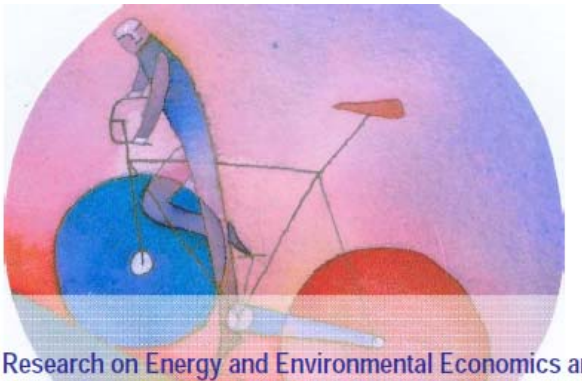

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Efficiency versus transaction costs in multidimensional auctions: the case of Brazilian oil and gas lease auctions

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Abstract

In Brazil, a scoring auction decides which firm has the right to explore oil and gas in a region. One of its dimensions is the amount of local content that firms are willing to implement. However, local content programs are subject to significant uncertainty and complexity so mal-adaptation costs are relevant. We characterize players' bidding behavior when they have information on local content implementation and when they do not. We test those predictions using historical bids. Our tests suggest that the mechanism would be more efficient if the definition of local content programs was left out of the auction.

Key words: Local content; Scoring auctions; Adaptation costs; Oil and gas industry.

JEL: D23, D82, H57, L14, L22, L74.

1. Introduction

One of the main challenges faced by governments of countries with potential for oil and gas production is to design the mechanisms to coordinate exploration and production activities. A typical arrangement consists in the allocation of exploration and production rights to market players. In that context, public administrations and market players need to coordinate their decisions. The building block for such coordination between public and private decisions is a contract. In this paper, we consider an institutional arrangement where the mechanisms for the coordination of public and private parties is a concession contract: a type of lease contract, which grants an oil and gas company rights to explore, develop, sell and export oil and gas extracted from a specified area for a fixed period of time[1].

[1] Note that there are other possible mechanisms where the natural resource property may be transferred through the contract. For instance, in the US, the property of the natural resource would be associated with the property of the land; in Brazil, on the other hand, all natural resources are Union's property.

In order to allocate the concession contract, the government needs to decide the winner. In this regard, the problem is similar to other procurement problems and hence we may place our study within the broad literature analyzing procurement, see for instance (Dimitri et al., 2006). In this paper, we focus on translating the trade-off "bilateral negotiations versus allocation through auctions" that is typical of procurement problems, (Manelli and Vincent, 1995), (Bajari et al., 2009), into the design of mechanisms to allocate these concession contracts. In particular, we will analyze the effects of concession contract complexity in the choice of allocation mechanism.

The challenge stems from the fact that the design of oil and gas contracts is a difficult task with many dimensions, involving constitutional law, macroeconomics, engineering or industrial policy, etc. For instance, public administrations are typically concerned with maximizing rent extraction in the lease contract. But they are also concerned with the effects of oil and gas exploration in the local economy, or with the development of a local industry associated with those economic activities. All those additional dimensions[2], from the allocation mechanism point of view, may be viewed as qualifiers to the basic rent-extraction objective. In that view, they may be considered as "non-price" dimensions, which add complexity to the contract design.

Consider first that the only criterion used to determine the winner of a concession contract is how much the winner is willing to pay for the concession contract. This is typically referred to as 'government take', and it may be viewed as an oil and gas version of the production-cost criterion of procurement problems. A frequent representation of this situation consists in a certain public administration that needs to make decisions with inferior information relative to its counterpart, so it implements an information revelation mechanism. The practical application would be a tendering process involving an auction. This situation is the focus of a significant amount of empirical literature dealing with practical auction design, including oil industries, see for instance (Cramton, 2007).

[2] This is not exclusive of oil and gas contracts. As noted in (Estache et al., 2009), multidimensionality is a pervasive characteristic of public-private relationships.

Nonetheless, public administrations have usually other criteria besides the government take, e.g. the commitment to try to produce made by the company. Hence, we are concerned with the allocation of items with more than one dimension, which may be viewed as an abstract representation of the fact that prices do not contain all the information that characterizes the item. This problem is often identified with one of "quality". That is, besides prices, the complete characterization of the item requires defining its quality –so the item is defined by several dimensions: price and possibly multiple quality dimensions.

Traditionally, the mechanism to cope with that kind of item was some standardized administrative process by which bidders first sent the information to a central authority, and then the central authority chose one of the proposals. This kind of administrative process is often called "beauty contest". However, these administrative processes lacks transparency and are subject to corruption. Hence, auction design literature has proposed the use of scoring auctions, (Che, 1993) or (Branco, 1997). The idea is that, when quality is measurable and contractable upon, they perform better than traditional beauty contests. In that context, (Asker and Cantillon, 2010) shows that, in a context where quality is contractable, scoring auctions perform better than other mechanisms, including sequential negotiation. This result can be understood as the extension of (Bulow and Klemperer, 1994).

Using the previous results, the tendering process seems to require a multidimensional auction. The economic problem implied in the justification for the multidimensional auction may be summarized as follows. The public administration chooses, among several competing companies, the winner of the contract according to several dimensions, some of which are non-price dimensions, e.g. the amount of equipment that will be purchased in local markets. Oil and gas companies have information about those dimensions (including the value that the concession contract has for them) that the public administration does not have. The public administration needs to implement a mechanism to reveal firms' private information. To that end, it defines a scoring function: the way in which the different dimensions will be weighted in order to choose

the recipient of the concession. Firms then decide in a scoring auction, which is efficient when quality dimensions are measurable and contractable upon.

On the other hand, literature dealing with the costs of information an uncertainty complements the previous picture, and casts doubt on the previous "contractability" assumption. (Goldberg, 1977) analyzes the problem of competitive bidding considering that producing information is costly. When the contract is complex, the provision (and acquisition) of information may be more significant than the price dimension. Along these lines, (Bajari and Tadelis, 2001) showed that when contracts are complex, ex post needs of adaptation requires frequent renegotiations, which in turn tends to be costly. In an empirical investigation, (Bajari et al., 2009) identifies several limitations of auction mechanisms in the context of the building sector. This view is closely related to the analysis developed in (Barzel, 1982), where measurement costs are identified as the source of contract incompleteness.

