Oilfield Unitization Under Dual Fiscal Regime: the Regulator Role over the Bargaining*

William Michon Jr Humberto Moreira Érica Oliveira†

October 5, 2018

Abstract

Unitization is a deliberate agreement to consolidate royalties and participating interests in a pool of contiguous oil fields exploring a common reservoir. It also determines the common operation of the pool. In this paper we consider the case of (two) identical firms operating under different fiscal regimes, which are defined as the set of rules that characterize the concession or the production sharing agreement. We study how the existence of different fiscal regimes affects the unitization process. We model the negotiation protocol of the share and the production plan as a bargaining problem resolved by the Nash's axiomatic solution. As a result, we show that firms operating leases sharing larger portion of its profit with the government end up being more benefited in the negotiation. Furthermore, pro-industry (profit maximization) regulatory bias, which is in opposition to the government's interest (revenue maximization), can reduce the distortion generated by the existence of dual fiscal regime.

1 Introduction

A common practice of the oil industry in many countries is to grant licenses for companies to search for commercially feasible deposits of petroleum. The geographical area defined by the government for the tender process is based on roughly estimates of possible oil leases. Due to the lack of precise information, sometimes two or more oil companies end up having access to the same reservoir. This situation is the core of our analysis.

Without regulation, when two or more companies have the access to the same reservoir, overexploitation may occur, consistent with the common-pool problem.[1] This regime is the so-called rule of capture where each company extracts as much oil as it can, given that the other

*We thank Helena Garcia for the research assistance. Moreira acknowledges CNPq for financial support. This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001.

†Michon Jr: FGV EPGE Escola Brasileira de Economia e Finanças (wjmichon@gmail.com). Moreira: FGV EPGE Escola Brasileira de Economia e Finanças (humberto@fgv.br). Oliveira: INSPER (ericado@insper.edu.br).

[1]For a discussion, see Hardin (1968).

companies are doing the same. This situation, however, has some adverse effects. Although there is no production stoppage, a first negative effect is an inefficient increase of the production cost, since companies have to duplicate capital investments by creating separate structures to extract the oil. A second negative effect is the externality caused by the competition for extracting the oil. As the extraction rate increases, the pressure conditions of the reservoir deteriorate, reducing the total amount of oil that can be recovered.[2]

The unitization process (or individualization of production) emerges as an alternative to avoid the perverse effects of the rule of capture. This is an agreement between the companies that access the same reservoir which defines a joint production plan for the oil extraction. One of the companies is responsible for operating the reservoir and extracting the oil, and the rule defines how the profits will be shared between the companies. According to Kim and Mahoney (2002), this agreement can reduce economic losses from the common-pool problem by half. However, due to the complexities of this kind of agreement, the conflict of interest and the high economic value of the oil reservoir, the negotiation can take a very long time. Even worst, sometimes the bargaining process can break down leading to a production governed by the rule of capture, which is sub-optimal for the society. Aware of this possibility, the government can demand firms to reach an agreement within a limited amount of time. If an agreement is not achieved by the parties, the government may propose a take-it-or-leave-it agreement. Under this alternative regime, firms anticipate a threaten point of the bargaining process different from the rule of capture.

Once companies consider the sharing rule proposed by the regulator, it is important to understand the fiscal regime details under which these companies produce since it shapes the take-it-or-leave-it proposal. Johnston (1994) has a survey of fiscal regimes around the world and documents that some countries adopt the production sharing agreements (PSA). Under this regime the government remains the single owner of the resources, reimburses the cost of the oil companies and shares a portion of their profits. There are two important features of the PSA: (i) the government can interfere the production plan; (ii) the (winner) oil company shares the profit with the government according to the auction result. The interference can occur, for example, when the bargaining process breaks down and the government has the right to enforce the take-it-or-leave-it proposal.

Another important fiscal regime is concession. Under this regime the company or consortium contracted by the government (through a public bidding process) takes the risk of exploiting the acquired area, i.e., the development and the production are conducted by the oil company's sole cost and risk. On the other hand, the company becomes the owner of all the oil produced in the granted area and has exclusive control of the operation, holding both the commercialization and exportation rights.

Brazil poised to become one of the top oil producers in the world after the discovery of huge reserves in the pre-salt layer in 2007. The International Energy Agency (IEA, 2013) estimated

[2]See Libecap and Wiggins (1984, 1985a,b).

the country's oil production will triple by 2035, turning Brazil the sixth-largest oil producer in the world, and the pre-salt layer will account for 52% of the total domestic oil production by this year, according to the report of Petrobras, Brazil's semi-public multinational energy corporation. It is estimated that the total recoverable oil and natural gas to be about 100 billion barrels of oil equivalent in the pre-salt area, which would triple the current national reserve. In response, the federal government amended the regulatory framework in order to create specific rules for the exploration and production of gas and petroleum in these new areas. The new regulatory framework was proposed by the federal government in 2009 and approved by the Brazilian Congress in 2010. The fiscal regime adopted for the pre-salt reserves was the PSA, with some adaptations. Before the discovery of the pre-salt layer, the only fiscal regime operating in Brazil was the concession regime. Therefore, Brazil now features two fiscal regimes for the oil industry and, in the near future, some of the reserves located in contiguous areas may be exploited by different fiscal regimes.

According to the Brazilian law, firms operating contiguous leases with access to the same reservoir must unitize their production, and the heterogeneous fiscal regimes will certainly affect the negotiation of the unit agreement. This is our main object of interest, i.e., the analysis of how different fiscal regimes affect the unitization agreement.

Using the Nash's axiomatic solution for the bargaining problem, we show that technologically identical firms operating under different fiscal regimes can be benefited differently in the unitization process. The benefit is measured by the profit share the firm gets compared to the one the firm is generating. We consider two outcomes if the negotiation breaks down: the rule of capture and the regulator's proposal according to the Brazilian law.

The next section discusses in detail the Brazilian fiscal regimes. Section 3 discusses the short literature on unitization. Section 4 presents our model and the common-pool problem. Section 5 introduces unitization as a bargaining problem resolved by the Nash's axiomatic solution. Section 6 studies the two possible resolutions considered in this paper and Section 7 concludes.

2 Brazilian fiscal regimes

A fiscal regime is a regulation that rules the exploration and production of hydrocarbons. Hence, it establishes the rights, obligations and the division of revenues between the government and companies. Around the world, we can find many different fiscal regimes relative to the oil exploration and production (E&P), but the two most common fiscal regimes are concession and PSA.

