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Falhas nos Processos de Leilões de Transmissão: os Efeitos da Interdependência e Restrição de Capacidade

Lucas Varjão Motta

Tese de Doutorado

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A Comissão Examinadora composta pelos professores abaixo, sob a presidência do primeiro, considera o Candidato Lucas Varjão Motta **APROVADO.**

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Abstract

The Brazilian Electricity Sector adopted the auction mechanism to allocate Power Transmission assets. Using auctions the Brazilian Power Transmission Sector faced an intense expansion in the last decade. Since 2001 more than 61.000 km of power lines was contracted. The auctions' results are impacted by interdependence and the capacity constraint. We investigate the reasons behind the growing rate of failures observed in the Brazilian Power Transmission Auctions (BPTA). More specifically, we analyze the cases of Empty auctions and Removed projects in the BPTA. We also analyze the policies utilized by the regulator as a measure to deal with the issues and enhance the objects attractiveness. We attempt to answer the following question: "How well are auctions allocating projects in the Brazilian Transmission Sector (BTS)?". We develop a theoretical model to evaluate these issues in a procurement auction sequence. The theoretical model shows that the joint action of interdependence and of capacity restriction decreases the competitiveness of the participants and the payoff of auctioneers. We also study what happens after the projects are contracted. We conclude that the transmission sector is facing a management issue as the government has difficulties to contract and the contracted projects are not usually delivered in time. We verify a significant and increasing gap between the planned and the executed projects. We found that the interdependence affected the probability of winning and the behavior of the bidding. Finally we empirically check for reasons that are affecting bidders participation. We verify that Interdependency and Capacity Constraint affects participation decision and winning likelihood. We suggest policies based on the results achieved.

Keywords: Brazilian Power Sector. Auction Failures. Interdependency. Capacity Constraint. Combinatorial Auctions. Electrical Sector Planning.

Resumo

Neste trabalho, procurou-se avaliar o Setor de Transmissão de Energia Brasileiro desde seu planejamento à efetiva expansão da sua estrutura. O Setor Elétrico Brasileiro adotou leilões como seu mecanismo para alocar os projetos de transmissão de energia. Utilizando leilões, o setor de transmissão enfrentou uma intensa expansão na última década. Desde 2001 mais de 61.000km de linhas de transmiss ao foram contratadas. Neste trabalho, analiza-se a hipótese de os resultados dos leilões sofrerem dos efeitos de interdependência e restrição de capacidade. Investigou-se ainda, as razões por trás da crescente taxa de falhas observadas nos leilões de transmissão. Mais especificamente, analiza-se a presença de leilões vazios e da remoção de projetos antes da realização dos leilões. Também analizou-se as medidas utilizadas pelo regulador afim de mitigar a ocorrência dessas falhas e elevar a atratividade dos projetos nos leilões. Para tais análizes, formulou-se um modelo teórico que incorpora interdependência e restrição de capacidade num leilão sequencial. Encontra-se envidência empírica de que ambos os efeitos estão presentes nos leilões de transmissão, afetando o comportamento dos lances e a probabilidade de vencer. Verifica-se a grande dificuldade de gerenciamento da expansão enfrentada pelo regulador, desde a contratação até a conclusão das obras. Verifica-se uma grande e crescente diferença entre a expansão planejada e executada no setor. Por fim, recomenda-se políticas baseadas nos resultados obtidos.

Palavras-chave:

Transmissão de Energia. Falhas de Leilões. Interdependência. Restrição de Capacidade. Leilões Combinatoriais. Planejamento do Setor Elétrico.

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Chapter 1
Introduction

Brazil is the fifth largest country in the world in geographical area, with a population of over 190 million people most of which are concentrated along the coastal areas and in the south and south-eastern regions. The Brazilian power generation is based mostly on renewable resources, with the majority being hydropower. The locations with highest generation potential are geographically dispersed and often far away from highly populated regions. These characteristics represent a significant challenge for ensuring the supply of electricity, a necessary good. This geographic separation of between power supply and population requires the development of a large and costly power transmission system.

Worldwide, the electricity sector, as a whole, has been recently reformed to introduce more competition and efficiency. In many countries, this reorganization has included the vertical separation of generation, transmission, and distribution sectors, thereby allowing for competition within each of the markets.

In Brazil, the reform was conducted in such a manner that the government's role was to regulate and promote public policies, while the investment responsibility was to be left to the private sector. Despite this plan, both the private sector and the government currently invest in the system expansion. The following list states the reform objectives: 1- to guarantee power supply; 2- to promote lower tariffs to the final consumers; and 3- to promote country-wide access to electricity. To do this, the reform included the following mechanisms: 1- development of an investment friendly-environment; 2- introduction of tariff-based contracting; 3- and the creation of programs for house-hold electricity accessibility.

The National Electricity Agency (Aneel) introduced auctions in the Power Transmission Sector (PTS) to organize the asset allocation between interested companies. The mechanism features a two-phase auction of decreasing prices. The first phase is a closed-bid auction, with all bids being revealed after the last bid is submitted. Companies which bid in a range of 5% from the lowest bid, enter the decreasing open-bid phase. The offers start from the lowest bid in the previous phase and finish when there is no company interested in making a better (lower) bid. The winner company is entitled to build, operate, and maintain the power line. In this framework, the companies' objectives are to bid as high as possible but lower than any opponent's best offer.

Besides the mundane reasons that make auctions important, such as speed of sale, auctions are useful for a variety of informational purposes. Often the buyers know more than the seller about the value of what is being sold, and the seller, not wanting to suggest a price first, uses an auction as a way to extract information (Rasmusen, 2006). Despite excellent properties, Klemperer (1999) states that auction design is not a one-size-fit-all, but that the auction design must be tailored for both its environment and to the designer's objectives.

Since 2001, this competitive setting has allocated over 200 contracts, representing an expansion of 60,000 km of power lines and over 220 substations. Within these contracts, the average discount between the maximum allowed revenue and the final winner bid was approximately 17% (while the highest discount reached 60%), suggesting strong competition, and resulted in lower costs for the electrical system.

Despite the already large system, the recently launched Power Investment Program (PIEE) forecasts R$ 186 billion investment in both the transmission and generation sectors between August 2015 and December 2018.

Although many contracts have been signed, there are several auctions that have closed without any bids (empty auction). Until 2007, only one empty auction was seen. From 2008 to 2015, however, the frequency of empty auctions increased significantly. During this period, 36 of 190 auctions did not receive any bids, representing a 19% rate of uncontracted projects. This statistic has grown faster in recent years reaching 28% in 2013, 46% in 2014, and 63% in 2015.

These allocation failures imply expansion delays in the transmission system and will likely lead to consequences in the transmission sector, as well as for the power system as a whole. As ANEEL simultaneously plans for transmission and generation sector expansion, delays in projects in one sector can lead to resource mis-allocation, lack of supply, and system-reliability issues.

Power system agents have voiced significant protests regarding these failures. According to Instituto Acende (2013) - an observatory of the Brazilian Power System -, the transmission expansion is a barrier for the power generation expansion.

As the country is currently suffering from a prolonged hydrological crisis, delays in transmission expansion are becoming more costly. According to ANEEL, in 2013, ready-to-operate wind power facilities were not connected to the grid as scheduled, forcing the ONS to use the more costly thermal power. The Agency claims that this issue cost the system more than R$ 770 million.

In addition to the auction-based delays, several of the currently contracted projects are facing difficulties delivering facilities. According to Aneel (2015a), in September 2016, approximately 64% of the ongoing projects were experiencing delays, while only about 30% were on track. Some of these companies with delayed projects cited lengthy processing periods during environmental licensing as the cause for delay (Instituto Acende, 2015).

To minimize the delays of ongoing projects, the regulator instituted a new law which prevents companies with delayed contracts to compete for new projects. This participation policy has excluded several companies from bidding in recent auctions, thereby further reducing competition.

In summary, it can be seen that a company's participation and interest in projects can be affected by regulatory limitations, lengthy bureaucratic processing times, as well as by the rate of return.

According to Instituto Acende (2013), the low return rate, set by the regulator, is the main reason for the lack of interest in contracts. The institute claims that the capital cost rate, used by ANEEL to calculate the Revenue Cap (RC), is lower than other investment options, such as the Treasure Bills, that offers a 6% return rate in real terms.

When ANEEL sets the RC, it faces a trade-off between attracting more competitors and finding the lowest cost for the service. Higher reserve prices are related to a higher number of competitors interested in the contracts, ensuring higher competition and lower costs. If the reserve price is too low, companies may be deterred from bidding, resulting in an unsigned contract, thereby delaying the national plan.

Analyzing radio licenses in the US, Milgrom (2004) claims that: "The scope and terms of the spectrum licenses can be even more important than the auction rules for determining the allocation, because a license can directly serve the needs of some potential bidders while being useless to others". In the same fashion, the Brazilian government is able to define the contract through its specifications: location, length, substations, voltage technology, and others, thereby modifying the contract evaluation by potential bidders. Seeking to allocate unsigned contracts, ANEEL is now modifying some of these projects to enhance their attractiveness.

