where the term $(\zeta - 1)S(v)$ captures the social cost of the subsidy, beyond its private value. Two schedules are available to the planner now to achieve her objective, the revenue schedule $R_c(v)$ and the subsidy schedule $S(v)$.[23]

The problem facing the planner is equivalent to

$$\min_{R_c(v),\, S(v)} (1 - \mu) \int \Pi_e(R_c(v) + S(v) - I) f(v)\, dv \\ + \mu \int R_c(v) f(v)\, dv + (\mu + \zeta - 1) \int S(v) f(v)\, dv, \tag{10a}$$

$$\text{s.t.} \quad \int \Pi_e(R_c(v) + S(v) - I) f(v)\, dv \geq 0, \tag{10b}$$

$$0 \leq R_c(v) \leq v, \tag{10c}$$

$$S(v) \geq 0. \tag{10d}$$

To solve this problem, note that as in the proof of Result 2, the participation constraint (10b) holds with equality. Hence the problem is similar to that in section 3 of Engel, Fischer, and Galetovic 2007, with the expropriation function Π_e playing the role of the firm's concave utility function u.[24] The only difference is that $\Pi_e(x)$ is linear in net profits for $x \leq x_E$, while the utility function considered in Engel, Fischer, and Galetovic 2007 is strictly concave everywhere.

Hence, the results of that paper apply to this case, with slight modifications. For example, $R_c(v) < v$ and $S(v) > 0$ cannot be optimal, since achieving the firm's participation constraint via subsidies has a higher cost for the government than achieving it via the income generated by the project. Also, demand states can be classified into high, intermediate, and low demand. In high-demand states the optimal contract stipulates $R_c(v) < v$ and $S(v) = 0$. Expropriation is most likely in these states; the optimal contract assigns the same value of $R_c(v)$ to all states in this group (denote it by $\tilde{M}$); and the government collects a windfall tax equal to $v - \tilde{M}$. Similarly, $R_c(v) = v$ and $S(v) > 0$ in low-demand states. In these states there are no expropriations and no windfall taxes. Finally, a range of intermediate-demand states exist, where $R_c(v) = v$ and $S(v) = 0$. There are no windfall taxes in these states, yet expropriations can happen but are less likely than in high-demand states.

Result 6 (Optimal Contract with Subsidies) Consider the planner's problem described by (10a)–(10d). If a finite M exists that satisfies

$$\int \Pi_e(\min(M, v) - I) f(v)\, dv = 0, \tag{11}$$

and $\Pi'_e(M - I) > \mu/(\mu + \zeta - 1)$, then the optimal contract is either the one described in Result 1 (if $\Pi'_e(M - I) = 1$) or the one described in Result 2 (if $\mu/(\mu + \zeta - 1) < \Pi'_e(M - I) < 1$).

Otherwise—that is, either if (11) has no solution or M solving this equation satisfies $\Pi'_e(M - I) < \mu/(\mu + \zeta - 1)$—the optimal contract is characterized as follows:

Define $\tilde{M}$ via $\Pi'_e(\tilde{M} - I) = \mu/(\mu + \zeta - 1)$. Clearly $M > \tilde{M} > x_E$. The optimal contract then satisfies $R_c(v) = \min(\tilde{M}, v)$ (figure 5.2 shows the resulting contract). Furthermore, subsidies are handed out only in states where $v < x_E$ and

$$\int_0^{x_E} S(v) f(v)\, dv = -\int \Pi_e(\min(\tilde{M}, v) - I) f(v)\, dv. \tag{12}$$

Proof As mentioned above, $S(v) > 0$ and $R_c(v) < v$ cannot be optimal. Hence states can be classified into three categories: (a) $R_c(v) < v$ and $S(v) = 0$; (b) $R_c(v) = v$ and $S(v) = 0$; and (c) $R_c(v) = v$ and $S(v) > 0$.