According to the Brazilian Federal Constitution, enacted in 1988, all national oil and natural gas reserves belonged to the Federal Government. The Union held a natural monopoly over research, exploration, production, refinement, transportation, importation and exportation of oil and its by-products. Petrobras, the Brazilian National Oil Company, was the sole agent allowed to explore the Union's monopoly.

In 1995, the Brazilian government reformed the oil and gas regulatory framework and authorized the Union to contract any company headquartered in Brazil to conduct the activities previously designated only to Petrobras. As a result, the oil and gas public monopoly was ended in Brazil. The Oil Act, enacted by the Congress in 1997, allowed competition in all segments of the oil and gas industry and established that their exploration and production in Brazil should be carried out under the concession regime.

Under the concession regime, the exploration, development and production are conducted by the oil company's sole cost and risk. In return, the concessionaire is granted a contract lasting up to 35 years, becomes the owner of the extracted hydrocarbons and has exclusive control of operations, holding both the commercialization and exportation rights. The contracts are granted based on the signature bonus and the local content auction organized by the National Petroleum Agency (NPA). The signature bonus is the amount of money offered by the winning bidder to explore and produce the field, paid when the concession agreement is signed. The local content represents the bidder's commitment to contract a minimum percentage of goods and services from Brazilian companies.

Therefore, according to the Oil Act and the concession agreements, the concessionaires must pay (i) the signature bonuses – consisting of a lump sum payment by the winning company(s) of the bidding procedure upon the signature of the concession agreement; (ii) royalties – defined by law as a financial compensation according to the oil production; (iii) annual rental fees – consisting of the annually paid value from the execution of the concession agreement and fixed per square kilometer or fraction of the auctioned block; and (iv) special participation – defined as an extraordinary financial compensation payable only in cases of high volume of production or high profitability. The special participation is a tax over the net revenue of the concessionaire based on its location (onshore or offshore) and the production level. The two most important government taxes in terms of total revenue under this regime, along with signature bonus, are the royalties and special participation. According to the 2010 Statistical Yearbook of NPA, royalties and special participation accounts for (average value from 2000 to 2009) 50.6% and 47.8% of the revenue, excluding the signature bonus.

In 2006 Petrobras has announced an evidence of ultra-deep-water oil reserves beneath underground salt layer, the so-called pre-salt. This layer extends along the Brazilian outer continental shelf about 300 kilometers from the shoreline. The prospect of huge reserves of hydrocarbons in the pre-salt with low exploratory risk[3] raised the discussion of whether concessions would be the appropriate legal regime to govern the development of oil and gas in these areas. In response to this discovery, in 2010 Brazil adopted the PSA regime to govern the exploration and production of the oil in the pre-salt area.

Under the PSA, differently from the concession contract, the property rights over of the hydrocarbons still belongs to the government. The contractor will, at its own risk, explore, develop and produce the oil and, in the case of any commercial discovery, such contractor is

[3] Although the exploratory risk is reduced by the findings of Petrobras, the companies still bear the development risk, which is considered very high in these areas.

entitled to receive a share of the produced oil after being reimbursed from the exploration and production costs, the so-called oil cost. The remaining oil production, the so-called oil profit, is shared between the government and the contractor according to the terms of the production sharing agreement, defined by the proposed bid of the winning contractor for the lease auction. Thus, under the PSA, the government take is paid through its share of oil profit as well as the payment of a signature bonus and royalties.

The 2010 Federal Law also created the Petróleo e Gás Natural S.A. (PPSA), a government-owned company, is responsible for managing the production sharing agreements and the sale of the government's share of the oil output. This company represents the Union in the PSA and in the unitization process, but it has no responsibility over exploration and production activities. PPSA does not bear any exploratory and development risks, but it has a mandatory participation in all consortia formed as well as the right to nominate the majority of the operational committee, including its president who has a tie-breaking vote. Petrobras was the sole operator of all oilfields under the PSA, and it must have at least 30% of each field tendered. However, 2016 Federal Law modified these two obligations, allowing Petrobras to freely choose whether to be or not the operator. In case of Petrobras' interest, the National Council for Energy Policy (CNPE) indicates its minimum participation in the planned consortium, which may not be less than 30%.

Finally, the Brazilian legislation defines that when the reserve is under two different leases, possibly under two different fiscal regimes, it is mandatory to unitize the production in order to reduce the cost of production of the reserve, and as soon as one consortium finds its reserves goes beyond its area, it must notify NPA. If the parties involved in the unitization process do not reach an agreement before a deadline specified in the PSA, the NPA will propose an agreement. In case it is not accepted by the parties, their contract can be terminated.

Consequently, Brazil now has a dual fiscal regime for hydrocarbons exploration and production. While the PSA governs exploration and production of the oilfields located in the pre-salt area as well as those considered strategic by presidential decree, the concession regime governs all other fields. However, since it is not possible ex-ante to delimit the areas according to the type of reserve, there might be situations in the near future in which companies have to unitize their production, operating under different fiscal regimes. The focus of this paper is to study how the existence of dual fiscal regime may affect the negotiation of the unitization agreement.

3 Literature

The United State (US) oil industry flourished after 1890s and an oil rush in many states has started. In most of the states, the ownership of the underground resources was initially given to the company that extracted the oil first, i.e., the rule of capture prevailed initially. A landowner neighbor of a land in which oil was found had an incentive to rent her/his land to an oil company, which would probably extract the oil from the same oil reservoir. This unregulated competition and the decrease of the crude oil prices experienced during the 1970s became a big concern for

the industry and an important research topic for economists to discuss.

Gary Libecap and Steven Wiggins, among others, studied the competition in the oil industry and its rent dissipation during the 1980s. Libecap and Wiggins (1984) show an estimate from Federal Oil Conservation Board that the recovery rate was only $20-25\%$ under competitive extraction, while under controlled withdrawal could be $85-90\%$. As firms compete for migratory oil and gas, they dissipate reservoir rents with excessive capital, too rapid production, and the impossibility of total recovery. However, with a unitization agreement among producers, a single firm is designated the unit operator to develop the entire reservoir. The gains from an agreement can be huge both from savings in capital costs and from increasing the overall production by two to five times the unregulated production.