Regarding the macroeconomics of the auction environment, Instituto Acende (2015) claims that due to the recent exchange rate depreciation, credit access and imported component costs are further affecting the auction results. Moreover, the companies are now being forced to fund their projects at higher interest rates, as the National Development Bank (BNDES) reduced its participation in total funding from 75% to 50% in electricity projects.

It follows then that a company building a facility may eventually face temporary financial, equipment, labor, and/or management constraints, resulting in higher costs. Auction theory literature claims that these capacity constraints are able to directly affect a firm's participation in auctions (Jofre-bonet & Pesendorfer, 2000; De Silva *et al.* , 2005, see). For this reason, setting reserve prices without accounting for these constraints can also affect a company's interest in a contract, thereby affecting the auction's competition.

In the Chapter Two of this work, we develop a theoretical model and empirically analyze the relation of an object's Interdependency and a firms' Capacity Constraint in bids and winning probability. In Chapter Three, we analyze the auction's failure in allocating transmission projects and the different approaches utilized by ANEEL to enhance allocation likelihood. In Chapter Four, we make a general evaluation of the sector's recent development and future challenges the sector may face.

1.1 The Power Transmission Expansion Plans

According to EPE (2016), between 1960 and 1999 the planning of power expansion was centralized and coordinated by Eletrobras in a determinative way, i.e. every planned plant would be built, making the necessary adaptations for the demand size or resource availability in case of delays.

During this period, the country did not have a proper expansion plan other than mapping and exploring the national hydro-power potential, without a deeper attention to the demand forecast. According to Aneel (2008) in 1966, under the coordination of the Ministry of Mines and Energy (MME), an international consulting effort assessed the hydro-power potential and electricity market in the South-East. Three years later, the Southern region was mapped. The study is later used as the base for the expansion plan in the following years.

By the end of the 1990s, the country was experiencing the highest frequency blackouts in history, and one of its longest electrical power rationing periods, both prompted by the lack of significant investment. According to Aneel (2008), the Constitution of 1988 extinguished taxes that financially supported the electricity sector expansion, resulting in a significant decrease in investments. Furthermore, while the Constitution required expansion of the power generation, transmission and distribution sectors to be tendered, some of the necessary laws were only created 7 years later.

Following the world-wide deregulation wave, Brazil decided to de-verticalize its electricity sector into three sub-sector: generation, transmission, and distribution. In 1997, Brazil created its independent electricity regulatory agency - ANEEL, to help monitor the development of these sub-sectors. Furthermore, the expansion planning faced a transition towards a market-oriented model, through which Electrobras lost the role of planning the sector to the Company for Energy Research - EPE. and the operation role goes to an agent created with this only mission, the National System Operator - ONS. In this new period, firms are now contracted separately in each sector, and planning and operating of the system are conducted by specialized agents.

According to EPE (2016), the new regulatory setup aims to ensure "sufficient"electricity supply and expansion of generation and transmission sectors, in order to accommodate the growth of demand.

The grid expansion plan is divided into two different reports, one for short term and another for long term expansion. Both of them, the Transmission Expansion Plan Report - PET and the Long Term Expansion Plan - PELP, are produced by the EPE; the former presents the projects to be developed within 6 years, while the latter presents projects for a "seven plus years" phase. The projects proposed in the second report may be modified or dropped, depending on the system need.

While in the pre-deverticalization period, the expansion was driven by generation potential, and little attention to demand, in the new period, the power distribution companies must contract 100% of the demand forecast for the next 5 years. This setting allows the transmission expansion plan to adjust to the power expansion and, consequently, to the market demand.

Right after the new model implementation, the system faced significant investments in both power generation and transmission after a long period without investments. According to EPE (2015a), several projects were required with high priority to reduce the risk of system failure and to connect new power plants.

According to EPE (2015a) the power transmission expansion should allow the market agents to access the grid and promote a competitive environment for the power generation and distribution. Also, by reducing the transmission bottle necks between the regions, the transmission grid allows the price equalization among sub markets and the optimization of power delivery.

A significant part of the grid expansion effort was to connect the Brazilian geographic regions, in special, to connect the country to the north region and, therefore, benefiting from the different hydrological patterns among the regions. EPE (2015a) reports several reinforcement connections for the north region: North-South in 2008; North-North East in 2007; North-South East; and connections within the North area itself.

The North-South East grid reinforcement plan seeks to connect the major hydro-power investments made in Brazil in the recent decades to the largest consumption region. The Jirau and Santo Antônio power plants, in the Madeira River, and the Belo Monte power plant, in the Xingu river, together will add about 18.500MW of installed capacity to the system.

For the 2015-2024 period, the EPE plans[1] new power lines connecting North/North-East to South/South-East. The new lines increase transmission capacity to the grid and will allow the delivery of power surplus created by new wind power plants (in the North-East region), and by new hydro power plants (in the Madeira and Xingu rivers) that will come on-line.

According to EPE (2015b), specially in times like the recent hydrological crisis faced by the country, extra connection between the regions are required. The same document affirms that, the actual transmission capacity is not sufficient to delivery power surplus, requiring the use of costly thermal plants. The EPE affirms that, counting with this expansion, in 50% of the simulated scenarios the transmission capacity between North/North-East and South/South-East regions reaches its maximum.

This scenario suggests that beside the significant investments in course, several others will be necessary in the following years to reinforce the system and accommodate for the demand growth - specially when the country faces hydro crisis and fast economy growth.

[1] See EPE (2015b)

CHAPTER 2

Auctions with Interdependency and Capacity Constraint: Assets Allocation in the Brazilian Power Transmission Sector

Abstract

The Brazilian Electricity Sector adopted the auction mechanism to allocate Power Transmission assets. The auctions' results are impacted by interdependence and the capacity constraint. We develop a theoretical model to evaluate these issues in a procurement auction sequence. The theoretical model shows that the joint action of interdependence and of capacity restriction decreases the competitiveness of the participants and the payoff of auctioneers. Using Switching Regression models and Quantile Regressions, we found that the interdependence affected the probability of winning and the behavior of the bidding. We suggest policies based on the results achieved.

Keywords: Auction Failures, Interdependency, Capacity Constraint, Quantile Regression, Sequential Auctions.

2.1 Introduction

Repeated auctions can be affected by synergies between objects and by bidders suffering of capacity constraint. We study how these issues, acting together, are affecting procurement auctions for Power Transmission contracts in Brazil. In this industry, operating and maintaining structures in the same region can be a economy of scale opportunity, leading to synergies between contracts. Despite that, building complex facilities requires the allocation of significant amount of resources and additional contracts during this phase can lead to higher costs.

Although these two issues have been analyzed in different industries, the Brazilian Power Transmission Sector (BPTS) has two particular characteristics that can emphasize the effects and requires further investigation: First the industry complexity and high investments can reduce entry; Second the participation of big public companies in the competition. Furthermore, the raising number of failures in the sector's auction can clearly be a result of a miss-inclusion of these effects on the regulator actions and policies.

In the following section of this paper we describe the BPTS setting and the results of previous auctions. In section 3 we model these effects in the BPTS setting to understand possible consequences to the industry. In section 4 we empirically assess the interdependency and the capacity constraints effects in the BPTS setting. Section 5 concludes the study.

2.2 Brazilian Transmission Auctions

During the 90s wave of restructuring the electricity sector, Brazil decided for the vertical separation of power generation, transmission and distribution. In the same period, the electricity regulatory agency - ANEEL was created and entitled to promote public tenders for contracting services on the three areas. For the power transmission sector, the ANEEL introduced a hybrid auction to allocate contracts for building, operating and maintenance the transmission facilities.

The pay-as-bid auction has two stages, a sealed and an open one. In the first phase, the companies submit a closed financial bid of how much it requires for the service, which must be lower than the maximum allowed revenue (RAP) set by the regulator. All bids are revealed after all offers are placed and the lowest offer wins. The second-phase auction only happens if there is at least one bid in a 5% range from the best one. In the open stage, bids start from the first phase best offer and finishes when no company wants to lower the currently best offer. The winner then submits a power transmission project and signs an 30 year contract.

To minimize monitoring difficulties and costs, the regulator checks quality and deadlines during the building phase. Furthermore, during the operation phase, the contracted company is punished in case of power transmission failures, and the fine is proportional to interruptions reasons and duration.

If the company does not suffer from interruptions its revenue is constant and equal the winner bid value. During the concession length, the regulator reviews this revenue each 5 years utilizing the discounted cash flow procedures and accounting for the weighted average capital cost.

According to EPE (2015c) by 2014 the country had more than 111.000 KM of power lines and 133.000 MW of installed capacity. Its length is justified by the power generation model, that highly relies on hydro power, usually located far from the cities.