Applying the previous reasoning to oil and gas contracts, the idea is that information related to some or all of the dimensions are costly. Differently put, adding a certain dimension in the scoring rule implies an increase in the contract complexity, which in turn increases mal-adaptation costs. Consequently, if the benefits associated with including an additional dimension in the scoring rule are outweighed by the increased mal-adaptation costs, it would be more efficient to leave out such additional dimension. Specifically, we investigate whether bidding for local content, i.e. including a local content dimension in the scoring rule, performs better than defining a required policy outside the auction and then implementing a simpler mechanism. Our argument rests on the previous reasoning: when information is costly, contract complexity and uncertainty reduce the adequacy of the auction as a mechanism to reveal information.

The relationship between contract complexity and ex post costs has been tested in several industries, (Guasch et al., 2008), (Estache et al., 2009) and (Chong et al., 2014). These studies aimed at analyzing the relationship between awarding mechanisms and probability of renegotiation. However, those studies have not been able to analyze the trade-off "incentives vs.

transaction costs" for each dimension of the award mechanism separately. To cope with this challenge, we propose a different methodology: we do not look at increased probability of renegotiation but at lack of information revealed through the bidding process. To that end, we develop a theoretical model to describe players' bidding behavior both when players have information on local content programs and when they do not. In the model, players' behavior depend on the amount of information they measure (at a cost) in an early stage of the process, where they design their future local content programs. If they have little information, they will bid randomly. If they have relevant information, they will bid according to it because multi-dimensional auctions are efficient mechanisms.

We develop several non-parametric estimations on historical bids, and we observe that neither the properties of the items auctioned nor players' characteristics explain players' behavior. On the contrary, bids seem to be related to auction rules. According to our model, these results suggest that, in the Brazilian oil and gas lease auctions context, auction bids seem to reveal little information. Therefore, as complex contracts are costly, benefits of including a local content dimension in the scoring auction are outweighed by the costs associated with the increased complexity.

The rest of this paper is organized as follows. Section 2 describes the Brazilian regulatory context for the oil and gas lease auctions. Section 3 describes the modeling strategy. We begin by developing a model to represent players' behavior in the scoring auction both in the case where they have rational expectations about adaptation costs and in the case they are uninformed about them. Then we develop a model to represent the costs of contract design in regard local content policies, and finally we show predictions derived from the modeling approach. Section 4 tests the previous predictions using historical bids in the Brazilian oil and gas auctions. Finally, section 5 concludes.

2. Local content in the Brazilian oil and gas lease auctions

The constitutional amendment 09/95 ended the monopoly of Petrobras, and the oil exploration and production activities were opened up to competition later on in 1997, when the Oil Law (Lei 9.478/1997) was implemented. The regulatory framework implemented then, which is still in place nowadays for a large part of industry activities, may be viewed as a concession regime. The lease auctions are conducted by the regulator (ANP, *Agencia Nacional de Petróleo, Gás Natural e Biocombustível*). The objective of this paper is the study of such auctions.

These auctions for exploration rights are defined by a scoring auction where bids for bonus, production plan and local content are placed. The winner is determined by a formula defined *ex ante*, (Lévêque and Hallack, 2013). On the other hand, local content policies in oil and gas industries are typical cases of contract complexity. The government defines very detailed plans to implement local content, which may or may not be easily implemented by producers. When lease auction takes place, there is significant uncertainty about the geological characteristics of the blocks to be explored. This uncertainty also affects the tools that will be necessary to explore and produce oil. It is especially important in Brazil, where most of the oil fields are in deep-water areas, and such production frequently demands goods and services with specific, high technology components.

Since 1998, ANP has been auctioning licenses for leasing exploratory blocks under the concession regime. The model in place is a competitive sealed bid auction. Such auction takes the form of a scoring auction, whose bids have three dimensions:

- The signature bonus – it is an upfront payment in exchange for the contract, paid in Reais (the local currency).
- The bid on the exploratory program – this is a commitment to a minimum program for exploratory activities.
- The bid on local content – it is a percentage of local content in services and operation to be applied in both the exploratory and production development phases.

The winner is the company that bids the higher combination of bonus, exploration program and a percentage of local content in services and operation to be applied in both the exploratory and production development phases, (Rodriguez and Suslick, 2008). The weights of each dimension have changed over the different rounds. Hence, in this regulatory framework, all firms have the same rights and duties: there were no separation between national and foreign enterprises. The government intervention was limited to the choice of auction mechanism (which variables are included in the scoring auction), and in the choices of the regions the will be offered in the auction. The institutional framework for the concession regime is made up of two main bodies: the regulator (ANP) and the national council for energy policy (CNPE, *Conselho Nacional de Política Energética*). ANP is responsible to oversee the contracts enforcements and penalize the enterprises deviating from the contract; the CNPE is the government agent.

The oil and gas lease auctions have been studied in a number of previous papers from a general point of view, see for instance (Matoso and Rezende, 2014). In this work, we are concerned with the local content component of the auctions. The justification for including local content comes from the understanding that local development requires the use of domestic resources, especially domestic labor and skills. This does not need to be necessarily associated with a national company, but it can be a company with foreign ownership installed within national borders. The objective is to encourage the aggregation of value in the production chain within national borders (by employing local staff, local materials, local services and facilities). This means that local content policies should encourage foreign firms to collaborate with local companies. Such collaboration is expected to generate dynamics that will have positive impacts on the development of indigenous firms, (Nordas et al., 2003).

In Brazil, the definition of local contents is done by the regulator (ANP) and has changed between the first and seventh rounds. At first, local content was defined as any product by a company which was legally installed in Brazil, independently of the product components. There were several adaptations and, since the 7th round, local content is defined by the national percentage of each component and service. It has been an evolution to define the local component more

accurately, so it reflects the actual aggregate value by national products and services. On other hand, it has been implemented through a complicated mechanism that increases administrative costs, (Rocha, 2010).