Even though there is a huge rent dissipation due to the rule of capture, studies showed that by 1947 only 12 in $3,000$ fields in the US were fully unitized. Libecap and Wiggins (1984, 1985a) considered two possible explanations for this failure of reaching an agreement. The first is the concentration in the field, as more firms have access to the same tract, the harder will be to reach a mutual interest agreement. The second reason, related to the first one, is the heterogeneity of firms' interest and information. As most of the unitization processes started during the development phase after the commercial petroleum deposits have been found, the information about firms' tracts and their estimated value diverge, making it harder for the parties to reach an agreement.

In a comparative analysis, Libecap and Wiggins (1985b) evaluated how different regulatory policies affect the unitization process in the US. They chose three US states that had different regulatory policies and high production levels. In Wyoming, high success in achieving unitization agreements was observed. In that state, most of the oilfields were federal land and the policy encouraged early exploratory units, before commercial petroleum deposits have been found. This led to large gains from unitization and eased the bargaining process since the information about the deposit was more homogeneous. The Brazilian regulatory framework adopted the same principle as firms must notify the NPA as soon as they find that their tracts extend beyond their leases. Another incentive provided by the federal policy in the US is that firms are usually granted the area for up to 20 years. However, if a lease is unitized, it is automatically extended for the life of the unit. In the other states, the unitization typically starts late in the field development, and small number of successful unitization agreements was observed.[4]

More recently, Libecap and Smith (1999, 2001) show that if the field contains two (or more) substances that differ in kind (like oil and gas), then different forms of non-unitized ownership and operation (with conflicted production incentives) may dominate unitized development of the resource.[5] According to them, unitization may not be a Pareto improvement in situations where the tract contains oil and gas, due to different interests about timing and forms of extraction. Mohan and Goorha (2008) show that the nature of contractual incompleteness of the unitization can also provide wrong incentives to firms, resulting in under-investment during the exploratory

[4]For an extensive comparative analysis of the US regulation on unitization, see Weaver and Asmus (2006).
[5]For an extensive review about the unitization contracts, see Libecap and Smith (1999).

phase.

In a setting closely related to ours, Smith (1987) presents unitization process as the Nash's axiomatic bargaining and shows that small-interested holders are more benefited in the unitization process when the alternative solution is the rule of capture. This follows from the hypothesis in Libecap and Wiggins (1984, 1985a) that small firms are reluctant to accept unitization agreements, expecting that large firms offer concession to small firms. Smith argues that, if a neutral arbitration with respect to distribution of the profit were possible, large-interested firms would threaten to invoke arbitration when its cost is not large enough. Differently from our model, he does not consider dual fiscal regimes. Our model explicitly shows the effect of the fiscal regimes over the bargaining position of the firms involved in a unitization process. We also show the role of a regulator concerned about both the government take and the firms' profits.[6]

4 The environment

We consider two firms ($i = 1, 2$) operating over their granted areas to explore and develop oilfields. The oil extracted by these firms comes from the same reservoir underneath their areas. The average production cost is represented by the function $AC_i(q_1, q_2)$ that satisfies the following assumption on externality that leads to a common-pool problem:

Assumption. $AC_i(q_1, q_2) \equiv c_i q_i + b(q_1 + q_2)$, *where* $c_i > 0$ *and* $b > 0$.

Thus, the extraction by one of the firms leads to an increase in the production cost of the other firm. We assume that the output price of the produced oil is exogenously determined and given by p, and the gross profit function for a firm i is given by:

$$\tilde{\pi}_i(q_1, q_2) \equiv [p - AC_i(q_1, q_2)]\, q_i. \tag{1}$$

Each firm may be operating under different fiscal regime. We consider two contracts or fiscal regime that can be used by the government to lease areas for exploration and development of oil. The fiscal regime determines the economic relation between firms and the government. In particular, it determines the government take on the total output revenue.

The first type of contract is the PSA, described in Section 2. Under this contract, the firm i's profit from the production is shared with the government according to the parameter λ_i, established during the auction phase, and the firm i still needs to pay royalty rate r_i to the government. As we assume there is no other tax, the firm i's (net) profit function is

$$\pi_i(q_1, q_2) \equiv (1 - \lambda_i)\, [\tilde{\pi}_i(q_1, q_2) - r_i q_i] \tag{2}$$

[6]Regarding the PSA contracts, Aghion and Quesada (2010) study the moral hazard and risk sharing problems that affect the production under different contracts, once they consider that government may change the agreement to increase its take. This is exactly what happened in Venezuela and Bolivia where oil companies anticipated the possibility of holdup and underinvestment. For a survey about the PSA fiscal regime see Johnston (1994), and for a comparison of the legal framework between Brazil and the US see Pinto (2013).

and the government revenue is

$$\psi_i(q_1, q_2) \equiv \lambda_i \left(\tilde{\pi}_i(q_1, q_2) - rq_i\right) + r_i q_i. \tag{3}$$

The other type of fiscal regime is the concession contract that grants the lease to a firm in exchange for a fixed payment in advance and requires the firm to pay the royalties based on the production. The advanced payment is sunk for the firm at the exploratory and development phases, so the production level considers only the royalty, along with the price and the production cost. We consider royalties as a function of the production level. Therefore, under the concession regime, the (net) profit function and the government revenue can be represented by (2) and (3) where λ_i is equal to zero.

As our main goal is to analyze the impact of two different fiscal regimes during the unitization process, in order to easy computation and to have a parsimonious analysis, we will assume identical firms (i.e., $c_1 = c_2 = c$) and the same royalty rate under both regimes (i.e., $r_1 = r_2 = r$). By doing so, we are isolating the fiscal regime problem, excluding firms' heterogeneity and evaluating only the impact of the dual fiscal regimes in the unitization process. In the next subsection we will present the common-pool problem under the considered fiscal regimes.

4.1 The common-pool problem

We now introduce the existing common-pool problem in this setting. In order to do so, we examine two benchmark cases: (i) rule of capture where firms act non-cooperatively by choosing their production levels seeking to maximize their own profit; and (ii) firms collude and seek to maximize the joint-profit.

First, let us analyze what would happen if both firms are acting under the rule of capture. This rule establishes that the ownership of the extracted resource belongs to the firm responsible for extracting it. This allocation rule induces firms to act strategically, seeking to extract as much as possible without considering the negative externality over the competing firm. A simple solution concept that captures this behavior is the Nash equilibrium. Henceforth, this solution concept will be interchangeably called the rule of capture solution.

Firms seeking to maximize their profit function (2) do not consider the fiscal regime (λ_i), as it is just a fixed proportion of its profit. On the other hand, the royalty r acts as an additional marginal cost for the firm, thus reducing the output level of both firms. As we are considering identical firms in terms of the cost structure, the rule of capture solution involves both firms choosing the same output level denoted by q^N, where N stands for the Nash equilibrium concept. The externality introduced in the cost function reduces the total profit that firms could make if they behave as a single firm operating in two different fiscal regimes, by internalizing the externality as shown in the following proposition.