To accommodate consumption expansion the regulator holds several auctions every year. In average 4.060 km of power lines are contracted per year, enhancing the system reliability. The peak of contracting was 2008, when over 10.000km of power lines was auctioned. The consistent expansion pattern resulted in more than 60.000 km power lines contracted since 2001. The figure 2.1 shows the contracted extension length by year.

it is noticeable an pattern of aggressive bidding in the Brazilian auctions. For instance, in 2007 the average discount on the Revenue Cap reached 55%, while the biggest discount was 60% and happened in 2008. The Figure 2.2 shows the discounts and the number of offered contracts evolution along the years.

Francelino & Polito (2007) accounts the high level of discounts to the higher competition level, especially coming from Spanish companies. According to the author, there are several reasons for this aggressive behavior, but the main are the easy access to credit and tax benefits.

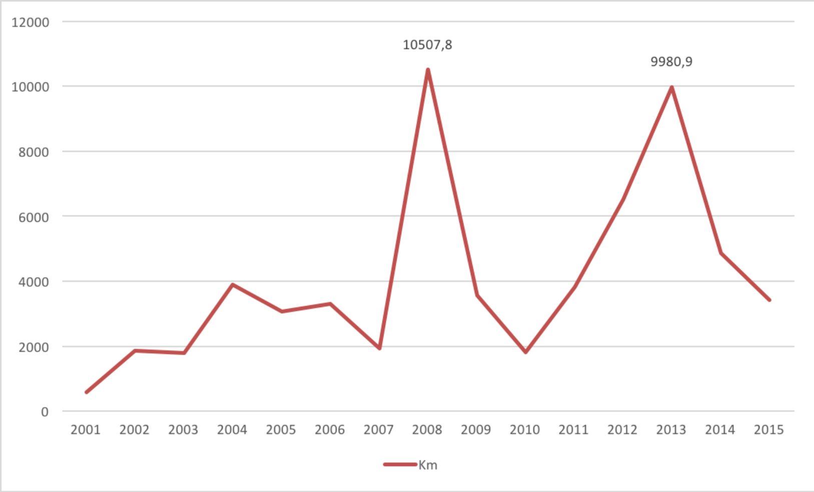

Figure 2.1 Contracted length per year
Source: Author

Castro (2006) shows a model to explain the growing discounts: they are related to the country risk reduction, that's it, with the perception of investment risk in country by foreigners investors. Yet, according to the author, that's not enough to explain the aggressive behavior on the transmission auctions: the optimism created by the easy access to credit by the National Development Bank (BNDES) and financial markets should be taken in account.

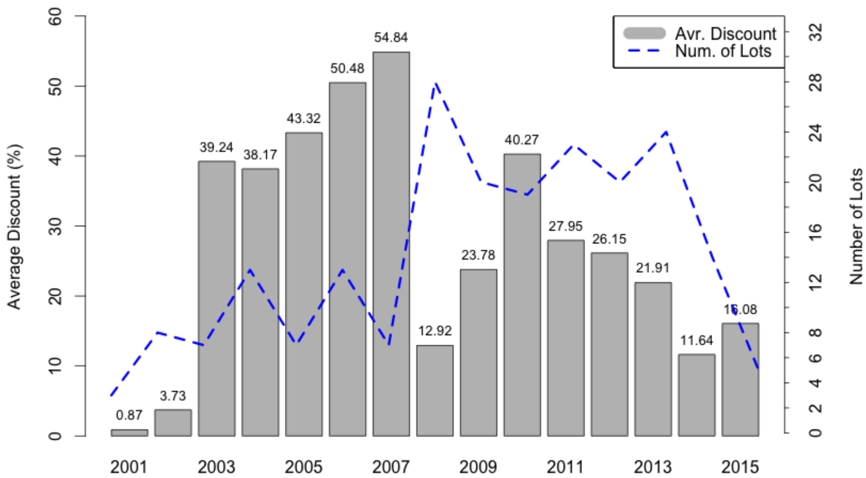

Figure 2.2 Average Discounts and Number of Contracts per year
Source: Author

In a different assessment Hirota (2006) evaluates that the transmission sector has been affected by the interdependency between the already installed facilities and the objects being auctioned. According to the author, a transmission line that's going to be build in an area that already has transmission facilities can benefit from scale gains, "as the transmission company won't need to build new facilities or do new environmental studies, lowering the cost and raising the project value". In this way, the existent economy scale creates an interdependency effect among transmission contracts and affects bidding.

Tozei *et al.* (2014) analyze the effects of consortia participation on the average bid and discount in the BTA. They claim that consortia were less competitive than individual firms, offering higher bids/ lower discounts for the projects.

Carlos & Saraiva (2008) highlights that the interdependency comes from economy scale in jointly operating and managing nearby transmission facilities. The authors also shows that this effect is relevant in companies bid strategy and that interdependent objects auctions tend to have more aggressive bidding behavior.

Ausubel *et al.* (1997) analyzed auctions for communication services with the intention to identify the impact of geographic synergies on its closing prices. The author observes that besides the capacity constraints, synergy effects conduct closing prices to higher levels when the second best bidder has connected licenses.

The BTA allow companies to partner and bid as a consortia, thereby companies my decide to join a group to, among other reasons, reduce the effects of its own capacity constraints. Nevertheless, Tozei *et al.* (2014) claims that in average consortia participation are not related to more aggressive bids when compared to individual firms.

Serrato (2006) utilizes a Frontier Production Model and ANEEL's restricted data from 1997 to 2005 to analyze efficiency in the Brazilian Transmission Sector. The author claims that although in average firms get more efficient over time, the older companies (mostly state companies) are more efficient in terms of costs than the newer companies. Furthermore, the new companies are more efficient in costs related to management but presents higher fixed costs, which are related to financial costs.

Serrato (2006) also affirms that while older and newer companies have proportionally the same total cost related to the infrastructure, the relative size of the companies is not related to its efficiency. They also concludes that firms that operates in smaller areas are more efficient.

it is worth mentioning that Serrato reinforces the presence of the two analyzed effects on the BTA: the relative inefficiency of newer companies can be related to (financial) capacity constraint; and the efficiency gains prompted by the operation of nearby and interdependent infrastructure.

2.3 Interdependency and Capacity Constraint

According to Pitchik & Schotter (1988), in sequential auctions, objects can be interdependent. It can occur due to complementarity and capacity constraint. To Gandal (1997), sequential auction can be divided in distinct parts, auctions of independent value units and interdependent value. For the former, the unit value is not related to previous added units, while it is related for the second.

Krishna (2002) separates multiple auctions units by identical and not identical object units. According to him, identical units are perfect substitutes, while not identical can be substitutes or complements. The object is substitute if the marginal value of acquiring an additional object "A" is smaller the bigger the previously acquired objects set "B". So,

$$x^i(A \cup B) < x^i(A) + x^i(B)$$

where x^i : Marginal value of agent i.

Ashenfelter & Genesove (1992) analyzed identical units results in condominium units auctions and compared to negotiation results. They found that prices decreases with the number of auctioned units and after auction negotiated units reaches lower prices. The same pattern was identified by Ashenfelter (1989) analyzing wine auctions.

More recently, Reiss & Schondube (2010) study a first price sequential auction of independent objects in which competitors face capacity constraint. They identified a pattern of equivalence between commercialized object prices and auctioned values.

Some works analyze the objects complementarity and its effect on the prices trend. Gandal (1997) verified the interdependency existence in sequential auctions for cable TV licenses in Israel. The author claims that due to economies of scale, bids for the last auctions tend to be more aggressive. Ausubel *et al.* (1997) analyzed auctions for communication services on the intention to identify the impact of geographic synergies on its closing prices. The author observes that although capacity constraints, synergy effects conduct closing prices to higher levels when the second best bidder has connected licenses.

Some works evaluate the synergy existence in the Brazilian transmission auctions. Motta & Ramos (2011) conclude that the existence of interdependency between objects, associated with the competition level, is the growing discounts reason. Carlos & Saraiva (2008) and Hirota (2006) also concluded on the existence of interdependency between objects in the transmission auction.

The literature indicates that the complementarity between objects affect the prices trend. As the marginal value of acquiring an object is higher when the agent already owns a related object, the later auctioned objects have higher closing prices than former ones and the bids are more aggressive when sequential auctions gets closer to its end. On the other hand, the capacity constraint has the opposite effect on price trend, as a significant part of resources were applied in the first object.

Jofre-Bonet & Pesendorfer (2003) assess results of repeated auctions of highway contracts in California. They evaluate if the existence of an ongoing contract can affect the company capacity of winning new contracts. According to the authors as the building contract duration can last for months, winning a contract means allocate resources while the construction lasts. In this way the presence of inter-temporal capacity constraint reduce the available resources and then reduces the competitor chance of winning new contracts.

Silva (2005) examines road construction procurement auctions and finds that bidders with synergies have higher participating probability and tend to bid more aggressively. Also, firms capacity unconstrained tend to bid more aggressively than one that is capacity constrained.

Saini & Suter (2015) utilizes experiments to assess bidding behavior in a sequential procurement auction where bidders suffers from capacity constraint. They find that bidders account for capacity constraint effects but they underestimate its magnitude.