3. Our modeling strategy

This paper considers a two-stage setting, where players first gather information by means of project design and then bid to win items in the auction. To that end, we consider that each auction participant, indexed by $\{1, \dots, n, \dots, N\}$, submits bids defined by three dimensions:

- The signature bonus. Player n's bid on bonus will be denoted B_0^n
- The bid on the exploratory program. Player n's bid will be denoted Q_E^n
- The bid on local content. Player n's bid will be denoted Q_{LC}^n

The auctioneer receives the bids and calculates each participant's score. In that view, players first engage in the costly activity of designing the project for the lease, which will result in the definition of their information on each dimension. After that, players compete in the auction to win the lease contract. In this article, we are concerned with the definition of the bid Q_{LC}^n. Specifically, we consider two extreme possibilities: either players define their bids according only to the information gathered during the project design stage, or they define their bids not having information. In this regard, we are concerned with the same basic problem as (Bajari and Tadelis, 2001), in the sense that we study whether local content bids are dominated by an asymmetric information context or by a (strong) uncertainty one.

We develop our reasoning using the following process: we begin by characterizing players' bidding behavior in each of the two previous situations, with and without information (section 3.1); then we model precisely what we mean by information gathering process (section 3.2), which in turn will allow us to express players' bidding behavior as a combination of the two extreme cases (section 3.3). With that, we will develop testable predictions in order to understand

whether players are bidding as predicted by the information model, or as predicted by the no-information model (section 3.4).

3.1 Bidding behavior in the scoring auction

In order to develop a precise description of the bidding behavior, we set up two stylized models based on two fundamental assumptions: 1) players have private information on local content and 2) players have no information on local content.

The first one is a model of bidding behavior in multi-dimensional auctions where players use private information. From this article's point of view, one of the main assumptions behind that model is that players have rational expectations about adaptation costs. That is, players know that they will not implement the exact exploratory and local content programs that they submit in their bids, but they can anticipate how costly the adaptation process will be. As argued in (Bajari et al., 2014), this may be interpreted as players having symmetric uncertainty about actual costs resulting in common rational expectations.

The second model, on the other hand, assumes that there is no information regarding local content programs, though they still have private information regarding the other dimensions. We will justify these two models in the following section in terms of the project design process.

3.1.1 Possibility 1 – Players have rational expectations about adaptation costs

Consider that we have firms indexed by $\{1, \dots, n, \dots, N\}$, and that the item being auctioned (the exploratory block) has a value v^n. Auction participants submit bids in two kinds of dimensions: an upfront payment, b_0^n, and several "quality dimensions" indexed by $\{1, \dots, t, \dots, T\}$. In our case, these quality dimensions will be the quantity committed to the exploratory program and to local content programs. The quantities required to honor the auction commitments are denoted q_t^n, and the costs associated with each quality dimension are c_t^n. Both values and costs are private information (we assume private values) and are drawn from a joint density function $f_n(v^n, c_t^n)$. Before the block is allocated, we consider that players have rational expectations about the

quantities that will be necessary to honor the contract. We denote q_t^n the actual quantities required to honor the contract. The producer wins the exploratory block if

$$S(b_0^n, q_1^n, \dots, q_T^n) > S(b_0^m, q_1^m, \dots, q_T^m)$$

where $S(\cdot)$ the scoring function and m any index different of n.

In addition, we consider an aggregate variable K_t^n that includes all terms associated with adaptation costs. That is, we consider that players have rational expectations about adaptation costs. Therefore, firm n's profits P^n can be defined as

$$P^n = Prob\{S^n > S^m, \forall m \neq n\}\left\{v^n - b_0^n - \sum_{t=1}^{T} c_t^n q_t^n - K_t^n\right\}$$

In order to obtain a representation of the bidding behavior, let us define $G_m(\cdot)$ as the distribution function of producer m's score, so that $G_m(S^n)$ is the probability that a bid S^n is lower than producer m's score.

$$P^n = \left[\prod_{m \neq n}\left(1 - G_m(S^n)\right)\right]\left[v^n - b_0^n - \sum_{t=1}^{T} c_t^n q_t^n - K_t^n\right]$$

(Che, 1993) or (Asker and Cantillon, 2008) split the above problem into two stages: find first, given a score S^n, the optimal bid if she won the auction, and then find the optimal score that each player wants to submit. Although they studied the case of a quasi-linear scoring rule (one where the price dimension enters linearly into the scoring equation), (Hanazono et al., 2013) generalizes the previous analyses to the case of non-quasi-linear scoring rules. Similar to Che's "productive potential" and Asker and Cantillon's "pseudotype", (Hanazono et al., 2013) generalized the idea to a pseudotype function.

The first step of the two-step maximization can be expressed by:

$$u(s, v^n, c_t^n) \equiv \max_{b_0^n, q_t^n} \quad v^n - b_0^n - \sum_{t=1}^{T} c_t^n q_t^n - K_t^n$$
$$s.t. \quad S^n = s$$

The solution to this problem is what (Hanazono et al., 2013) called induced utility. Denoting μ as the Lagrange multiplier of the constraint, the solution is characterized by the following optimality conditions:

$$\mu \frac{\partial S^n}{\partial b_0^n} = 1$$

and

$$\mu \frac{\partial S^n}{\partial q_t^n} = c_t^n$$

These two optimality conditions are the analogue to the ones obtained in (Dastidar, 2014): note that $\frac{\partial S^n}{\partial q_t^n} / \frac{\partial S^n}{\partial b_0^n} = c_t^n$. The second step is:

$$\max_s \left[\prod_{m \neq n} \left(1 - G_m(S^n)\right) \right] \left[v^n - b_0^n - \sum_{t=1}^{T} c_t^n q_t^n - K_t^n \right]$$

The optimality conditions are

$$\left[\prod_{m \neq n} \left(1 - G_m(S^n)\right) \right] \left(- \frac{\partial b_0^n}{\partial s^n} - \sum_{t=1}^{T} c_t^n \frac{\partial q_t^n}{\partial s^n} \right)$$

$$+ \left[v^n - b_0^n - \sum_{t=1}^{T} c_t^n q_t^n - K_t^n \right] \left(- \sum_{k \neq n} g_k(s^n) \prod_{m \neq k \neq n} \left(1 - G_m(s^n)\right) \right) = 0$$

The previous expression can be recast as

$$v^n - b_0^n - \sum_{t=1}^{T} c_t^n q_t^n = K_t^n - \left(\frac{\partial b_0^n}{\partial s^n} + \sum_{t=1}^{T} c_t^n \frac{\partial q_t^n}{\partial s^n} \right) \left(\sum_{m \neq n} \frac{g_m(s^n)}{\left(1 - G_m(s^n)\right)} \right)^{-1}$$

The first term of the right-hand side represents the mark-up relative to the costs of implementing the local content program (internalizing adaptation costs). The second term represents the effects of private information. Differently put, if assumptions on rational expectations are fulfilled, producers' bids in local content programs will be defined by their costs, the expected adaptation costs and the associated informational rents.