Proposition 1. *The total profit under the rule of capture is strictly less than the profit made by a single firm operating two distinct areas.*

Proof. Consider the problem of a single firm operating two areas under different fiscal regimes, given by

$$\max_{q_1,q_2\geq 0} \sum_{i=1,2} (1-\lambda_i)\left[\tilde{\pi}_i(q_1,q_2) - rq_i\right]. \tag{4}$$

We denote q_i^*, $i=1,2$, the solution for this problem and $Q^* = q_1^* + q_2^*$ the total production. The first-order condition implies that the total marginal profit is greater than zero:

$$p - cQ^* - \frac{3}{2}bQ^* - r > 0, \tag{5}$$

while summing the first-order condition of each firm from the rule of capture solution (Cournot-Nash solution), using the notation $Q^N = q_1^N + q_2^N$ in this case, we have

$$p - cQ^N - \frac{3}{2}bQ^N - r = 0. \tag{6}$$

The comparison between (5) and (6) implies that the total production under a single firm operation is less than under a competitive solution, i.e., $Q^N > Q^*$. Since the cost function is strictly convex and the price is fixed, the total profit from competition is strictly less than the profit made by a single firm operating both areas.[7] □

The common-pool problem occurs when a firm does not consider the negative externality the other firms will bear due to its production. In the oil industry, this means that costs become higher due to competition as firms overproduce leading to a costly way of extraction. In our static model, although we are not considering the cost of stock level, externality competition induces firms to produce more at higher costs and thus profits are reduced.

The total profit loss due to competition could be internalized if firms cooperate and split profits between them. However, in general, the problem to decide the proportion of the profit that each firm will receive is not a trivial problem. In the next section we solve this problem using the Nash's bargaining solution.

5 The bargaining problem

As we saw in the previous sections, due to the common-pool problem, competition would reduce the total profit possible to achieve when firms cooperate. On the other hand, negotiating a cooperation agreement involves attrition about the profit-sharing rule. According to Osborne and Rubinstein (1990), this is a typical bargaining situation because cooperating is mutually beneficial and there is a conflict of interest about the terms of the agreement.

We are interested in studying how the presence of dual regimes affects the negotiation between firms. Thus, we model the unitization agreement as the Nash solution to the bargaining problem

[7] Notice that this result is analogous to the classic result that monopoly profit is greater than the Cournot's profit, but now the interaction between firms is given by the externality.

between firms over an agreement that includes the production plan (q_1, q_2) and the profit sharing rule $\alpha \in [0,1]$, where α represents the joint-profit portion given to firm 1. Since the firm i's profit function is $\pi_i(q_1, q_2)$, the joint-profit is given by $\Pi(q_1, q_2) = \sum_i \pi_i(q_1, q_2)$. As it was discussed above, sometimes the bargaining process breaks down and, depending on the threaten disagreement outcomes, firms would compete for the resource or the government would propose a take-it-or-leave-it agreement. We will analyze both resolutions in Section 6. For the moment, these threat points are denoted by $\overline{\pi}_i$. Nash (1950) showed that this problem can be (axiomatically) solved by the following maximization problem:

$$\max_{(\alpha, q_1, q_2) \in [0,1] \times \mathbb{R}^2_+} \{\alpha \Pi(q_1, q_2) - \overline{\pi}_1\} \cdot \{(1-\alpha)\Pi(q_1, q_2) - \overline{\pi}_2\}. \tag{BP}$$

Figure 1 shows a representation of the stake of the bargaining. The vertical axis represents firm 1's profit and the horizontal axis represents firm 2's profit. The green line represents the profit possibility frontier, which is found by solving the following problem,

$$\max_{q_1, q_2 \geq 0} \quad \pi_1(q_1, q_2) \text{ s.t. } \pi_2(q_1, q_2) = \overline{\pi}_2,$$

for each possible $\overline{\pi}_2$. Point $D = (\overline{\pi}_1, \overline{\pi}_2)$ represents the threat point of each firm, i.e., the outside option that firms have. For example, a firm could prefer not to agree with any proposed deal and decide to compete for the resource according to the rule of capture, if this is possible. In this case, the profit this firm has is equal to the rule of capture profit level. However, due to the common-pool problem, there exist deals that can improve both firms' payoffs, represented by the blue area.

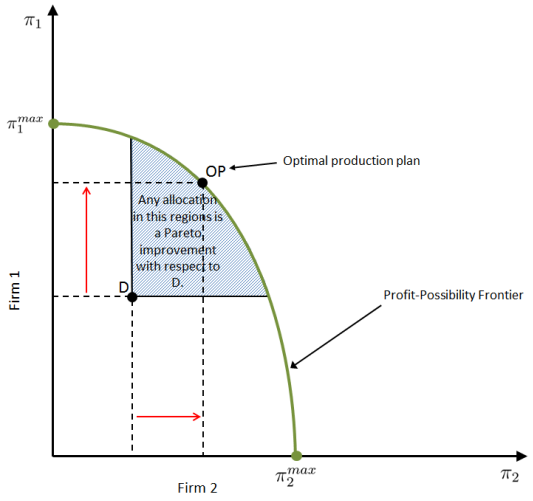

Figure 1: Optimal production plan.

According to the axiomatic bargaining proposed by Nash, we know that the bargaining solution must be Pareto optimal, otherwise there would still be a room for a costless negotiation that would improve firms' profits. Since both firms are splitting the profit, it would be optimal to choose the production plan (q_1, q_2) that maximizes the total profit $\Pi(q_1, q_2)$. As denoted before, let (q_1^*, q_2^*) be the optimal production plan that maximizes the total profit. Therefore, under a unitization agreement the problem of common pool is resolved when only one of the firms will explore the reservoir and, in order to maximize its payoff, the firm must choose the optimal production that generates the highest possible payoff for both firms.