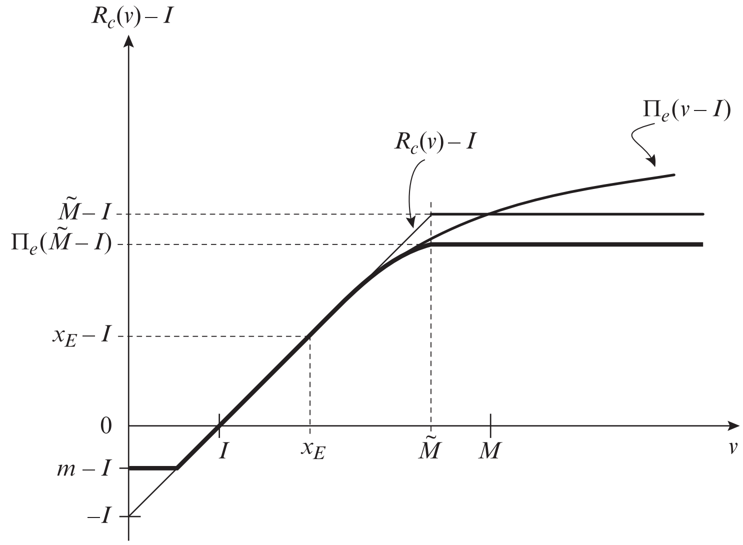

Figure 5.2
The optimal contract in the case of subsidies

Next we extend the argument used to prove Result 2. The planner's cost of providing an additional dollar of revenues to satisfy the firm's participation constraint, is

$$\rho_R(v, R_c(v)) = (1 - \mu) + \frac{\mu}{\Pi'_e(R_c(v) - I)},$$

where we have used that $S(v) = 0$ since additional revenue from the project can be provided to the firm only if $R_c(v) < v$.

Similarly, the planner's per-dollar cost of providing an additional dollar via subsidies is

$$\rho_S(v, R_c(v)) = (1 - \mu) + \frac{\mu + \zeta - 1}{\Pi'_e(v + S(v) - I)},$$

where this time we used that $R_c(v) = v$ when $S(v) > 0$. In particular, this cost is lowest (and equal to ζ) when $v \leq x_E$.

In the optimal contract the planner resorts to more expensive options to satisfy the firm's participation constraint only once cheaper options are exhausted. Since the social cost of financing the firm with subsidies is ζ, and there is no limit to the resources available to finance the firm with this option, the planner will use revenues as long as their social cost is smaller than ζ and will then resort to subsidies to complete the amount needed to satisfy the firm's participation constraint.

It follows that the planner sets $R_c(v) = \min(\tilde{M}, v)$ since this assigns to the firm all the revenue with marginal cost less than or equal to ζ. From the assumptions we know that the income obtained in this way is not enough to satisfy the firm's participation constraint, because it adds up to $\int \Pi_e(\min(\tilde{M}, v) - I) f(v)\, dv < 0$. Thus the firm obtains the remaining income needed to satisfy its participation constraint via subsidies in states where expropriations are impossible. ■

Implementation A simple two-threshold auction, analogous to the one derived in Engel, Fischer, and Galetovic 2007, implements the optimal contract in this case.

Result 7 (Implementation with Subsidies) The following two-threshold, scoring auction implements the solution to the planner's problem (10a)–(10d):

- The government announces the probability density of expected discounted profit flow from the project, $f(v)$, and the parameter ζ that summarizes the social cost of subsidies.
- Firms bid on the minimum revenue guarantee, m, and the cap on their user-fee revenue, M, so that, in case of winning: $R_c(v) = \min(M, v)$ and $S(v) = \max(m - v, 0)$.
- The firm that bids the lowest value of the scoring function

$$W(m, M) = \mu M(1 - F(M)) + \mu \int_m^M v f(v)\, dv + (\mu + \zeta - 1) m F(m) - (\zeta - 1) \int_0^m v f(v)\, dv$$

wins the contract.[25]

Proof We first note that the optimal contract can be implemented via a contract characterized by the threshold pair (M, m), where M denotes the revenue cap, and m the minimum revenue guarantee. In the first scenario described in Result 6, M is defined via (11) and m can be any number less than or equal to $v_{\min}$ (recall that the support of $f(v)$ is $[v_{\min}, v_{\max}]$). In the second scenario in Result 6, M is defined via

$$\Pi_e'(M - I) = \frac{\mu}{\mu + \zeta - 1}$$

and m via

$$\int_0^m (m - v) f(v)\, dv = -\int \Pi_e(\min(M, v) - I) f(v)\, dv. \tag{13}$$

It is easy to see that in a Nash equilibrium the winning bid minimizes the scoring function, subject to the firm's participation constraint, among all contracts in the two-threshold family described above. Since the scoring function differs from the planner's objective function only in a term proportional to the firm's expected profits, and this term is equal to zero for the optimal contract, the optimal contract also solves the planner's problem constrained to the family of two-threshold contracts described above. The proof concludes by noting that this family includes the optimal contract. ∎

What is the intuition underlying this result? Note first that the planner's problem is equivalent to minimizing an objective function that does not require knowledge of I or Π_e. The objective function only depends on the probability distribution of the present value of revenue that the project can generate and the distortions associated with government expenditures, as summarized by ζ. By awarding the contract to the bidder that maximizes his objective function, and assuming competitive bidding, the planner induces firms to solve society's problem without knowing the cost of the project or the expropriation risk.