The above equation implies two basic characteristics of the expected producers' behavior: i) the bid will depend on possible cost advantages in a particular exploration block; ii) the bid will depend on the information (including local content costs) associated with a particular block. In the next section, these two characteristics will be used to investigate whether auction participants behave according to this model.

3.1.2 Possibility 2 – Players do not have information about adaptation costs

The other possible behavior happens when oil and gas producers do not have rational expectations about adaptation costs (or any other *ex post* cost). In this context, we consider that players do not have information to reveal during the auction process, but they are anyhow forced to bid a value. Thus, the problem is not a private-information problem but an uncertainty problem. Under these assumptions, the stylized bidding model put forward in the previous section is not accurate enough in the representation of players' bidding behavior.

Actually, the situation may be better described by strategies where players bid what they think others will bid. That can be considered as a substitute for bidding true value, as they do not have information about such true value. That is, excluded the possibility that they behave according to private information, they will tend to imitate what they expect the others to bid.

Consider first the case where the weight of local content in the scoring auction is very low, and let us define the minimum bid as q_{LC}^{min}. This minimum bid represents the minimum local content that all producers are able to honor (note that it is the same for all producers). When the local content dimension has reduced impact in the scores of players, they will bid this minimum. This can be compared to a beauty contest where the price is given to the player that bids at some point below the average of bids: the Nash equilibrium for that game is all players bidding zero. When the weight of the local content dimension increases, players will bid the maximum allowed, q_{LC}^{max}. Again, this can be compared with a beauty contest where the price is given to the player that bids above the average of bids: the Nash equilibrium is 100. We will denote the bid resulting from beauty-contest reasoning $q_{LC}^{B} = \{q_{LC}^{min}, q_{LC}^{max}\}$.

3.2 Design of local content programs and their costs

In this step players define the information they have, and consequently the information they do not have. We will use a slight modification of the model developed in (Bajari and Tadelis, 2001) to represent such decision-making process. Oil and gas producers, in our setting, need to design the project in order to determine their local content program. To that end, we assume that there are a certain set of factors that need to be defined in order to specify the program. We denote $\psi \in [0,1]$ the fraction of those factors that players are able (or willing) to specify. Consequently, along the lines of (Tadelis, 2012), we may interpret ψ as the probability of oil and gas producers having rational expectations about local content programs. Accordingly, $1 - \psi$ is the probability that producers do not have information about local content programs and their costs.

We use D to refer to the complexity associated with the program ($D \geq 0$). This parameter is associated not only with the amount of factors you need to define the program, but also with the difficulty to measure them. This can be related to the idea of measurement costs described in (Barzel, 1982). We also denote $c(\psi, D)$ the costs of designing the program with a specification level of ψ. We know from the description of (Bajari and Tadelis, 2001) that, if complexity does not vary, design costs increase with program specification level ψ; that if program specification does not vary, design costs increase with complexity; and that marginal cost of design (with respect to level of program specification) increases with complexity. That is, specifying a local content program and hence obtaining information about is a costly activity, so market participants will face a trade-off.

We use a slightly adapted representation to model the uncertainty of local content programs. In (Bajari and Tadelis, 2001), project complexity came from the fact that items had many dimensions, and each of them was equally costly to measure. Hence, players needed to choose some dimensions not to be measured. In our case, complexity (the complexity of the item being sold) comes from the fact that some item characteristics are very costly to measure (in the limit,

infinitely costly). That is, complexity is only associated with the local content dimension of the scoring auction, being the rest of dimensions very easy to measure.

3.3 Firms' expected behavior

We consider the two previous bidding behaviors as extreme cases of information conditions. If informational properties dominate, they behave as in the model of section 3.1.1. If uncertainty properties dominate, players behave as in the model of section 3.1.1 in all dimensions except local content bids. In order to bid on local content, they behave as in section 3.1.2.

Whether they use one model or another, in our setting, depends on the probability ψ. Let us denote Q_{LC}^{n} the actual bid for local content program. Using the previous reasoning, we have that

$$Q_{LC}^{n} = \psi q_{LC}^{n} + (1 - \psi) q_{LC}^{B}$$

where q_{LC}^{n} is the quality bid described in section 3.1.1 corresponding to the local content dimension. As described in section 3.2, the probability ψ represents the probability that producers have information about local content programs. Hence, we model a first step that occurs before the auction takes place, in which players engage in the costly activity of obtaining information. One possible result of such activity is not gathering any information about local content programs, either because players decide not to design the program and economize the corresponding costs, or because measuring is too costly or even impossible.

If producers have little information, the probability ψ will be close to zero, and players' bid will be very similar to the one obtained in the beauty contest model. On the other hand, if players have significant information and probability ψ is close to one, players' bid will be close to the one obtained in the multi-dimensional auction model. Next section, building on this results, will develop testable hypothesis.

3.4 Predictions

The consideration of complexity associated with the definition and measurement of local content programs may result in a certain level of (strong) uncertainty for which players have no information. Regardless, they are required to bid for the local content dimension, even in the case where they do not have information. Thus, the combination of the previous models imply that players bid revealing the known costs, but as there is missing information, they incur in adaptation costs *ex post*.