The power transmission contract requires the winner company to build, maintain and operate the transmission facility. The power lines and substation construction can request the following steps: topography and environment study, deforestation and area cleaning, land and rock excavation, and construction. These activities shows the need of specialized machinery and labor, which can be source of capacity constraint. Also, the contract set specific schedules for the construction and operation start, varying from 18 to 36 months.

These contracts characteristic allow the bidding strategies to be affected by capacity constraint.

In sequential auctions of not identical objects the interdependency and capacity constrains, when acting together, affects more than prices trend. The competitor may have to chose what auctions to participate as each object can reflect in different capacity constraint and interdependency effects. Also, not competing for a contract can allow opponents to be more competitive in later rounds, reducing the winning probability.

2.4 Theoretical Model

Here we study the procurement sequential auction of complementary objects. The interdependency of the objects act in a way that for any bidder j, its evaluation x of the objects A and B is such that

$$x^j(A \cup B) > x^j(A) + x^j(B)$$

This relation means that the marginal value of adding an object A to a set B is larger than the value of the object when considered in separate.

For a procurement auction, the object's complementarity can emerge from economy scale reasons. So, the bigger the number of interdependent objects (I), the lower the object marginal cost of adding another object. For simplification, we consider the cost as a function of I, $C(I)$, such that

$$\frac{dC}{dI} < 0 \qquad \frac{d^2C}{dI^2} > 0 \qquad C(I) > C(I+1) \tag{2.1}$$

The bidder j maximize the expected payoff $\pi_e = (B_j - C_j)P(B_j < B_{-j})$, where B_j is its own bid, B_{-j} is the opponent bid and C_j is the cost. The auctioneer reserve price is R, so $B \leq R$.

2.4.1 Auctions of Two Objects under Interdependence

In this first game we consider two risk neutral identical bidders, $J = 2$, and two complementary objects ($N = 2$) with identical auctioneer reserve price R. The game state Z represents the number of objects operated by each bidder (the interdependency level). We start with the initial state $Z = \{0,0\}$.

1. Suppose that bidder 1 is the winner on the first round lottery, so $Z = \{1,0\}$. It means that player 1 has an interdependent object and that its cost for the second object is C^1, and $C^1 < C^0$. In Round 2 the player 2 best strategy is to bid its own cost C^0. So, player 1 best response is to bid $C^0 - \varepsilon$. In the second round we have the following

   Round 2

   $J_1 : C_1 = C(1) \to c \leq B_1 \to B_1 = C(0) - \varepsilon \to \pi_1 = C(0) - C(1) > 0$

   $J_2 : C_2 = C(0) \to c \leq B_2 \to B_2 = C(0) \to \pi_2 = (C(0) - C(0)) = 0$

   $\pi_1 = C(0) - C(1) - \varepsilon, \qquad \pi_2 = 0$

   it is clear that to the first round winner is granted great advantage when competing for the second object, so the bidders are willing to reduce the first round bid lower than its own cost. Suppose now that they adopt strategy *s_2:* $B_j = C(0) - \varepsilon$ in the first round. In such case

   Round 1

   $J_1 : C_1 = C(0) \to B_1 = C(0) - \varepsilon \to \pi_1 = ([C(0) - \varepsilon] - C(0))P(\cdot)$

   $J_2 : C_2 = C(0) \to B_2 = C(0) - \varepsilon \to \pi_2 = ([C(0) - \varepsilon] - C(0))P(\cdot)$

   $\pi_1 = -\varepsilon, \qquad \pi_2 = 0$

   The competitors can keep on reducing the first round bid until its final payoff equal zero. Adopting this strategy *s_** the auction happens as following

   Round 1

   $P_1 : C_1 = C(0) \to B_1 = C(0) - [C(0) - C(1) + \varepsilon] = C(1) + \varepsilon \to \pi_1 = (C(1) - C(0)) + \varepsilon < 0$

   $P_2 : C_2 = C(0) \to B_2 = C(0) - [C(0) - C(1) + \varepsilon] = C(1) + \varepsilon \to \pi_2 = (C(1) - C(0)) + \varepsilon < 0$

If player 1 is the winner, the payoffs are

$\pi_1 = C(1) - C(0) < 0, \qquad \pi_2 = 0$

So the final payoffs are

$$\pi_1 = C(1) - C(0) + \varepsilon + C(0) - C(1) - \varepsilon = 0, \qquad \pi_2 = 0 + 0 = 0$$

The previous game is now organized in a normal form matrix, as the second round bids are given, the game is reduced to bidding in the first round. The figure 2.1 shows the expected payoffs related to the available strategies. [P_1][P_2]

Table 2.1 Normal Form Matrix

	s_1	s_2	$\dots$	s_n	s_{n+1}
s_1	$\frac{C(0)-C(1)}{2}, \frac{C(0)-C(1)}{2}$	$0, C(0) - C(1) - 2\varepsilon$	$\dots$	$0,0$	$0, -\varepsilon$
s_2	$C(0) - C(1) - 2\varepsilon, 0$	$\frac{C(0)-C(1)-2\varepsilon}{2}, \frac{C(0)-C(1)-2\varepsilon}{2}$	$\dots$	$0,0$	$0, -\varepsilon$
$\vdots$	$\dots$	$\dots$	$\dots$	$\dots$	$\dots$
s_*	$0,0$	$0,0$	$\dots$	$\mathbf{0,0}$	$0, -\varepsilon$
s_{n+1}	$-\varepsilon, 0$	$-\varepsilon, 0$	$\dots$	$-\varepsilon, 0$	$\frac{-\varepsilon}{2}, \frac{-\varepsilon}{2}$

Playing s_* for both bidders is an equilibrium. So, in this structure, all the excedent - including the interdependency gains - are captured by the auctioneer. Also, this game establishes that bids should grow along the rounds, as the bidders strongly competes in the first round and collect the gains in the second.

2.4.2 Auctions of Three Objects under Interdependence

The novelty in this game is an additional object in auction. The initial state is $Z = \{0, 0\}$, indicating that players don't have any interdependent objects before the auction and costs are identical among bidders.

1. We start assessing what's the biggest excedent a competitor could achieve in this three objects auction. Suppose player 1 adopts strategy $B_1 = C(0) - \varepsilon$ while player 2 bids $B_2 = C_2$. The auction result is

   Round 1

   $J_1 : C_1 = C(0) \rightarrow B_1 = C(0) - \varepsilon \rightarrow \pi_1 = ([C(0) - \varepsilon] - C(0)) = -\varepsilon$

   $J_2 : C_2 = C(0) \rightarrow B_2 = C(0) \rightarrow \pi_2 = 0$

   Round 2

   $J_1 : C_1 = C(1) \rightarrow B_1 = C(0) - \varepsilon \rightarrow \pi_1 = ([C(0) - \varepsilon] - C(1)) > 0$

$J_2 : C_2 = C(0) \rightarrow B_2 = C(0) \rightarrow \pi_2 = 0$

Round 3

$J_1 : C_1 = C(2) \rightarrow B_1 = C(0) - \varepsilon \rightarrow \pi_1 = ([C(0) - \varepsilon] - C(2)) > 0$

$J_2 : C_2 = C(0) \rightarrow B_2 = C(0) \rightarrow \pi_2 = 0$

Final Payoff

$$\pi_1 = 2C(0) - C(1) - C(2) - 3\varepsilon > 0, \qquad \pi_2 = 0 + 0 + 0 = 0$$

2. We now analyze the game utilizing backwards induction. In the last round, supposing player 1 won the two previous stages, the best bid player 2 can do is bidding its own cost. In reaction to that, player 1 should bid its adversary cost minus ε. The resulting auction is

Round 3

$J_1 : C_1 = C(2) \rightarrow B_1 = C(0) - \varepsilon] \rightarrow \pi_1 = C(0) - C(2) - \varepsilon$

$J_2 : C_2 = C(0) \rightarrow B_2 = C(0) \rightarrow \pi_2 = 0$

Round 2

Facing a two auctions object ahead, against an competitor with interdependency, the best a player can do is to bid its own cost. Let's imagine that it bids lower than its cost and wins the game. In the third round, it is going to compete in equal forces, and the result is an auction where both player bid its costs. So, the player cannot recover the discount made in the previous round and its final payoff is negative.

Then, in the second round the player won't bid any value lower than its own cost, while the one who has interdependency bids just ε below the adversary's cost,

$J_1 : C_1 = C(1) \rightarrow B_1 = C(0) - \varepsilon] \rightarrow \pi_1 = C(0) - C(1) - \varepsilon$

$J_2 : C_2 = C(0) \rightarrow B_2 = C(0) \rightarrow \pi_1 = 0$

Round 1

Under this setting, the game is reduced to winning the first round, as the winner will have advantages for the next rounds. The most aggressive strategy that can be utilized is to discount the potential next rounds gains in the first round bid. So,

$J_1 : C_1 = C(0) \rightarrow B_1 = C(0) - [2C(0) - C(1) - C(2) - 2\varepsilon] = C(1) + C(2) + 2\varepsilon$

$J_2 : C_2 = C(0) \rightarrow B_2 = C(0) - [2C(0) - C(1) - C(2) - 2\varepsilon] = C(1) + C(2) + 2\varepsilon$

Suppose player 1 is drawn,

$\pi_1 = C(1) + C(2) - 2C(0) + 2\varepsilon < 0, \qquad \pi_2 = 0$

Final Payoff

$$\boxed{\pi_1 = 0, \qquad \pi_2 = 0}$$

In the first round bidders are induced to offer all gains that can be reached in the following rounds due to interdependency. This way, as in the two objects case, all the excedent is captured by the auctioneer, due to the high level competition. Also, a growing bid pattern is verified along the rounds.