As before, in the case of a high-demand project—that is, a project where the firm's participation constraint can be satisfied without expropriation risk—the two-threshold auction is equivalent to a PVR auction. In this case any bid with $M = I$ and $m \leq I$ wins the auction, and no subsidies are paid out.

5.4.2 Moral Hazard in Effort

The possibility of expropriations may lead firms to spend less on upfront investments that reduce costs during the exploitation of the natural resource. The framework developed in this chapter is not needed to make this point, because it can be made with the simpler, static model discussed in the appendix. Yet it is instructive to derive this result within the framework developed in this chapter, and explore the extent to which the results of previous sections continue holding. That is what we do in this section. We show that, loosely speaking, the optimal contract combines the two effects, by providing incentives for effort (investment) while lowering the probability of costly expropriation—that is, it resembles a progressive tax above a predetermined operating profit threshold.

5.4.2.1 The Planner's Problem We embed the benchmark model of section 5.3 in a simple moral-hazard framework. The Firm's marginal extraction costs are decreasing in the firm's effort, ϵ, exerted at the time the up-front investment I is made. This can be summarized by assuming that the probability density describing the firm's discounted profits is determined by $\epsilon \geq 0$, so that we may write $f(v|\epsilon)$. The impact of effort is larger when price turns out to be higher, since optimal production can be expected to be higher in this case. Thus the monotone likelihood ratio property (MLRP) holds, so that $\ell(v,\epsilon) \equiv \frac{\partial f}{\partial \epsilon}(v|\epsilon)/f(v|\epsilon)$ is increasing in v for all ϵ—that is, effort increases the probability of higher realizations of demand. Effort ϵ costs the firm $k\epsilon$, $k > 0$, so that its expected profit in state v, net of expropriation, is $\Pi_e(R_c(v) - I) - k\epsilon$. Since it is necessary to ensure that the firm provides effort, we need to introduce an incentive compatibility constraint in the planner's program.

The planner chooses effort ϵ and a revenue schedule $R_c(v)$ to solve the following program:

$$\min_{\{R_c(v),\epsilon\}} \int [\mu(R_c(v) - I) + (1-\mu)\{\Pi_e(R_c(v) - I) - (v - I)\}] f(v|\epsilon)\, dv \tag{14a}$$

$$\text{s.t.} \quad \int \Pi_e(R_c(v) - I) f(v|\epsilon)\, dv \geq k\epsilon, \tag{14b}$$

$$\epsilon = \arg\max_{\epsilon'} \left\{ \int \Pi_e(R_c(v) - I) f(v|\epsilon')\, dv - k\epsilon' \right\}, \tag{14c}$$

$$0 \leq R_c(v) \leq v. \tag{14d}$$

Comparing program (1a)–(1c) with program (14a)–(14d), it can be seen that the term $v - I$ can no longer be dropped because effort affects the p.d.f. of revenue (or operating profit). Constraint (14b) is the firm's participation constraint, and (14c) is the incentive compatibility constraint.

Under standard assumptions,[26] we can use the First Order Approach to examine the properties of the solution. The concessionaire's incentive compatibility constraint then can be replaced by

$$\int \Pi_e(R_c(v) - I)\ell(v, \epsilon)f(v|\epsilon)\, dv = k. \tag{15}$$

Denoting by $\gamma > 0$ the multiplier associated with (14b), which will hold with equality, and by $\tau > 0$ the multiplier associated with (15), we have that the Lagrangian of the problem is

$$\begin{aligned}\mathcal{L} = &\int [\mu(R_c(v) - I) + (1-\mu)\{\Pi_e(R_c(v) - I) - (v - I)\}]f(v|\epsilon)\, dv \\ &- \gamma\left[\int \Pi_e(R_c(v) - I)f(v|\epsilon)\, dv - k\epsilon\right] \\ &- \tau \int \Pi_e(R_c(v) - I)\ell(v, \epsilon)f(v|\epsilon)\, dv.\end{aligned} \tag{16}$$