In order to specify the model, we cannot use a measure of maladaptation, because it is only observable to players. The only event that is observable is players not fulfilling their commitments. In this regard, there are two possible basic explanations for the observation:

1. Players exaggerate their bids on local content in order to win the auction
2. Players make mistakes because they do not have information about local content programs and play as in a "beauty contest"

The analysis of these two possibilities allows us to build the empirical study of the Brazilian case and draw conclusions. Let us assume the following working hypothesis: if players are not using their bids to win, then they do not have any relevant information (so they play as in a "beauty contest"). In both cases, as there is no specific information being revealed, we are not benefitting from including local content programs in the auction. As we know, from the analysis above, that adaptation is costly, the net result of including local content in the auction is negative.

Besides, it may be argued that players may lie about their possibilities in local content programs to defend themselves against government corruption. We assume that corruption is not affecting players' bidding behavior. The justification is that we do not see any particular reason that makes them lie with respect to local content and not to the other dimensions. In particular, as we do not observe maladaptation in exploratory programs, it seems approximate enough to assume that corruption threat is not the main driver for maladaptation.

The next section will analyze this problem. Specifically, if we prove that strategic behavior (reason number 1 above) is not driving maladaptation either, we are prepared to conclude that maladaptation comes from lack of information. However, that alone does not allow concluding that adaptation costs are higher than information-revelation benefits. It might be the case that most information is revealed, but some errors remain. We need to also show that little or no information is contained in local content bids.

4. Statistical learning to analyze bidding behavior

Those are the two steps of our empirical analysis: first, we will show that the observed results are not explained by strategic behavior; second, we will check whether information is being revealed. In the case the answer is negative, it will suggest the consideration of alternative methods to decide on local content program

One of the main characteristics of the bidding behavior in scoring auctions is that it requires analyzing complex datasets. In our context, we will need to define the relationship among a set of input variables (e.g. field characteristics or firm bids) and some output variable (e.g. bid for local content). Statistical learning refers to a large toolkit devoted to understand that kind of relationship. In particular, we will rely on non-parametric methods. The main reason for that choice is the fact that non-parametric techniques do not make explicit assumptions about the functional form of the previous relationship between input and output. Hence, the main advantage of non-parametric methods is that they are able to accurately fit a wider range of functional forms. They avoid the problem associated with parametric methods of using the wrong functional form to represent the relationship. That comes at the cost of requiring significantly larger sets of observations.

4.1 The data

We analyze an original dataset made up of 1725 bids in 12 rounds of lease auctions in Brazil. The first round took place in 1999 and the 12th one took place in 2013[3]. The first variable simply specifies the round where the bid was submitted. The variables FIELD and BLOCK characterizes the object that was being negotiated (each exploratory block pertaining to one gas field). We have called each field and block using one integer number. BONUS is the bid for the upfront payment that constitutes the first dimension of the scoring auction. It is measured in Reais. FIRM also associates one integer number with each of the firms bidding in the auctions. PEM is the minimum exploratory program specified in the auction bids. IFWON is the variable we use to control whether the bid won the auction or not. This will be important in the study of strategic use of local content. If the bid won the variable will take the value 1. If the bid was unsuccessful the variable will be 0.

NAME	MEAN	STD	MIN	MAX
ROUND	7.78	2.595	1	11
FIELD	9.88	7.47	1	28
BLOCK	506.62	266.48	1	904
BONUS	1	2.893	0.0009	33.78
FIRM	71.51	53.398	1	179
PEM	1	1.76	0	25.63
IFWON	0.233	0.972	0	1
VALLC	0.23	0.082	0.15	0.40
MAXLC	0.86	0.09	0.8	1
LC	0.72	0.185	0.10	1

Table 1. Overview of the data set.

[3] 13th round was in the end of 2015 but we have not included its results in this study.

VALLC is the variable that represents the weight of the local content dimension for the scoring auction to which the bid was submitted. Historically, of the 12 rounds, the minimum weight has been 15% and the maximum 40%. Figure 1 represents schematically the values for the weights, which are represented by the variable VALLC.

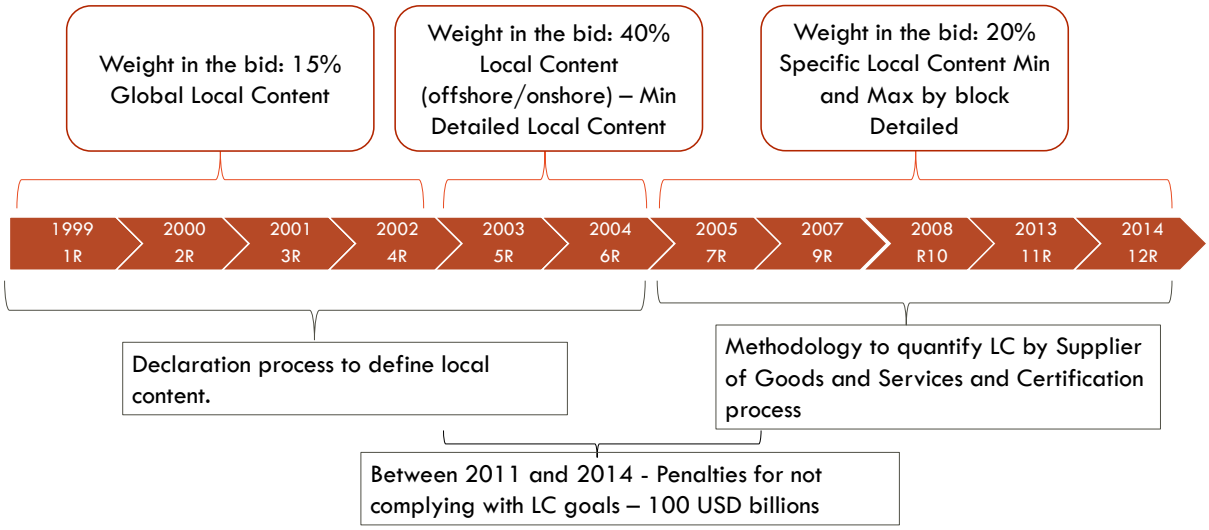


Figure 1. Change in the rules for the local content component over the 12 rounds studied in the paper.