Let $\Pi^* = \Pi(q_1^*, q_2^*)$ be the maximum profit. Thus, the unitization problem can be simply reduced to the problem of splitting the profit. According to the Nash's bargaining solution, the splitting rule solves the following problem:

$$\max_{\alpha \in [0,1]} \{\alpha \Pi^* - \overline{\pi}_1\} \cdot \{(1-\alpha)\,\Pi^* - \overline{\pi}_2\}\,. \tag{BP'}$$

Now, the problem of how firms actually share the profit shows the importance of the threat points in the analysis, as we can clearly see from the optimal splitting rule formula:

$$\alpha^* = \frac{1}{2} + \frac{\overline{\pi}_1 - \overline{\pi}_2}{2\Pi^*} \quad \text{and} \quad 1 - \alpha^* = \frac{1}{2} + \frac{\overline{\pi}_2 - \overline{\pi}_1}{2\Pi^*}. \tag{7}$$

From (7), if the threat point is the same for both firms, they will equally share the profit. Otherwise one of them will end up receiving a larger share of the profit. More precisely, firm i will have greater share of the profit if and only if it generates more profit at the given threat point.

In the next section we present two models of agreement breakdowns that induce different threat points for the firms. Based on each of them, we analyze the solution of the bargaining problem.

6 Two models of negotiation breakdown

Unitization is usually a long and complicated process in which companies work on to reach the deal. Each company is aware of what the other company can do if an agreement is not reached, and they use this information to get a better deal. The outside option of this negotiation corresponds to the threat point of the Nash's bargaining problem. As we saw in Section 5, the bargaining solution depends on the threat point which is the optimal solution for the considered institutional framework. One possible threat point is the non-cooperative solution where firms compete for the oil and face the common-pool problem. The other possibility is when the regulator proposes an agreement that firms can accept or not. If they do not accept, the government terminates their contract and they end up with no profit.[8] This last situation

[8]This is an extreme scenario and the threat of contract termination may not be credible. However, we would like to illustrate the effect of the commitment power of this termination possibility on the bargaining solution.

represents the Brazilian regulatory framework.

Next, we will see how the fiscal regimes affect unitization. First, we consider the benchmark where firms compete for the resource according to the rule of capture. In this case, both firms can improve their profits by cooperating given the common-pool problem. The interesting question we address is how the dual fiscal regime affects the bargaining for the shares and the resulting transfers between the firms.

6.1 Rule of capture resolution

The rule of capture states that the ownership of the extracted resource from the nature belongs to the one who is able to extract it. In the past and in some countries like the US, the government did not interfere in the competition of the oil industry. This is exactly our first benchmark case, as we consider the rule of capture as the status quo condition. As we saw before, this is the Nash equilibrium of the common-pool problem, whose solution was called the rule of capture. Thus, the threat point is given by $\overline{\pi}_i = \pi_i^N$ and defines the outside option of an individual rationality condition, i.e., the minimum amount a firm accepts to receive in the bargaining.

As we saw in Subsection 4.1, firms can improve payoffs by acting as a single unit and then sharing the joint-profit between them. In Section 5 we showed that the production plan that maximizes the joint-profit, (q_1^*, q_2^*), is consensus for both firms. However, attrition comes up when firms are negotiating how to share the joint-profit. Firms act strategically seeking to capture gains from cooperation as much as possible. Both firms are aware that if they cannot reach an agreement, the rule of capture will induce profit $\pi_i^N = \pi_i(q_1^N, q_2^N)$ for firm i. As one would expect, the following proposition shows that the firm that generates higher profit for the unity should receive larger share of the joint-profit.

Proposition 2. *Under the rule of capture threat, the firm that shares less profit with the government receives larger share of the joint-profit (i.e., α is decreasing in λ_1).*

Proof. The rule of capture solution $\left(q_1^N, q_2^N\right)$ can be found by solving the best-reply problems that characterize the Nash equilibrium of the game:

$$q_i^N \in \arg\max_{q_i \geq 0} (1 - \lambda_i) \left[\tilde{\pi}_i(q_i, q_j^N) - r q_i\right]. \tag{8}$$

Notice that the output choice of each player does not depend on the fiscal regime λ_i. However, the profit is a decreasing function of λ_i. Without loss of generality, suppose that $\lambda_2 > \lambda_1$, thus firm 1 has lower profit than firm 2, i.e., $\pi_2^N < \pi_1^N$.

Let α^N be the share of the joint-profit that firm 1 receives as a solution of the bargaining process. According to (7), $\alpha^N > 1/2$. Thus, the firm that shares large portion of the profit with the government receives lower share of the joint-profit. □

Even though the firm that has larger profit under the rule of capture receives larger share of

the joint-profit, the difference of the fiscal regimes and the strategic behavior may allow one firm to gain from the cooperation more than it contributes for the joint-profit. If this is the case, one firm is transferring part of its profit to the other firm. The role of transfers is to ensure that the deal will always be reached.

Although the firm with higher threat gets larger share of the profit, is the profit share equal to the firm contribution for the total profit? To answer this question, let us define the transfer as the amount of payoff a firm receives in excess of its contribution to the total profit. For example, the transfer received by firm 1 is $t_1^N \equiv \alpha^N \Pi^* - \pi_1^*$. If $t_1^N < 0$, firm 1 is implicitly transferring to firm 2 in order to reach an agreement. At the rule of capture threat, these transfers are given by

$$t_1^N = \frac{\pi_2^* - \pi_1^*}{2} + \frac{\pi_1^N - \pi_2^N}{2} \text{ and } t_2^N = -t_1^N. \tag{9}$$

Hence, firm 2 receives positive transfer if and only if $\pi_1^* - \pi_1^N > \pi_2^* - \pi_2^N$ (i.e., when firm 2's gain from cooperation is less than firm 1's). The idea is that the firm with lower gain from cooperation asks for positive transfer in order to agree with the deal. Since cooperation benefits relatively more firm 1, it is willing to transfer some of the benefit from cooperation to be in a better position than the status quo. We can see the representation of the transfers in the Figure 2. Firm 2 receives transfer from firm 1 under the threat point as its bargaining position. The figure shows an example that firm 2 is not benefited as much as firm 1 as we can see by comparing point PO relative to point D. The point PO represents the solution (π_1^*, π_2^*), where each firm receives what it generates. But, in order to firm 2 agree with the deal, firm 1 transfers a portion of its gains to firm 2 and the final solution is represented by point B.