2.4.3 Interdependency and Capacity Constraint

The game we develop now is an expansion adding the hypothesis that bidder face inter-temporal capacity constraint. It means that winning an object, the player faces a cost rise in the following round. We now consider that players cost is a function $C_i = h(Int, Cap)$ such that $\frac{\partial C}{\partial Int} < 0$ e $\frac{\partial C}{\partial Cap} > 0$.

So while interdependency reduces costs, the capacity constraint raises it. Also, the factors have different duration. While interdependency lasts during all auction rounds, the capacity constraint affects just the next round.

2.4.4 Extreme High Capacity Constraint

We begin assessing the game when the capacity constraint is extremely high, such that in the round following the win the player's cost is equal to the auctioneer reserve price, so for that round $C_i = R$.

1. Let's assess the three objects game strategy equilibrium, with initial state $Z = \{0, 0\}$.

   In this game, players know that the first round winner is in disadvantage in the second round but in advantage in the third. If she wins the first round, will be capacity constrained in the second and the adversary wins. In the third, though, she is in a favorable position as the adversary is under constraint and she has interdependency.

   Due to that, players want to bid stronger in the first round and recover the discount in the last round. If the discount is too large though, it can be more interesting to stick just with the second round. Players will increase the discount until the point where they're indifferent between objects 1 and 3 or just object 2.

   Round 3

   $J_1 : C_1 = C(1) \rightarrow B_1 = R - \varepsilon \rightarrow \pi_1 = R - \varepsilon - C(1)$

$J_2 : C_2 = R \to B_1 = R \to \pi_2 = 0$

Round 2

$J_1 : C_1 = R \to B_1 = R \to \pi_1 = 0$

$J_2 : C_2 = C(0) \to B_1 = R - \varepsilon \to \pi_2 = R - \varepsilon - C(0)$

Round 1

$J_1 : C_1 = C(0) \to B_1 = C(0) - [C(0) - C(1)] = C(1)$

$J_2 : C_2 = C(0) \to B_1 = C(0) - [C(0) - C(1)] = C(1)$

Suppose player 1 is drawn

$\pi_1 = C(1) - C(0) < 0, \qquad \pi_2 = 0$

***Payoff* Final**

$\pi_1 = C(1) - C(0) + 0 + R - \varepsilon - C(1) = R - \varepsilon - C(0)$
$\pi_2 = 0 + R - \varepsilon - C(0) + 0 = R - \varepsilon - C(0)$
Auctioneer:$R - C(1) + R - R + \varepsilon + R - R + \varepsilon = R - C(1) + 2\varepsilon$

Comparing with the no capacity constraint situation

Δ: Without - With

$\Delta\pi_1 = 0 - [R - \varepsilon - C(0)] < 0, \qquad \Delta\pi_2 = 0 - [R - \varepsilon - C(0)] < 0$
ΔAuctioneer $= 3R - C(0) - C(1) - C(2) + \varepsilon - [R - C(1) + 2\varepsilon]$
ΔAuctioneer $= 2R - C(0) - C(2) - \varepsilon > 0$

2.4.5 Moderate Capacity Constraint

1. Consider that players costs are a function of the Interdependency (I) and Capacity Constraint (T) such that $C(I,T) = c(\gamma I - \mu T)$, for $\gamma, \mu \geq 1$, $0 < c < 1$. The case where $\mu < \gamma$ can be interpreted as a reduction of the interdependency effect, in a way that it would be fully effective just after a period of time. If it is the case that $\mu = \gamma$ then we can also understand it as a delayed interdependency effect.

   Although one could say capacity constraint have minor effects on costs or that the impact degree depends on the firms size, this model seeks to assess the situation where capacity constraint is a strong effect and can reduce bidders competitiveness for some time period. So, considering $\mu > \gamma$ represents the situation where winning an object will make the bidder less competitive than its opponent, even if only for a round.

Here we suppose that capacity constraint raises competitors costs in two "degrees", while interdependency lower costs in one "degree", so $\mu = 2$ and $\gamma = 1$.

Round 3

$J_1 : C_1 = C(1) \rightarrow B_1 = C(-1) - \varepsilon \rightarrow \pi_1 = C(-1) - \varepsilon - C(1) > 0$

$J_2 : C_2 = C(-1) \rightarrow B_2 = C(-1) \rightarrow \pi_2 = 0$

Round 2

$J_1 : C_1 = C(-1) \rightarrow B_1 = C(-1) \rightarrow \pi_1 = 0$

$J_2 : C_2 = C(0) \rightarrow B_2 = C(-1) - \varepsilon \rightarrow \pi_2 = C(-1) - \varepsilon - C(0) > 0$

Round 1

$J_1 : C_1 = C(0) \rightarrow B_1 = C(0) - [C(0) - C(1)] = C(1)$

$J_2 : C_2 = C(0) \rightarrow B_2 = C(0) - [C(0) - C(1)] = C(1)$

$\pi_1 = C(1) - C(0), \qquad \pi_2 = 0$

Final Payoff

$\pi_1 = C(1) - C(0) + 0 + C(-1) - C(1) - \varepsilon = C(-1) - C(0) - \varepsilon$
$\pi_2 = 0 + C(1) - C(0) - \varepsilon + 0 = C(-1) - C(0) - \varepsilon$
Auctioneer: $3R - 2C(-1)$

Comparing with the extreme high constraint case

Δ: "E. High" - "2 Degrees"

$\Delta\pi_1 = R - C(-1) > 0, \qquad \Delta\pi_2 = R - C(-1) > 0$
$\Delta\text{Auctioneer} = -2R - C(1) + 2C(-1) + 2\varepsilon < 0$

The smaller capacity constraint reduces the competition degree, allowing the auctioneer to reach larger excedents. The 2 Degrees case is associated to lower competitors payoffs, then when capacity constraint is higher.

---

2. Let's now assess the game with three objects and two competitor where one holds an interdependent object. Suppose player 1 is low cost L and player 2 is high H, $Z = \{1, 0\}$, $C(I, T) = c(\gamma I - \mu T)$ where

$\mu = 2$ and $\gamma = 1$. To solve this game, let's also suppose L wins the first round. If it happens, in the second round, costs are equal between agents, $C_L = c(1(1+1)-2(1))$ and $C_H = C(0)$.

- In case L also wins round 2, we have the following on the third

  Round 3

  $J_L : C_1 = C(1) \rightarrow B_1 = C(0) - \varepsilon \rightarrow \pi_1 = C(0) - \varepsilon - C(1) > 0$

  $J_H : C_2 = C(0) \rightarrow B_1 = C(0) \rightarrow \pi_1 = 0$

- In case L loses the second round, the third is

  Round 3

  $J_L : C_1 = C(2) \rightarrow B_1 = C(-1) - \varepsilon \rightarrow \pi_1 = C(-1) - \varepsilon - C(2) > 0$

  $J_H : C_2 = C(-1) \rightarrow B_1 = C(-1) \rightarrow \pi_1 = 0$

As payoff is bigger in the second case, the type "L" agent just wants to win the round 2 in case it can be at least as good as when she loses second round and wins the third. So, if second round payoff in case of victory is X, then $x + C(0) - \varepsilon - C(1) \geq C(-1) - \varepsilon - C(2)$. So, L is indifferent between scenarios when $x = C(-1) + C(1) - C(2) - C(0)$.

Due to that, type L player lowest bid in the second round is $C(-1) + C(1) - C(2)$. As player H's has payoff zero in both cases, she is indifferent and has lowest bid equal to its cost $C(0)$. As L has a "higher lowest bid", the second round is

Round 2

$J_L : C_1 = C(0) \rightarrow B_1 = C(-1) + C(1) - C(2) \rightarrow \pi_1 = 0$

$J_H : C_2 = C(0) \rightarrow B_2 = C(-1) + C(1) - C(2) - \varepsilon \rightarrow \pi_1 = C(-1) + C(1) - C(2) - \varepsilon - C(0) > 0$

So, player H wins Round 2.

The same assessment is made for the case where L loses the first round:

- In case L wins round 2

  Round 3

  $J_L : C_1 = C(0) \rightarrow B_1 = C(0) \rightarrow \pi_1 = 0$

  $J_H : C_2 = C(1) \rightarrow B_2 = C(0) - \varepsilon \rightarrow \pi_2 = C(0) - \varepsilon - C(1) > 0$

- In case L loses round 2

  Round 3

  $J_L : C_1 = C(2) \rightarrow B_1 = C(0) - \varepsilon \rightarrow \pi_1 = C(0) - \varepsilon - C(1) > 0$

  $J_H : C_2 = C(0) \rightarrow B_2 = C(0) \rightarrow \pi_2 = 0$

As the cases are symmetric, both require the same payoff on the second round $\pi = C(0) - \varepsilon - C(1)$. In spite to that, players costs are different, requiring different bids to achieve such minimum payoff.