The variable MAXLC represents the maximum allowed bid for this component in each round. In several rounds, that maximum value was 80%. Finally, LC represents the bid for local content in the scoring auction.

4.2 Learning from bidding behavior

The logic for the analysis developed in this section can be summarized as follows: if players' bidding behavior is defined by block features, or by players' characteristics, one should be able to learn such behavior from data observation. Put differently, we will try and learn player's bidding behavior from the data, using statistical learning tools. We will show that one cannot explain players' behavior either by their characteristics or by block features. After that, we will show that bidding behavior is explained by the rules of each particular auction (specifically, by the 'scores'). As a result of the combination of both analyses, we show that bids for local content do not reveal private information, but they are a response to the weight put in the local content bid.

Next, we will tackle the analysis by answering specific questions.

■*Is local content determinant of the winning bid?* – This first question aims at showing whether local content bids are a result of strategic behavior. The idea is that, if bids are not revealing private information, they might still be part of a strategy to win the auction. In that case, we would observe that winners of the auction can be related to their local content bids. That is, we should be able to learn a relationship between the bid on local content and the winner of the auction.

To that end, we will use a Classification Tree (see (Friedman et al., 2001) for the details of the technique). The basic idea behind this method is as follow:

- First, we associate a binary variable to each bid, which takes 0 values when the bid was not winner of the auction, and 1 when it won the auction
- Second, we characterize our sample of bids according to three variables: i) minimum exploratory program (PEM); ii) bonus; and iii) local content bid (LC)
- Third, we classify the sample according to the binary variable defined in the first point

Using the Classification Tree, we obtain the results represented in Figure 2, where it is possible to observe that the non-parametric classifier only uses the variables bonus and minimum exploratory program to classify the dataset. The first cut made by the classification tree uses the minimum exploratory program. The branch on the right (with less elements, as represented by the width of the line) represents the first rounds, where no score on exploratory programs was specified. The branch on the left (with the largest part of the sample) is cut again using the bonus, and then using the minimum exploratory program. We observe that, as we are closer to the leaves of the tree, the lines are thinner. Hence, as observed in Figure 2, bids on local content are not required to explain the winning bids. Therefore, bids on local content do not correspond to strategic behavior.

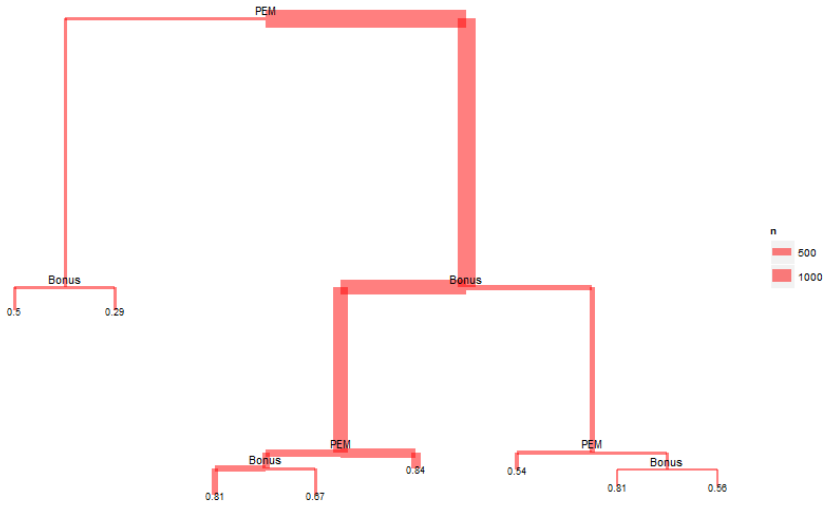


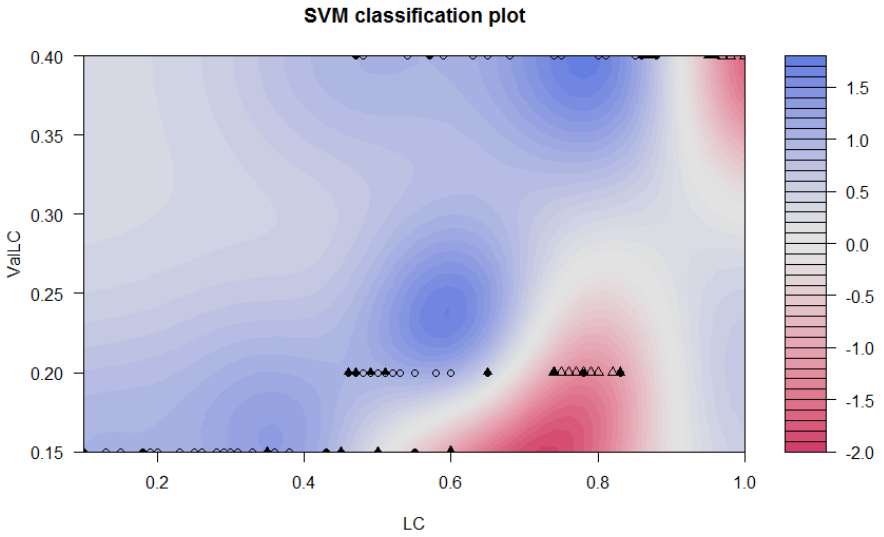
Figure 2. Classification tree to analyze whether the local content bid defines the winner of the auction.

As the bids are not strategic ones, two options remain: either they reveal private information, or they are guesses driven by auction rules. Next questions aim at identifying which option is observed.

■*Is there any relationship between local content bids and whether the block is offshore?* – The logic for this question is that offshore fields are technically more demanding than onshore ones. Especially in the case of deep-offshore fields, workers and equipment need to be significantly specialized. That would complicate the inclusion of local content (equipment or workers), making the bids for local content lower. So, if we can learn from data a relationship between whether the block is offshore or not, that would mean that the auction is revealing information.