The first-order condition w.r.t. to ϵ, combined with (15), provides an expression for τ where the multiplier for the participation constraint does not appear:

$$\tau = \frac{\int [\mu(R_c(v) - I) + (1-\mu)\Pi_e(R_c(v) - I) - (v - I)]\ell(v, \epsilon)f(v|\epsilon)\, dv}{\int \Pi_e(R_c(v) - I)\frac{\partial^2 f}{\partial \epsilon^2}(v, \epsilon)\, dv}.$$

If $0 < R_c(v) < v$ the first-order condition for $R_c(v)$ derived from the Lagrangian yields

$$\Pi_e'(R_c(v) - I) = \frac{\mu}{(\mu + \gamma - 1) + \tau\ell(v, \epsilon)}. \tag{17}$$

The MLRP then implies that $R_c(v)$ is strictly increasing in v. Furthermore, the solution is interior if and only if the denominator in the expression on the right-hand side is positive (which ensures that $v > 0$) and

$$\Pi_e'(v - I) < \frac{\mu}{(\mu + \gamma - 1) + \tau\ell(v, \epsilon)},$$

which ensures that $R_c(v) < v$.

Standard arguments used for moral-hazard models (as in the proof of Proposition 5.2 in Laffont and Martimort 2002) can be used to show that $\mu + \gamma - 1 > 0$ and $\tau > 0$. This, combined with the MLRP, implies that for sufficiently large v the denominator in the right-hand expression in (17) is positive. It then follows that if $\Pi_e'(v - I)$ tends to zero faster than $\ell(v, \epsilon)$ tends to infinity, in the sense that for all positive constants a and b

$$\lim_{v\to\infty} \Pi_e'(v-I)[a+b\ell(v,\epsilon)] = 0, \tag{18}$$

then there exists a threshold M s.t. $R_c(v) < v$ for all $v \geq M$.

For example, if $\Pi_e(x) = 1 - \exp(-cx)$, for $x > 0$, with $c > 0$, and $f(v|\epsilon)$ is exponential with mean $\theta(\epsilon)$ and $\theta'(\epsilon) > 0$, then

$$\lim_{v\to\infty} \Pi_e'(v-I)[a+b\ell(v,\epsilon)] = \lim_{v\to\infty} ce^{-c(v-I)}[a'+b'v] = 0,$$

where a' and b' denote constants that depend on a, b, θ, and θ'. Condition (18) then holds and the optimal contract involves a windfall tax when profits are high enough.

5.4.3 Political Investment

There is an additional way that a firm may exert effort in order to increase its profits: it can invest in political support, either by lobbying politicians or by trying to influence the press, in order to reduce the probability of expropriation.[27] This can also be treated as a moral-hazard model, but in this case effort affects the probability of expropriation and hence expected profits, rather than the probability of high-profit states directly.

5.4.3.1 The Planner's Problem Assume then that political effort can be described by ϵ and that expected profits are $\Pi_e \equiv \Pi_e(x,\epsilon)$, which we assume satisfies

$$\frac{\partial \Pi_e}{\partial \epsilon} \geq 0, \quad \frac{\partial^2 \Pi_e}{\partial \epsilon^2} < 0, \quad \frac{\partial^2 \Pi_e}{\partial v \partial \epsilon} > 0, \quad \frac{\partial^3 \Pi_e}{\partial v^2 \partial \epsilon} > 0$$

and where $\partial \Pi_e/\partial \epsilon = 0$ for $v \leq 0$ because $\Pi_e(v,\epsilon) = v$ for $v \leq 0$.[28] Using the first-order approach, the problem for the planner can be stated as

$$\min_{\{R_c(v),\epsilon\}} \int [\mu(R_c(v)-I) + (1-\mu)\{\Pi_e(R_c(v)-I,\epsilon) - (v-I)\}] f(v)\, dv \tag{19a}$$

$$\text{s.t.} \quad \int \Pi_e(R_c(v)-I,\epsilon) f(v)\, dv \geq k\epsilon, \tag{19b}$$

$$\int \frac{\partial \Pi_e}{\partial \epsilon}(R(v)-I,\epsilon) f(v)\, dv = k \tag{19c}$$