Minimum Bid

$J_L : C(0) - \varepsilon - C(1) + C(1)$

$J_H : C(0) - \varepsilon - C(1) + C(-1)$

As $C(-1) > C(1)$, we have

Round 2

$J_L : C_1 = C(0) \rightarrow B_1 = C(0) - \varepsilon - C(1) + C(-1) \rightarrow \pi_1 = C(0) - 2\varepsilon - 2C(1) + C(-1)$

$J_H : C_2 = C(0) \rightarrow B_2 = C(0) - \varepsilon - C(1) + C(-1) - \varepsilon \rightarrow \pi_2 = 0$

So, player L wins second round.

Closing this assessment let's check the bidders lowest bid in first round.

Player L wants object 1 in case

$$\begin{aligned} x + C(-1) - \varepsilon - C(2) &\geq C(0) - 2\varepsilon - 2C(1) + C(-1) \\ x &\geq C(0) - \varepsilon - 2C(1) + C(2) \\ Bid_L &\geq C(0) - \varepsilon - 3C(1) + C(2) \end{aligned}$$

Player H wants object 1 in case

$$\begin{aligned} y + C(0) - \varepsilon - C(1) &\geq C(-1) + C(1) - C(2) - C(0) \\ y &\geq C(-1) + 2C(1) - C(2) - 2C(0) + \varepsilon \\ Bid_H &\geq C(-1) + 2C(1) - C(2) - C(0) + \varepsilon \end{aligned}$$

2.5 Empirical

In this section we quantitatively assess the effects of interdependency and capacity constraint acting together on the Brazilian transmission auctions.

As suggested by Rocha *et al.* (2013) the selection between winner and losers is endogenous, resulting in a bias when estimating an OLS due to non observable variables that turns a bid winner.

The bid can be explained by non observable variables as information asymmetry, company's efficiency, interdependency, etc. These non observable effects are revealed when its bid is the winner. One approach to deal with this situation is to admit that those variables won't change the relation between the independent variables and the bid, what would imply in heterogeneity between winner and loser coefficients (Rocha *et al.* , 2013).

In the transmission auction, the regulator reveals all the bids, but it is only observable in the different states: winner or loser. This setup can be handled by the **Roy Model**, also called **Switching Regression Model** by Maddala (1983) and **Tobit type 5 model** by Amemiya (1985). We follow Fiebig (2007) to describe it.

A latent variable W^* determines whether the outcome observed is y_2^* or y_3^*. In our specific case, W^* specifies whether the bid is a winner ($W = 1$) or a loser ($W = 0$) one. Also, according to that we observe exactly one of y_2^* or y_3^*,

$$y = \begin{cases} y_2^* & \text{if} \quad W^* = 1 \\ y_3^* & \text{if} \quad W^* = 0 \end{cases} \quad (2.2)$$

We can specify a linear model with additive errors for the latent variables, where

$$\begin{aligned} W^* = & \quad \mathbf{x}_1^{'}\beta_1 + \varepsilon_1, \\ y_2^* = & \quad \mathbf{x}_2^{'}\beta_2 + \varepsilon_2, \\ y_3^* = & \quad \mathbf{x}_3^{'}\beta_3 + \varepsilon_3. \end{aligned} \tag{2.3}$$

The simplest parametric model for correlated errors is the joint normal, with

$$\begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \end{bmatrix} \sim N \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \sigma_{12} & \sigma_{13} \\ \sigma 12 & \sigma_2^2 & \sigma_{23} \\ \sigma 13 & \sigma_{23} & \sigma_3^2 \end{bmatrix} \tag{2.4}$$

Given 2.2, for $w^* > 0$ we observe y_2^*, with probability equal to the probability that $y^* > 0$ times the conditional probability of y_2^* given that $y_1^* > 0$. Thus for positive y_2 the density of the observables is $f^*(y_2^*|y_1^* > 0) \times Pr[y_1^* > 0]$. For $y_1^* \leq 0$ the density of the observables is $f(y_{3i}|y_{1i}^* \leq 0) \times Pr[y_{1i}^* \leq 0]$. The switching regression model has the following likelihood function

$$L = \Pi_{i=1}^n \{f(y_{3i}|y_{1i}^* \leq 0) \times Pr[y_{1i}^* \leq 0]\}^{1-y_{1i}} \{f(y_{2i}|y_{1i}^* > 0) \times Pr[y_{1i}^* > 0]\}^{y_{1i}} \tag{2.5}$$

Using this procedure, $\mathbf{x}_1^{'}$ are the winning probability explanatory variables, while $\mathbf{x}_2^{'}$ and $\mathbf{x}_3^{'}$ explain bids in the winners group ($w = 1$) and losers group ($w = 0$), respectively. In this exercise we utilize bidder characteristics as explanatory variables for the winning probability while both bidder and auction characteristics to explain bidding.

Table 2.2 reports descriptive statistics of the data base.

Table 2.2 Descriptive Statistics

Variable	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Price Cap	9.3e+05	8.7e+06	2.3e+07	4.4e+07	4.9e+07	1.2e+09
Bid	6.6e+05	7.2e+06	1.7e+07	3.4e+07	3.5e+07	1.0e+09
Discount	0	6.24	18	20.52	32	60
Investment	1.04e+7	6.2e+7	1.5e+8	4.7e+8	3.2 e+8	5.0e+9
Ext	0.0	65.0	195.0	288.2	389.0	2518.0
Sub	0	0	1	1.021	2	7
Interdep	0	0	2	3.631	4	38
Diff of Interdependency	-30	-7	-3	-3.402	0	27
Backlog	0	0	1	2.311	3	15
# of Registered Companies	2	6	8	7.913	10	14
# of Bids	1	3	5	5.185	8	10
Dummy Variable			**Freq**			
South			0.1878			
South East			0.3301			
North East			0.2638			
Center West and North			0.3191			
Consortium			0.2804			
State			0.1257			
Foreign			0.3771			
Total Number of bids	724		Total Number of Projects			209

Source: Author

The auctioneer Revenue Cap (*RC*) is likely to be the most important variable to explain bids. In a procurement auction it works as an upper bound for the bid. Specifically for the Brazilian transmission auction, the Reserve Price is estimated by making the Net Present Value of the investment cash flow goes to zero. Doing that, the investment return is equal to the Weighted Average Capital Cost (WACC), what reflects the average cost of different financing alternatives in the market. The investment cash flow considers among other the initial investment to build the transmission structure, the land usage costs and the projects development.

Although the reserve price already accounts for variables market indicators, we also include on our database variables like the Long Run Interest Rate ($TJLP$), Brazil-risk ($EMBI+BR$), and the relation between the $RevenueCap$ by the Estimated $Investment$.

As object characteristics we include location, extension and number of substations. The last two variables directly impacts the necessary investment requested by the object. The longer is the line extension the higher are the costs with cables, towers and land while substations are related to expensive equipments.

Each Brazilian region can affect investments and maintenance costs differently due to economic and geographic reasons. The North region is known for presence of the very dense Amazon forest what requires high equipment transportation costs due to location access difficulties. The region, as the South-

East, can also be hardly affected by lightning and strong wind storms. Also, the South and South-East due to higher population density can have more costly land.

As a auction environment variable, we have the number of registered companies, what refers to the companies that have attended to some requirements previously made by the auctioneer. Although all those registered companies are allowed to bid in the auction, not all actually do bid. For some reason, companies may decide not to bid. The number companies that are registered and bid in the auction are called by (*Num_Bid*). While the winning probability is directed affected by *Num_Bid*, it should not be affected by the *Num_Regist* as the companies may not actually bid. On the other way, as all bidder bid simultaneously, the *Num_Regist* seems to be more important for bid estimation.

For bidder personal information we utilize dummies variables indicating if the company is state-owned ($State = 1$) or foreign ($Foreign = 1$). The Interdependence level (*Interdependency*) is defined as the sum of contracts held by the company, in the specific region the object will be build. This variable works as a proxy for the economy of scale that can be provided by the structures in operation.

The player may adjust its strategy when playing against a competitor that is stronger or weaker than himself. To account for this adjustments we created a variable that measures the difference in the Interdependence Level. The *Diff Interdependency* is calculated as a difference of interdependency levels: the player and its opponent with higher interdependence level (among the opponents registered to compete for the object).

When in a disadvantage situation the bidder may want to bid even harder if its competing against a high *Interdependency* level company. On the opposite situation, when competing against weaker opponents the bidder may not want to bid too strong.