To analyze the issue, we rely again on non-parametric classification. In this case, we favor a more flexible tool: Support Vector Classifier (see (Friedman et al., 2001) for the details of the technique). The input for this study will be vectors of two dimensions: ValLC (which is the score of the local content bid in the round where the bid was done); and LC (which is the local content bid). The output will be a binary variable, which allows to transform the problem into a

classification one, which is 0 if the block is onshore and 1 if the block is offshore. Results are



shown in

Figure 3, which is a contour plot of the decision variables of a support vector machine. That means that the white lines represents the boundary. Blue zones correspond to onshore blocks and red zones are offshore blocks. We observe that, even if local content is higher for offshore blocks, it is dramatically affected by the value that local content had in the scoring function. In fact, accepting the logic that that large local content is associated with red zones (onshore blocks), the lower right corner of the figure should be also red, instead of almost white (very pale blue). The reason is that with lower values of the local content score, there were a maximum on the local content bids.

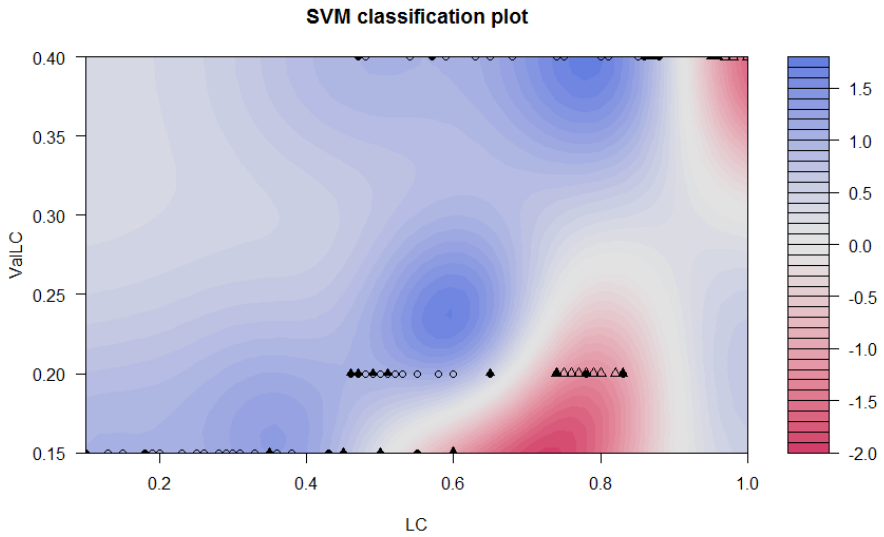


Figure 3. Classification of offshore blocks according to local content bids and the score of local contents.

Consequently, we do not observe that block characteristics (onshore/offshore) explain bidding behavior on local content. The next step will be analyzing whether players' characteristics are revealed during the auction process.

■ *Is Petrobras bidding more on the local content dimension?* – This question assumes that Petrobras, being a large national champion, has better access to local content (e.g. it has an easier relationship with national industries or services). In that context, Petrobras would bid higher for local content. Therefore, if we can learn from data that Petrobras has actually higher, we will conclude that auctions are revealing that information.

The input for this study will be vectors of the same two dimensions as before: ValLC (which is the score of the local content bid in the round where the bid was done); and LC (which is the local content bid). We transform again the problem into a classification one by assigning 0 if the bid is not from Petrobras and 1 otherwise. Results are shown in Figure 4, which is a contour plot of the decision variables of a support vector machine. That means that the white lines represents the boundary.

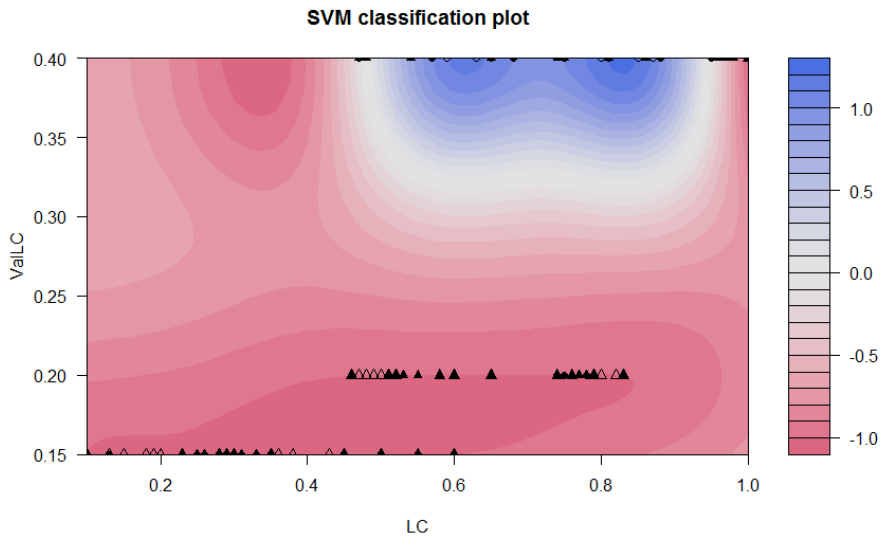


Figure 4. Classification of Petrobras' bids according to local content bids and the score of local contents.

We observe that Petrobras bid high (blue zone), but also other firms bid high (red zone). Consequently, we do not observe Petrobras to bid systematically higher than the rest of firms.

■ *Do local content bids depend on rounds?* – The two last questions investigated whether bids were defined by block characteristics or bidder's characteristics. In this last question, we analyze the conjecture that bids are determined by the rules of the auction. The motivation for this question can be illustrated by Figure 5, where we observe average local content bids, in each round, corresponding to different agents (average among all bidders or only Petrobras) and to different blocks (average among exploration bids or development bids). We observe that, although in each rounds all bids are similar, they vary significantly across rounds (horizontal axis).