$$0 \leq R_c(v) \leq v. \tag{19d}$$

Denoting by $\gamma > 0$ the multiplier associated with (19b), which will hold with equality, and by $\tau > 0$ the multiplier associated with (19c), we have that the Lagrangian of the problem is

$$\mathcal{L} = \int [\mu(R_c(v) - I) + (1-\mu)\{\Pi_e(R_c(v) - I, \epsilon) - (v - I)\}] f(v)\, dv$$

$$- \gamma \left[\int \Pi_e(R_c(v) - I) f(v)\, dv - k\epsilon \right] - \tau \int \frac{\partial \Pi_e}{\partial \epsilon}(R_c(v) - I, \epsilon) f(v)\, dv. \quad (20)$$

The first-order condition w.r.t. to ϵ, and using (19c), lead to

$$\int (1-\mu-\gamma) \frac{\partial \Pi_e}{\partial \epsilon}(R_c(v) - I, \epsilon) f(v)\, dv + \gamma k - \tau \int \frac{\partial^2 \Pi_e}{\partial \epsilon^2}(R_c(v) - I, \epsilon) f(v)\, dv$$

$$= (1-\mu)k - \tau \int \frac{\partial^2 \Pi_e}{\partial \epsilon^2}(R_c(v) - I, \epsilon) f(v)\, dv$$

from which we derive an expression for τ:

$$\tau = \frac{(1-\mu)k}{\int \frac{\partial^2 \Pi_e}{\partial \epsilon^2}(R_c(v) - I, \epsilon) f(v)\, dv} < 0.$$

Now consider the first-order conditions with respect to $R(v)$:

$$\mu + (1-\mu-\gamma) \frac{\partial \pi_e}{\partial v}(R_c(v) - I, \epsilon) = \tau \frac{\partial^2 \Pi_e}{\partial v \partial \epsilon}(R_c(v) - I, \epsilon). \quad (21)$$

Recall that $0 < \mu < 1$, that $\tau < 0$, and that $\partial \Pi_e / \partial v > 0$ and $\partial^2 \Pi_e / \partial v \partial \epsilon < 0$, and therefore $\gamma > 1 - \mu > 0$. Now consider the function

$$\mathcal{H}(R(v)) \equiv \tau \frac{\partial^2 \Pi_e}{\partial v \partial \epsilon}(R_c(v) - I, \epsilon) - (1-\mu-\gamma) \frac{\partial \Pi_e}{\partial v}(R_c(v) - I, \epsilon),$$

where (21) is equivalent to $\mathcal{H}(R(v)) = \mu$. The conditions we imposed at the beginning of the section ensure that $\partial \mathcal{H}(v)/\partial v < 0$. Let M be the value where $\mathcal{H}(v) = \mu$. Then if $v > M$, we have that the Lagrangian is maximized at $R(v) = M$, and if $v \leq M$, the Lagrangian is maximized at $R(v) = v$.

We have shown that there is a bound M such that the optimal contract is

$$R(v) = \begin{cases} v & \text{if } v \leq M, \\ M & \text{if } v > M. \end{cases}$$

Hence, in contrast to the case of moral hazard, in the case of political investment, the planner does not provide incentives to the firm, except in the range $v \in [0, M]$. The reason is that effort affects the probability of expropriation across all states, but does not increase the probability of higher-income states v, hence there is no conflict between reducing the probability of expropriation by limiting $R(v)$ and providing incentives in order to increase the probability of higher states. The resulting contract belongs to the family of threshold contracts that are optimal in the absence of moral hazard, even though the threshold itself will usually be different.

5.5 Conclusion

Developing countries need foreign investment in order to develop their natural resources. In order to attract investment, they offer favorable conditions. When prices rise and revenues increase beyond expectations, there are often calls to change the terms of the original contracts, or to expropriate the investment and appropriate the windfall profits. This can be costly because the investor will try to defend the original contract in local and international courts. Moreover, there will be less investment in the next price cycle. We have proposed an alternative contract that improves welfare by reducing the attraction of expropriation by lowering profits in the good states of the world. This implies that there is a smaller cost of expropriation directly, because there will be less expropriation, and indirectly, because the expropriated assets are less profitable and therefore worth less to the foreign firm, which will not fight as forcefully to retain the project.