Silva (2005) and Jofre-bonet & Pesendorfer (2000) defends that as the number of projects under construction grows the firm may suffer from a capacity constraint, i.e. it may be less competitive as a bigger part of its resources are in use. The *Backlog* variable counts the number of projects in execution hold by a bidder, as a proxy for the capacity constraint faced by the firm in the auction.

While operating contracts can add competitiveness to the bidder, it is possible that having multiple projects in the building stage can decrease bidder competitiveness due to Capacity Constraint. To evaluate this effect, *Backlog* counts the number of projects, in the building phase, the company will hold on the date the contract it is competing for is supposed to start.

A possible way to get away from *Backlog* effects is by setting partnership with other companies to share responsibilities. For this reason, we also utilize a dummy variable for the situation where the bidder is actually a Consortia ($Consortia$) of companies[1].

We proceed estimation for two different variables, the Bid (*Bid*) value and the relative discount (*Disc*) between the *RevenueCap* and the *Bid*. While the first represents how much the company is accepting

[1] For more information on consortia participation on the BTA seeTozei *et al.* (2014)

the contract, the second is a government measure of how much it saved by auctioning the object.

Table 2.3 Ols Estimations for log(bid)[a]

	(1)	(2)	(3)	(4)	(5)	(6)
Constant	4.829***	5.571***	-5.463	-10.539	5.065***	4.437***
	(0.119)	(0.092)	(49.698)	(57.193)	(1.005)	(0.990)
log(Investment)	1.001***	0.977***	0.935***	0.935***	0.938***	0.940***
	(0.010)	(0.008)	(0.012)	(0.013)	(0.012)	(0.012)
log(Interdependency + 1)	-0.089***	-0.058***	-0.045***	-0.049***	-0.055***	
	(0.014)	(0.010)	(0.012)	(0.014)	(0.013)	
Diff Interdependency				0.001	0.001	-0.025
				(0.002)	(0.002)	(0.023)
log(Backlog + 1)	-0.012	0.041***	0.051***	0.050***	0.049***	
	(0.017)	(0.012)	(0.013)	(0.013)	(0.013)	
log("Interdependency during" + 1)						0.009
						(0.011)
log("Previous Interdep." + 1)						-0.0002
						(0.002)
log("Previous backlog" + 1)						0.005
						(0.003)
Controls						
Year	No	Yes	Yes	Yes	Yes	Yes
Region	No	No	Yes	Yes	Yes	Yes
Auction	No	No	Yes	Yes	No	No
Contract Specifics	No	No	Yes	Yes	Yes	Yes
Company Type	No	No	Yes	Yes	Yes	Yes
Macroeconomics	No	No	Yes	Yes	Yes	Yes
Observations			724			
R^2						
Adjusted R^2						
Residual Std. Error						
F Statistic						

Note: *p<0.1; **p<0.05; ***p<0.01
[a]The numbers in parentheses are robust standard deviations.
Source: Author

Before running the Switching regression model, we present OLS estimation for the log(bid) in Table 2.3. The model (1) presents the estimations without the use of controls other than the $log(Investment)$, which is highly significant in all estimations. For that model, the coefficient of the interdependency is significant while the backlog one is not. In model (2), with the addition of the Year controls, both coefficients are reported significant at 1% level. As expected, the interdependency coefficient is negative and the backlog is positive.

In the third model, we control for the contract *Region*, the *Auction*, *Contracts specifics* as the line extension and the number of substations, the *Company type*, and Macroeconomics variables as the Long Run Interest rate and the nation risk index. The estimated coefficients for the interdependency and backlog are higher and still significant at 1% level. The model (4) adds the *Difference of Interdependency* to the control set, although it seems to not affect much the coefficient estimates.

The model (6) in Table 2.3 utilizes an adaptation of the procedure proposed by Silva (2005). The author tests for the existence of interdependency between contracts auctioned in the same day, part in the morning and the rest in the afternoon. The so called "morning effect" is related to the stronger afternoon bids realized by bidders that won contracts during the morning.

Our adaptated model tests if winning contracts in the auction day is related to lower bids for contracts in the same region. For that we use the variable "Interdependency During" auction. As the author, we control for any *previous interdependency*, i.e. for contracts previously won. Also following the author, we control for the Backlog level before the auction start.

Accordingly to Silva (2005), in his study the "morning effect" benefits on the fact that bidders know the contracts of the current auction, but not the contracts in the following one - to be held in about one month later. Therefore, the bidders focus on the interdependency gains of the current auction.

As presented in the last column of the table 2.3, the interdependency and backlog coefficients are not significant. it is worth noting that the expansion plans are presented long time before the auction, and usually bidders knows the contracts in several following auctions, in contrast to the setup in the De Silva study.

Table 2.4 presents the OLS results for the participation decision conditional on being registered for the auction. As expected, the model in column (1) suggests a positive correlation between the Interdependency level and the participation in the auction. Furthermore, the results for the *Diff of Interdependency* indicate that companies holding more interdependent projects than its opponents are more likely to participate in the auction. The model suggest that higher backlog levels are related to lower participation in the auctions, in accordance with the literature.

In all estimations, we control for changes in the contracts specifics, auction specifics, Long Run Interest Rate (LRIR), the country risk index (Embi),Year and Region fixed effects. It is worth noting that the OLS estimates consider robust correlation matrix.

In column (2), we test if winning contracts in the auction prompts to a higher participation likelyhood for contracts in the same region and in the same auction day. Our procedure is an adaptation of De Silva *et al.* (2005) model for the "morning effect". Thereby, we use the variable "Interdependency Within" auction. Following the author, we control for any *previous interdependency*, i.e. for contracts previously won, and for *Backlog* level before the auction start. The results doesn't suggests the presence of the "effect" in the same day.

it is worth noting that our original model differs from the adapted model in the time spam of the analyzed effect, i.e. while the former model doesn't restricts to any time spam, the later utilizes a short same-auction spam. Therefore, as the transmission bidders have information about several auctions

Table 2.4 Estimation Results for Participation Decision[a]

	Dependent variable:	
	(1)	(2)
Constant	-0.879	-0.777
	(1.515)	(1.557)
log(Interdependency + 1)	0.103***	
	(0.022)	
Diff of Interdependency	0.005**	
	(0.002)	
log(Capacity Constraint + 1)	-0.075***	
	(0.021)	
log(Interdependency Within + 1)		-0.018
		(0.032)
log(Previous Interdependency + 1)		-0.007
		(0.019)
log(Previous Backlog + 1)		0.0001
		(0.023)
Controls		
Year	Yes	Yes
Region	Yes	Yes
Company Type	Yes	Yes
Auction Specifics	Yes	Yes
Contract Specifics	Yes	Yes
Observations	1,547	1,547
R^2	0.271	0.247
Adjusted R^2	0.256	0.232
Residual Std. Error (df = 1516)	0.430	0.437
F Statistic (df = 30; 1516)	18.747***	16.566***

Note: *p<0.1; **p<0.05; ***p<0.01
[a]The numbers in parentheses are robust standard deviations.
Source: Author

to come, and as in Silva's case no previous information is obtained, we believe that our procedure is better adjusted to the transmission industry schedule.

The table 2.5 reports OLS results for the Winning probability conditional on participation. In column (1), the results shows that both the Interdependency level and its difference among bidders are positively correlated with winning the auction. A company holding more contracts in the region, and more contracts relatively to its opponents, is more likely to win the auction than otherwise. Furthermore, the *backlog* is reported negative and significant, as expected.

Table 2.5 Estimation Results for Winning Probability Conditional on Participation[a]

	Dependent variable:	
	(1)	(2)
Constant	0.412	1.787
	(2.118)	(2.251)
log(Interdependency + 1)	0.192***	
	(0.029)	
Diff of Interdependency	0.005*	
	(0.003)	
log(Capacity Constraint + 1)	-0.068**	
	(0.027)	
log(Interdependency Within + 1)		0.018
		(0.042)
log(Previous Interdependency + 1)		0.012
		(0.024)
log(Previous Backlog + 1)		-0.019
		(0.029)
Controls		
Year	Yes	Yes
Region	Yes	Yes
Company Type	Yes	Yes
Auction Specifics	Yes	Yes
Contract Specifics	Yes	Yes
Observations	724	724
R^2	0.313	0.243
Adjusted R^2	0.284	0.210
Residual Std. Error (df = 693)	0.384	0.404
F Statistic (df = 30; 693)	10.544***	7.410***

Note: *p<0.1; **p<0.05; ***p<0.01
[a]The numbers in parentheses are robust standard deviations.
Source: Author

The last result is even more interesting when analyzed with the Figure 3.11. In despite of a higher number of contracts allocated to firms with higher *backlog*, the number of projects under development is still reported negatively correlated with the winning likelihood. Therefore, a natural conclusion is that although winner firms have an increased *backlog* level over the years, in average the winner firms are not the ones with higher *backlog* levels among the competitors.