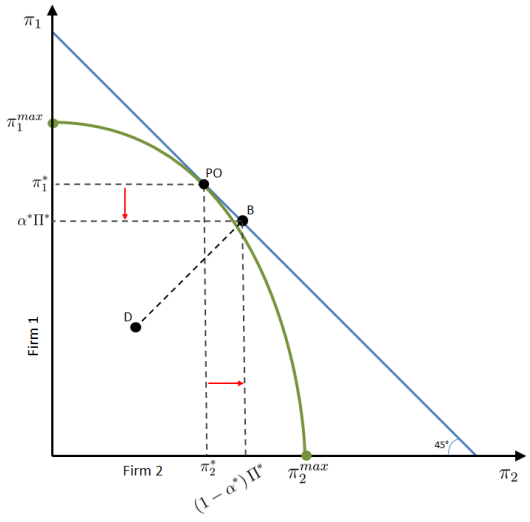

Figure 2: Optimal transfers.

We can now study which firm receives positive transfer. When the fiscal regime is the same (i.e., $\lambda_1 = \lambda_2$), at the rule of capture solution and at the cooperative solution firms' profits are the same (i.e., $\pi_1^N = \pi_2^N$ and $\pi_1^* = \pi_2^*$). Thus, there is no transfer from one firm to the other. However, when the fiscal regimes are different, we have the following proposition.

Proposition 3. *The firm that receives positive transfer in the bargaining is the one with the larger government share.*

Proof. Without loss of generality, assume that $\lambda_2 > \lambda_1$. Let us show that $q_1^* > q_2^*$. The first-order condition of problem (4) implies for each firm i the following condition:

$$(1-\lambda_i)\left[\frac{\partial \tilde{\pi}_i}{\partial q_i}(q_1^*, q_2^*) - r\right] + (1-\lambda_j)\frac{\partial \tilde{\pi}_j}{\partial q_i}(q_1^*, q_2^*) = 0, \tag{10}$$

and using (1) we can compare both first-order conditions through the following equation:

$$p - q_1^*(2c+3b) - bq_2^* - r = \frac{1-\lambda_2}{1-\lambda_1}\left[p - q_2^*(2c+3b) - bq_1^* - r\right]. \tag{11}$$

Since $\lambda_2 > \lambda_1$, we have $\frac{1-\lambda_2}{1-\lambda_1} < 1$ and thus it is clear that $q_1^* > q_2^*$ by (11).

Note that dividing (4) by $2-\lambda_1-\lambda_2$, it becomes clear that under cooperation the unit will choose the production that maximizes the weight sum of firms' profits. Since $\lambda_2 > \lambda_1$, firm 1 weights more than firm 2 and we must have $\tilde{\pi}_1(q_1^*, q_2^*) - rq_1^* > \tilde{\pi}_2(q_1^*, q_2^*) - rq_2^*$. From (8), we know that $\tilde{\pi}_1\left(q_1^N, q_2^N\right) - rq_1^N = \tilde{\pi}_2\left(q_1^N, q_2^N\right) - rq_2^N$ and, using $\frac{1-\lambda_1}{1-\lambda_2} > 1$, we find $\pi_1^* - \pi_1^N > \pi_2^* - \pi_2^N$, which shows that $t_2^N > 0$. □

Therefore, although firms are identical, operating under different fiscal regimes creates a distortion which allows one firm to gain more rent from the unit deal, in the sense that one firm earns more rent than the one it generated for the unit.

In the next subsection we will introduce the role of the regulator following the Brazilian legal framework. The regulator is responsible to propose a deal whenever firms cannot reach one. We will study how it affects the bargaining position and how firms use it strategically to gain more rent from the unit.

6.2 Regulator resolution

According to the Brazilian legal framework, during a unitization process firms have a period to negotiate and to reach an agreement. After the deadline, the regulator proposes a final agreement. The government is interested in collecting revenue to finance his/her policies and his/her utility is given by:

$$\Psi(q_1, q_2) \equiv \sum_i \left\{\lambda_i\left[\tilde{\pi}_i(q_1, q_2) - rq_i\right] + rq_i\right\}. \tag{12}$$

Therefore, the government has two sources of revenue: profit share from the PSA and royalties. The profit share is aligned with the firms' goal to maximize their profit. However, royalties add an extra burden to the firms since the government would like firms to operate above the optimal production level in order to collect more royalties.

A simple way to model the regulator's role in our model is by assigning weights for the firms' profits and the government's revenue, which we denote by $\rho \in [0,1]$. If $\rho > (<) 1/2$, the regulator cares more (less) about revenues than profits. In the extreme case $\rho = 0$, the regulator just cares about firms' profits and disregards the government's revenue. In the other extreme case $\rho = 1$, the regulator is totally aligned with the government and only cares about revenues. We say that the regulator is neutral when $\rho = 1/2$. Hence, we can write the regulator utility as

$$\begin{aligned} W(q_1, q_2) &\equiv \rho\Psi(q_1, q_2) + (1-\rho)\Pi(q_1, q_2) \\ &= \textstyle\sum_i \Lambda_i \tilde{\pi}_i (q_1, q_2) + (2\rho - 1)\, r \left[(1-\lambda_1)\, q_1 + (1-\lambda_2)\, q_2\right], \end{aligned} \tag{13}$$

where $\Lambda_i = \rho\lambda_i + (1-\rho)(1-\lambda_i)$ is a composite weight in which the first term is related to the government take and the second term refers to the firms' profits.

It is easy to see that if $\rho > 1/2$, the regulator would be better by increasing the firms' productions in order to raise the amount of royalties, and firm 1 would produce more than firm 2 if $\lambda_2 > \lambda_1$. When $\rho = 0$, the regulator's problem is equivalent to the one under cooperation, while with $\rho = 1$ the regulator chooses the production that maximizes the government revenue.

The following propositions show that the firm that produces more is determined by the regulator's alignment parameter ρ and the fiscal regime λ_i. In particular, when the regulator weights more firms' profits than government's revenue, the firm that shares lower portion of its profit would generate most of the unit profit.

Proposition 4. *A firm produces more than the other if and only if it shares lower portion of its profit with the government and the regulator is more aligned with the firms.*

Proof. We have to show that $q_1^R > q_2^R$ if and only if $\lambda_2 > \lambda_1$ and $\rho < 1/2$. Subtracting the first-order conditions for q_1 and q_2 and analyzing the derived equality, we have:

$$p - bQ^R - 2cq_1^R = \frac{\Lambda_2}{\Lambda_1}\left(p - bQ^R - 2cq_2^R\right). \tag{14}$$

Now comparing Λ_1 and Λ_2, we have that if $\rho < 1/2$ and $\lambda_2 > \lambda_1$, then $\Lambda_1 > \Lambda_2$ and $q_1^R > q_2^R$. □

If $r = 0$, then we can rewrite equation (13) as the weighted sum of firms' profits and we can show which firm generates most of the profit for the unit.