We have shown that in the case of high-demand projects, which are always profitable (though some states may be better than others), the optimal contract can be achieved by a present-value-of-revenue (PVR) auction and there will be no expropriation. In the case in which the project is profitable in expected value, but has bad states in which it never recovers the investment, the first best is achieved by setting a cap on profits, and this can be implemented fairly easily via an auction. We have shown that this is analogous to a lump-sum windfall tax on profits. Next, we showed that in the case when the government has the possibility of subsidizing the firm in the bad states of the world by relaxing regulations, the first best is achieved by a system of subsidies in bad states of the world and caps on profits in good states. Again, we found that the first best can be implemented via an auction. We examined the case in which the firm can invest in lobbying or other political activities (regional subsidies, for example) and showed that the optimal contract is of the same type as before.

The most interesting case, however, is when there is moral hazard and the firm can perform unobservable (or partially observable) effort that increases the likelihood of the high-revenue states. Here the planner must provide incentives, which implies that a constant cap on revenues is inappropriate. The optimal contract involves progressive taxation of revenues above a predetermined value, thus combining some incentives to attain higher-revenue states with a reduction in the attraction of expropriation, as well as its associated costs.

Note, however, that these measures—lump-sum windfall profits or progressive taxation—must be incorporated in the original contracts and must not be imposed ex post: in that case it corresponds to the standard natural resource contract. Finally, we showed that there is positive welfare gain from our contract, and that the gain is due solely to the better behavior of the government in the good states of the world, above the cap.

Appendix: The Effect of a Positive Expropriation Probability: A Simple Model

Consider the following simple model that describes the effect of potential expropriation on investment. For simplicity, we assume that the firm's present discounted profits, as a function of price p and unobservable effort F, are given by

$$\Pi(p, F) = pq(F) - F,$$

with $q > 0$, $q' > 0$, and $q'' < 0$. Price uncertainty is described by a probability density $g(p)$ with c.d.f. $G(p)$.

No Expropriation

Rents are dissipated via an up-front payment to the government in a competitive auction; all firms are the same.

Once it wins the auction, the firm solves

$$\max_F \int pq(F)g(p)\,dp - F$$

which leads to

$$q'(F) = \frac{1}{\int_0^\infty pg(p)\,dp}. \tag{22}$$

Denote the optimal value of F by F_{ne}.

Expropriation

If $p > \bar{p}$, the firm is expropriated and receives no income at all. The firm is aware of this when deciding how much to invest in effort, so that the price distribution it considers has mass $1 - G(\bar{p}) > 0$ at $p = 0$ and density $g(p)$ for $0 < p < \bar{p}$.

The same derivation that led to (22) now yields

$$q'(F) = \frac{1}{\int_0^{\bar{p}} pg(p)\,dp}. \tag{23}$$

Denote the solution by F_{e}. Since, trivially, the denominator in (23) is smaller than the one in (22), concavity of $q(F)$ implies that $F_{\text{e}} < F_{\text{ne}}$.

As before, ex ante rents are dissipated via an up-front payment to the government and all firms are the same. The up-front payment that wins is smaller than in the case without expropriation, for two reasons. First, the firm expects fewer rents since it realizes there is a probability of being expropriated. Even if the firm exerts effort F_{ne}, the up-front payment to the government by the firm would be smaller, by exactly the amount the government expects to collect via expropriation. Furthermore, as $F_{\text{e}} < F_{\text{ne}}$ we also have an efficiency loss to society, since the firm exerts less effort and therefore social welfare—which is equal to the sum of what the government collects from the firm up front and via expropriation—is lower.

Result 8 Expropriation when price realizations are high lowers social welfare because it induces the firm to do less unobservable, yet socially desirable, investment up front.

This conventional analysis has a limited scope, and it is difficult to obtain additional results. The approach used in the chapter leads to stronger results.

Notes

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1. “Ecuadorean President Rafael Correa has signed a decree giving the state a greater share of profits from foreign oil companies working in his country. He said the 50% of windfall oil profits stipulated in a law passed last year was not enough, and the state should now receive 99%” (BBC News, October 5, 2007). “Algeria is to levy a windfall tax on the profits of oil companies, as it tries to retain more of the economic benefits of its recent energy boom. . . . From early 2007, profits accrued by firms when prices are above $30 a barrel will be taxed at between 5% and 50% depending on total output” (BBC News, October 15, 2006).