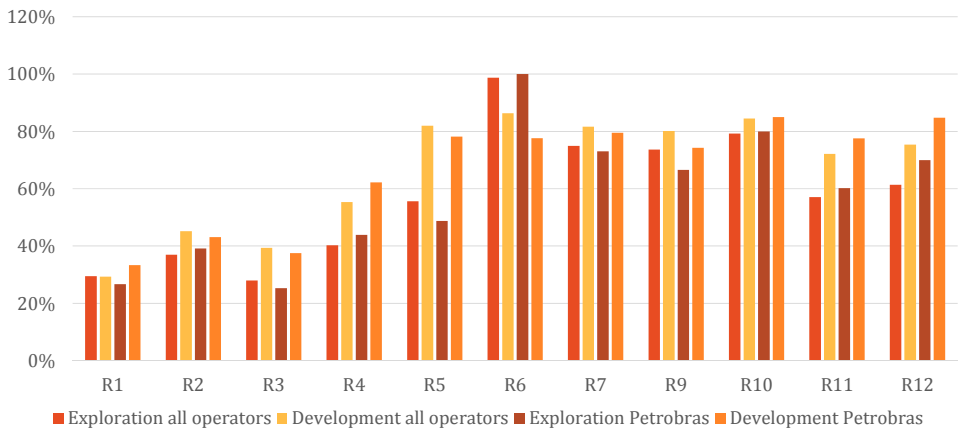


Figure 5. Overview of firms' bids for local content in different rounds.

In order to investigate the question, we use a Regression Tree (see (Friedman et al., 2001) for the details of the technique). We use it to find the functional relationship between local content bids (all of them, for all agents and blocks) and the round where they were made. Results are shown in Figure 6.

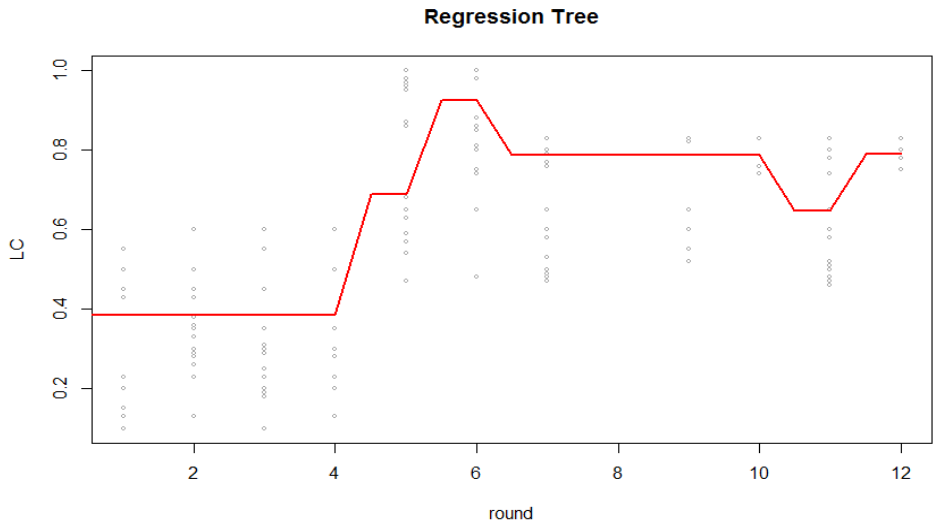


Figure 6. Regression tree representing the bids for local content as a function of the round where they were made.

We observe a steep change in local contents bids from round four to round five. This can be explained because in round five, the score corresponding to the local content dimension was increased from 15% to 40%. That score was maintained rounds five and six, and then reduced again to 20%, which was the score for the rest of the auctions. The bidders' response to that change of rules was to reduce their bids.

We observe also a reduction in the bids corresponding to round 11. It is possible that such behavior is explained by the application of non-compliance penalties. Nonetheless, the amount of available data in this regard is limited, because contracts are long-term ones and not all local content is exhaustively measured, especially the earlier rounds. We observe 383 investigations from ANP; among them, 116 cases have ended with penalties, i.e. 30%. Regarding the data from investigation. The penalties applied between 2011 and 2014 was around 200 Million USD (639 Million Reais)[4] (ANP, 2016). Moreover, there are still many open processes to be decided. The companies processed are both national (including Petrobras) and international ones. This

[4] Just in 2016, until September, the penalty a more than 9 million USD, (ANP, 2016).

preliminary data may indicate that the possibility of being penalized has considerably increased, which in turn might justify a response in the bidding behavior.

5. Concluding remarks

We developed a theoretical model to represent the bidding behavior of oil and gas producers in the multi-dimensional auctions currently implemented in Brazil. In our setting, players may bid according to their private information about local content costs or just submit a bid with no connection with information. Players' behavior depend on the amount of information they measure (at a cost) in an early stage of the process, where they design their future local content programs. If they have little information, they will probably bid randomly. If they have relevant information, they will bid according to it because multi-dimensional auctions are efficient mechanisms.

The consideration of complexity associated with the definition and measurement of local content programs may result in a certain level of (strong) uncertainty for which players have no information. Regardless, they are required to bid for the local content dimension. Our model imply that players bid revealing the known costs, but as there is missing information, they incur in adaptation costs *ex post*. In order to specify the model, we cannot use a measure of maladaptation, because it is only observable to players. The only event that is observable is players not fulfilling their commitments. We consider two basic reasons for that: i) players exaggerate their bids on local content in order to win the auction; or ii) players make mistakes because they do not have information about local content programs.

The analysis of these two possibilities allows us to build the empirical study of the Brazilian case and draw conclusions, because, if players are not exaggerating their bids, then they do not have information. As information is not revealed, we are not benefitting from including local content programs in the auction. As adaptation is costly, the net result of including local content in the auction is negative.

We developed several non-parametric estimations in order to find out which is the case in the Brazilian oil and gas industry. In order to minimize the impact of distributional assumptions on the behavior of auction participants, our estimations were based on non-parametric methods. First, we showed that strategic behavior is not driving maladaptation, so we deduced that maladaptation comes from lack of information. However, that alone does not allow concluding that adaptation costs are higher than information-revelation benefits. It might be the case that most information is revealed but some errors remain. We needed to show as well that little or no information is contained in local content bids. In this regard, we have found that neither the properties of the items auctioned nor players' characteristics explain this behavior.

In terms of the theoretical model, this implies that players are revealing little private information about local content programs. In that sense, our empirical study suggests that the complexity of designing local content programs is large enough to prevent players to engage in information-gathering activities. From a mechanism design viewpoint, our empirical study shows that the use of auctions to determine local content has no clear benefit (because little information is revealed). As forcing the specification of a local content bid may bring possibly relevant adaptation costs, our study suggests that the mechanism would be more efficient if the definition of local content programs was left out of the auction.

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