Proposition 5. *Suppose there is no royalty (i.e., $r = 0$). A firm has larger profit under the regulator's proposal if and only if it shares lower portion of its profit with the government and the regulator is more aligned with firms.*

Proof. The proposition is equivalent to show that $\pi_1^R > \pi_2^R$ if and only if $\lambda_2 > \lambda_1$ and $\rho < 1/2$. We apply the same strategy used to prove Proposition 3, but now the weights are found dividing equation (13) by $\Lambda_1 + \Lambda_2$. Firm 1 weights more firm 2 if and only if $(\lambda_1 - \lambda_2)(2\rho - 1) < 0$, which concludes the proof. □

The proof of Proposition 5 fails if $r > 0$ is sufficiently high. Notice that the production of the firm that has higher Λ_i increases. In addition, since the first-order condition implies that the production level is at the increasing interval of the profit function when $r = 0$, then increasing the quantity of firm i increases its profit.

6.2.1 Numerical analysis

The regulator resolution depends not only on λ_i but also on ρ. Thus, we do not have the symmetry as we found under the rule of capture resolution. Therefore, we cannot use the same strategy to show that $\pi_1^R > \pi_2^R$. Hence, in order to have some insights from this problem, we solve the regulator's problem numerically and identify the parameters' regions in which the profit of one firm is greater than the other one.

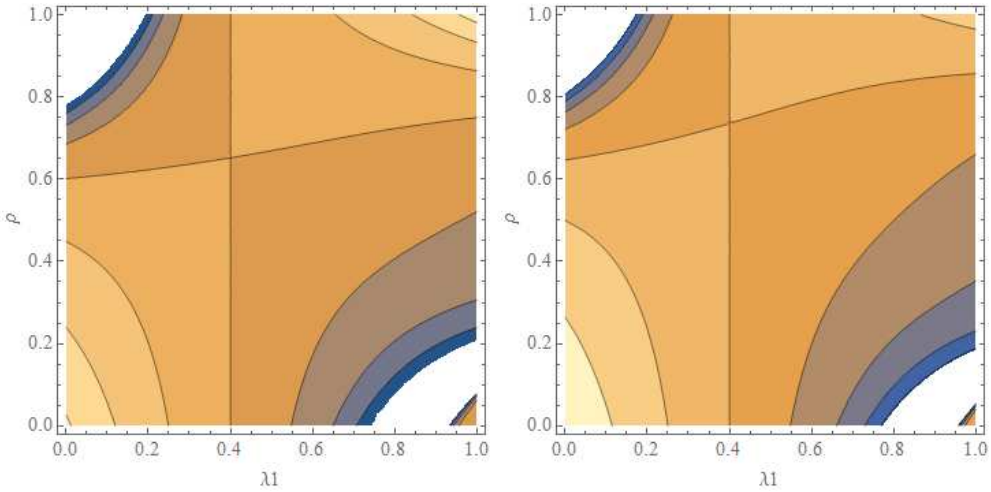

Figure 3: $\pi_1^R - \pi_2^R$ when $\lambda_2 = 0.4$; for $b = 3$ and $b = 2$, respectively.

Figure 3 shows the set of λ_1 and ρ where firm 1 generates most of the profit, assuming $\lambda_2 = 0.4$. The lighter color means $\pi_1^R > \pi_2^R$ and the darker color means $\pi_1^R < \pi_2^R$. In the left picture we assume $b = 3$, while in the right picture we assume $b = 2$. As we can see, the upper right and the lower left corners of the figures are the regions of (λ_1, ρ) with greater profit level for firm 1 compared to firm 2. The vertical line at $\lambda_1 = 0.4$ identifies which firm earns more profit. However, ρ is a function of other parameters of the model, like the fiscal regimes, cost and externality, as we can see by comparing both plots. In summary, we can argue that the

firm that shares less profit generates more profit relative to the other firm when the regulator is sufficiently aligned with firms.

Let us return to the bargaining problem when firms use the regulator's threat point. By (7) and the above numerical analysis, we can see that firm 1 has greater share than firm 2 (i.e., $\alpha^R > 1/2$) if the firm 1's profit share is less than firm 2's and the regulator cares more about firms' profits or when firm 1 shares more its profits and the regulator puts more weight on the government's revenue.

Even though firm 1 receives a larger portion of the joint-profit under the condition mentioned above, the transfer that a firm makes to the other one does not depend on ρ, according to the numerical exercise. Interestingly, the transfer seems to depend only on the fiscal regime and it is positive for the firm that shares larger portion of its profit with the government (i.e., firm 1 receives positive transfer if and only if $\lambda_1 > \lambda_2$). An illustration of this solution is given in Figure 4, where we display the contour plot of firm 1's transfer; the lighter color is $t_1^R > 0$ and the darker color means that firm 1 gives positive transfer to firm 2 (we are still assuming that $\lambda_2 = 0.4$). Note that transfers do not depend on ρ, but only on the fiscal regime. Hence, as in the rule of capture situation, the firm that benefits the most is the one that shares larger portion of its profit with the government.

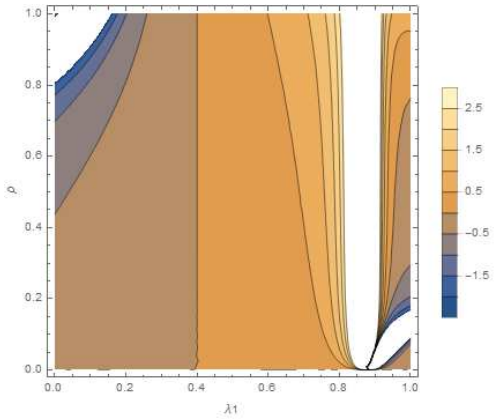

Figure 4: t_1^R contour plot.

6.3 Comparing the solutions via numerical analysis

Now we explore whether the existence of the regulator increases or not the transfer needed to reach an agreement. To address this question, we will compare the transfer t_i^R under the regulator's proposal with the transfer t_i^N under the rule of capture. Notice that

$$t_i^R - t_i^N = \frac{\pi_i^R - \pi_j^R}{2} - \frac{\pi_i^N - \pi_j^N}{2} \iff t_i^R - t_i^N = \frac{\pi_i^R - \pi_i^N}{2} - \frac{\pi_j^R - \pi_j^N}{2}. \tag{15}$$

Looking at (15), the transfer under the regulator's proposal is greater than the one under the rule of capture if and only if $\pi_i^R - \pi_j^R > \pi_i^N - \pi_j^N$. Therefore, the larger is the difference between firms' profits under the regulator's proposal compared to the firms' profits under the rule of capture, the larger is the transfer needed to reach an agreement. Transfers are determined by the fiscal regime under which firms are operating, and not by their production and cost functions. Therefore, the regulator's role is to minimize the misallocation of rents and to reduce transfers between firms.