2. See epigraph, corresponding to a previous cycle of high prices and expropriation.

3. “Zambia, meanwhile, plans to cash in on the stratospheric price of copper by renegotiating the generous terms it gave to foreign firms when it privatised its copper mines in 2000. Then the price was low. Although these investors rescued an industry close to collapse, Zambia now wants to increase royalties and other taxes. . . . Governments intent on reworking contracts or imposing new taxes clearly feel that they have the upper hand at the moment. When prices were depressed and profits scarce, foreign firms had to be lured with generous terms that now rankle” (*The Economist*, October 4, 2007).

4. Though profits are unobservable in general, we denote by operating profits the difference between the revenues of the firm and costs that are based on observable variables. These are the profits that are prespecified in the initial contract.

5. In general terms, this probability should depend on institutional aspects of the country such as the degree of belief in the sanctity of contracts, the impact of public pressure on governments, and so on.

6. We do not analyze the possibility of a project that does not break even in expected value—that is, one that impoverishes the country.

7. This may lead to procyclical government income, which should be addressed via a countercyclical spending rule.

8. This auction is similar to the present-value-of-revenue auction analyzed in Engel, Fischer, and Galetovic 2001.

9. The study of this case was suggested by our discussant in the Populism and Natural Resources Workshop, Richard Zeckhauser.

10. Since the revenue collected by the government from the project can be used to reduce distortionary taxation elsewhere in the economy, the deadweight loss associated with subsidies for the firm financed via taxes does not provide a rationale for the result that follows. For a formal derivation of this insight, see the Irrelevance Result in Engel, Fischer, and Galetovic 2007.

11. If the moral-hazard effect dominates the expropriation effect, the standard contract that provides full residual rights to the private firm is again optimal.

12. There also is an extensive literature, going back to Hotelling 1931, that derives the price of an exhaustible natural resource as an equilibrium outcome resulting from optimal extraction (see, for example, Devarajan and Fisher 1981, Salant 1995, and the references

cited there). We depart from this literature by assuming *exogenously* given demand uncertainty—that is, a small-country assumption—as well as by omitting the dynamic issue of optimal resource extraction. Moreover, we search for the optimal contract when expropriation is possible and depends on the price realization.

13. Osmundsen (1998) considers the case of optimal dynamic taxation with adverse selection in the firm's cost structure. By contrast, we assume identical firms.

14. The case where f responds to actions taken by the firm is considered when studying moral hazard in section 5.4.

15. In section 5.3.3 we discuss alternative options for how the government actually collects its share.

16. We relax this assumption in section 5.4.

17. Many of the results we derive are simpler if we assume $\Pi_e(x)$ strictly concave for all x—that is, when expropriations are possible for all realizations of v . In this case the planner's problem is analogous to the one considered in Engel, Fischer, and Galetovic 2007.

18. Alternatively, the value of the revenue stream is reduced because the new management is less efficient, or because experienced personnel leaves. Finally, there could be a cost due to an increase in the perceived riskiness in the country for foreign investment.

19. The resulting auction is analogous to the present-value-of-revenue (PVR) auction studied in Engel, Fischer, and Galetovic 2001.

20. What follows can be extended easily to the case where the price of the natural resource (or its log) follows a more general process—for example, a first-order autoregressive process.

21. The unique optimal contract takes this form when expropriation cannot be avoided (see Result 2), and one of many optimal contracts takes this form when expropriation can be avoided (see Result 1).

22. The "grab function" terminology was suggested by Richard Zeckhauser.

23. We assume no transfers from general funds are possible; these could be incorporated following the approach used in Engel, Fischer, and Galetovic 2007 without affecting the qualitative nature of the results we obtain.

24. The fact that here $\int \Pi_e(R_c(v) + S(v) - I) f(v)\, dv$ shows up in the objective function, while the utility function does not show up in the objective function in Engel, Fischer, and Galetovic 2007, is irrelevant, since the firm's participation constraint implies that this term is equal to zero.

25. Note that M here corresponds to $\tilde{M}$ in Result 6.

26. For instance, strict concavity of the agent's utility as a function of ϵ and the convexity of the distribution function condition (see, e.g., Proposition 5.2 in Laffont and Martimort 2002).

27. This section was suggested by our discussant, Richard Zeckhauser, at the Populism and Natural Resources Workshop.

28. In an abuse of notation, we have written $\frac{\partial \Pi_e}{\partial v}$ for the partial derivative with respect to the first argument of Π_e.

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