So far we identified the firm who benefited the most with the unitization process when operating under a dual fiscal regime and the firms' threat points are according to the rule of capture or to the regulator's proposal. Another important question is whether the regulator is able to reduce the distortion caused by the dual fiscal regime.

Notice that according to (15), the distortion is lower when the difference in the profits evaluated across the different threat point solution is lower. Figure 5 shows that the distortion increases with ρ, i.e., the more importance the regulator gives to the government's revenue, the higher are the generated distortion and the transfers. However, the transfer under the regulator's proposal is lower than the transfer under the rule of capture as long as the regulator is neutral between the government's revenue and the firms' profits (i.e., $\rho = 1/2$). If the regulator cares more about the government's take, then the distortion and the transfer needed to reach an agreement are higher.

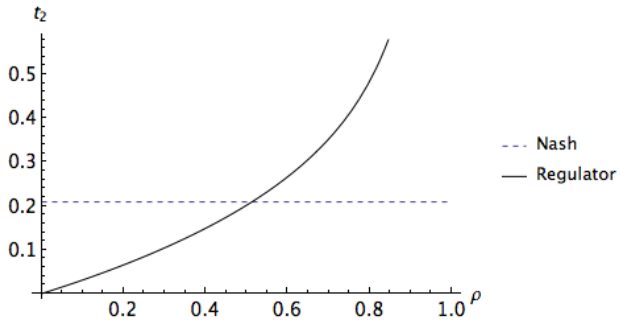

Figure 5: Transfer comparison.

The horizontal axis of Figure 5 represents the alignment level ρ between the regulator and government, and the vertical axis is the transfer that firm 1 receives, where we are assuming that $\lambda_1 > \lambda_2$. The blue line in the plot represents the transfer when firms' threat points are according to the rule of capture, while the orange line represents the transfer when firms' threat points are according to the regulator's deal. As we can see, the transfer associated to the regulator's proposal is lower if $\rho < 1/2$.

7 Conclusion

In this paper we studied the effects of the dual fiscal regime on the unitization negotiation. The new regulatory framework for the pre-salt areas in Brazil introduced the PSA to lease the oilfield for exploration and development. The concession contracts will then co-exist in different areas, but some of them might be contiguous to the pre-salt areas. Thus, the study proposed here sheds light on the distortion the dual regime can cause to the firms and how firms strategically use the regulator as a threat to be benefited in the negotiation.

Our paper modeled the negotiation of the unitization agreement as a bargaining problem solved by the axiomatic protocol proposed in Nash (1950). We showed that identical firms operating under different fiscal regimes may be benefited differently. The benefit is associated to a larger profit share a firm receives compared to the one it is helping to generate. This finding holds for the two possible resolutions considered in the paper: the rule of capture, used as a benchmark case and where firms compete for the resource suffering from a common-pool problem; and the regulator's proposal according to the Brazilian law. We also showed that the distortion caused by dual fiscal regime is reduced when the regulator is indifferent or more worried about firms' profits than the government revenue.

The future steps of the research agenda should consider a dynamic setting where the oil price is uncertain and firms operating under different fiscal regimes may be interested in producing in different paces to reduce the risks. Under the concession regime, firms are free to choose how fast they can produce, while under the PSA, since firms are more aligned with the regulator, faster recovery rates may not be accepted. Another important venue of research would be to model the bargaining protocol under asymmetric information once firms and the government have already accessed different sources of geological and market information when unitization agreement is at place.

References

Aghion, P. and L. Quesada (2010). Petroleum Contracts: What Does Contract Theory Tell Us? In *The Natural Resources Trap: Private Investment without Public Commitment*, Chapter 2. MIT Press. 6

Hardin, G. (1968). The tragedy of the commons'(1968) 162. *Science 1243*, 63. 1

IEA (2013). *World Energy Outlook 2013*. International Energy Agency. 1

Johnston, D. (1994). *International petroleum fiscal systems and production sharing contracts*. Tulsa, Us: PennWell Books. 1, 6

Kim, J. and J. T. Mahoney (2002). Resource-based and property rights perspectives on value creation: the case of oil field unitization. *Managerial and Decision Economics 23*(4-5), 225–245. 1

Libecap, G. D. and J. L. Smith (1999). The self-enforcing provisions of oil and gas unit operating agreements: theory and evidence. *Journal of Law, Economics, and Organization 15*(2), 526–48. 3, 5

Libecap, G. D. and J. L. Smith (2001). Regulatory Remedies to the Common Pool : The Limits to Oil Field Unitization. *The Energy Journal 22*(1), 1–26. 3

Libecap, G. D. and S. N. Wiggins (1984). Contractual Responses to the Common Pool : Prorationing of Crude Oil Production. *American Economic Review 74*(1), 87–98. 2, 3

Libecap, G. D. and S. N. Wiggins (1985a). Oil field unitization: contractual failure in the presence of imperfect information. *The American Economic Review 75*(3), 368–385. 2, 3

Libecap, G. D. and S. N. Wiggins (1985b). The influence of private contractual failure on regulation: the case of oil field unitization. *The Journal of Political Economy 93*(4), 690–714. 2, 3

Mohan, V. and P. Goorha (2008, December). Competition and Unitization in Oil Extraction: A Tale of Two Tragedies. *Review of Law & Economics 4*(1), 519–561. 3

Nash, J. (1950). The bargaining problem. *Econometrica: Journal of the Econometric Society 18*(2), 155–162. 5, 7

Osborne, M. and A. Rubinstein (1990). *Bargaining and markets*. San Diego, CA: Academic Press. 5

Pinto, G. (2013). Upstream Oil and Gas Legal Frameworks: Brazil and the United States Compared. *West Virginia Law Review 115*, 975–1004. 6

Smith, J. L. (1987, October). The Common Pool, Bargaining, and the Rule of Capture. *Economic Inquiry 25*(4), 631–644. 3

Weaver, J. L. and D. F. Asmus (2006). Unitizing Oil and Gas Fields around the World: A Comparative Analysis of National Laws and Private Contracts. *Houston Journal of International Law 28*(1), 3–100. 4