Table 2.6 Ols and Switching Regression Model for Discount[a]

Variable	OLS *Disc*		Eq. 1 Probit Winning		Eq. 2 Loser Group *Disc*		Eq. 3 Winner Group *Disc*	
(Intercept)	-89.2343		1.75260	***	-46.10	***	-55.31	***
	(69.0140)		(0.51901)		(10.12)		(15.41)	
# of Companies	0.504		-0.1133	***				
	(0.353)		(0.0218)					
State Company	8.204	***	0.49676	***				
	(1.718)		(0.1234)					
Foreign	4.006	***	-0.1148					
	(1.201)		(0.1176)					
Consortium	-4.568	***	-0.0529					
	(1.213)		(0.1333)					
log(interdependency + 1)	3.311	***		***	2.1544	*	7.6300	**
	(1.016)				(0.9628)		(2.4405)	
Diff of Interdependency	-0.068			**	0.1109		-0.2459	
	(0.136)				(0.11184)		(0.1887)	
log(Backlog + 1)	-3.340	***			-0.8943		-6.7395	***
	(0.919)				(0.9614)		(1.7129)	
log(Investment)	4.746	***			4.937	***	3.2213	**
	(0.891)				(0.872)		(1.245)	
Investment/Price Cap	0.193	**			0.2258	***	0.1550	·
	(0.095)				(0.0568)		(0.080)	
EMBI	0.059				-0.0185	***	-0.0230	***
	(0.518)				(0.0021)		(0.0036)	
L.R. Interest Rate	0.686				-0.0213	*	0.0099	
	(4.529)				(0.0106)		(0.0158)	
Controls								
Year	Yes		No		Yes		Yes	
Region	Yes		No		Yes		Yes	
Auction	No		No		No		No	
Contract Specifics	Yes		No		Yes		Yes	
N	724		724		209		515	
ρ_0 ($Win = 0$)							0.7815**	
							(0.0583)	
ρ_1 ($Win = 1$)					0.8934***			
					(0.0380)			

Signif. codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 " " 1
[a]The numbers in parentheses are robust standard deviations.
Source: Author

Table 2.6 shows the estimation results for OLS and for Switching Regression Model (SRM) procedures for the *Discount*. It presents the estimated coefficient and Standard Error (in parentheses) for each procedure and equation. The SRM should correct the auto-selection bias between the winner and loser groups.

The OLS estimates, in column (1), shows a positive coefficient for the *Interdependency* and a negative for the *Backlog*. As expected, a higher interdependency level is correlated to a higher *Discount*, i.e. with a lower bid. As part of the SRM, in column (2), we reports the estimations for the winning probability.

Comparing results in column (3) and (4) we can see that while *Backlog* is negatively correlated the *Disc* in the winner group, it is not significant for the Loser group. Also, for both groups, the coefficient for the *Interdependency* is positive and significantly different from zero.

The likelihood-ratio test for the joint independence of the three equations is reported in the last line of the output. The test suggests that the three equations are jointly independent, as required by the model. Both ρ_0 and ρ_1 are positive and statistically significant, meaning that there is positive selection into the Winner group and negative selection into the Loser group. Since ρ_1 is positive, it suggests that winners *Disc* are higher than a randomly selected one from the sample would be. Since ρ_0 is positive, it suggests that loser *Disc* are smaller than a randomly one selected one would be.

We repeat the SRM analysis for the *Bid* as the dependent variable, the results are reported in Table 2.7. Again the estimated ρ_1 and ρ_0 are significant and the model reportedly controls for selection bias, but now both parameters are negative. As ρ_1 is negative, the *Bid* in the winner group is smaller than a bid randomly selected from the sample would be. Also, as ρ_0 is positive, it suggest that a bid in the loser group is smaller than a randomly selected bid would be. Although the signs are the opposite of the previous model, the informations are in the same path.

Table 2.7 also reports the Winner group and Loser group results for the *Bid* in columns (3) and (4), respectively. As expected, the *Interdependency* coefficient is reported negative and significant for both, the winner and loser groups. Furthermore, the *Backlog* is significant and negative for the winner group, but not significant for the loser one.

it is worth noting that, as a result of the theoretical model with perfect information, would expect the *Diff of Interdependency* to be positive, suggesting that higher interdependency level would reflect higher bids in both groups. Besides that, the variable was not reported significant in any model.

Due to log-log estimations properties, the coefficients of $log(investiment)$ have a elasticity interpretation. it is worth noting that, for the $log(bid)$ estimations, we observed that the elasticity ranged between 0.9 and 1. As expected, variations in the investment prompt similar variations in the average *bid*.

To further analyze the relation between the *bid* and the *interdependency* and *backlog* levels, we run a Quantile Regression Model (QRM). This method allows to infer if the variables coefficients are different for different quantiles of the *bid*. Furthermore, as the *bid* is so closely related to the *investment* and therefore to the contract size, we can infer how the coefficients changes with the contracts sizes.

The table 2.8 presents the QRM results for *bid* with quantiles varying between 0.15 and 0.85. Our results shows that the coefficients of both the *interdependency* and *backlog* get closer to zero for higher

Table 2.7 Ols and Switch Regression Model for Bid[a]

Variable	OLS $log(bid)$	Eq. 1 Probit Winning	Eq. 2 Loser Group $log(bid)$	Eq. 3 Winner Group $log(bid)$
(Intercept)	5.0654 ***	1.6813	4.736 ***	4.791 ***
	(1.0049)	(0.5409)	(0.1393)	(0.2183)
# of Companies	-0.004	-0.1111 ***		
	(0.004)	(0.0222)		
State Company	-0.1068 ***	0.5286 ***		
	(0.0231)	(0.1255)		
Foreign	-0.0550 ***	-0.1523		
	(0.0156)	(0.0972)		
Consortium	0.0659 ***	-0.1206		
	(0.0158)	(0.1093)		
log(Interdependency + 1)	-0.0547 ***		-0.0249 .	-0.1138 **
	(0.0132)		(0.0131)	(0.0348)
Diff of Interdependency	0.0013		-0.0015	0.0030
	(0.0015)		(0.0015)	(0.0026)
log(Backlog + 1)	0.0488 ***		0.0140	0.1006 ***
	(0.0128)		(0.0132)	(0.0244)
log(Investment)	0.9382 ***		0.9274 ***	0.9559
***				
	(0.0116)		(0.0120)	(0.0176)
Investment/Price Cap	0.0034 *		0.0032 ***	0.0038 ***
	(0.0016)		(0.0007)	(0.0011)
EMBI	0.0006 ***		0.0001 ***	0.0002 *
	(0.0001)		(0.00002)	(0.00005)
L.R. Interest Rate	-0.0002		0.0003 *	0.00001
	(0.0010)		(0.0001)	(0.0002)
Controls				
Regions	Yes	No	Yes	Yes
Years	Yes	Yes	No	Yes
Auction	No	No	No	No
N	724	724	210	514
ρ_0 $(Win = 0)$				-0.6768***
				(0.0724)
ρ_1 $(Win = 1)$			-0.8997***	
			(0.0389)	

Signif. codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 " " 1

[a]The numbers in parentheses are robust standard deviations. *Source: Author*

Table 2.8 Quantile Regression Model Estimates for $log(bid)$

	Quantile				
	0.15	25	50	75	85
log(investment)	0.96943 ***	0.95846 ***	0.95637***	0.96783***	0.97602***
	(0.00996)	(0.00784)	(0.00759)	(0.00736)	(0.00452)
log(interdependency + 1)	-0.10723 ***	-0.08776 ***	-0.03470***	0.00243	0.00762
	(0.01575)	(0.01289)	(0.01288)	(0.01176)	(0.00756)
Diff Interdependency	0.00373 *	0.00251 *	0.00035	0.00014	-0.00073
	(0.00214)	(0.00150)	(0.00129)	(0.00106)	(0.00072)
log(backlog + 1)	0.09171 ***	0.06791 ***	0.03094***	0.01093	0.01434 **
	(0.01510)	(0.01361)	(0.01159)	(0.01123)	(0.00592)
Controls					
Year	Yes				
Region	Yes				
Auction	No				
Contract Specifics	Yes				
Company Type	Yes				
Macroeconomics	Yes				

Note: *p<0.1; **p<0.05; ***p<0.01
[a]The numbers in parentheses are robust standard deviations.
Source: Author

quantiles, with the exception of the last quantile.

The figures 2.5 and 2.5 graphically shows the table results for the Interdependency and for the Backlog, respectively. The solid red line represents the OLS estimation while the red dotted line represents the 90% level confidence interval. The coefficients are estimated for the quantiles ranging between 0.5 and 0.95. And the gray shade represents the 90% confidence interval for the various coefficients.

2.6 Conclusion

The theoretical model let us infer that, interdependence and capacity constraint acting together: 1- Decrease bidders competitiveness; 2- Decrease auctioneers payoff; 3- Can lead to a raising prices pattern; 4- Can be minimized by introducing additional competitors; and 5- Highlights the importance of correct reserve price setting.

We verified a significant negative correlation between the firm's backlog and the auction participation, i.e. a negative correlation between the firms capacity constraint and its participation. Finally, we also observe a positive correlation between the interdependency and both the participation and the winning probability.

We empirically confirmed that both interdependency and capacity constraint are highly correlated

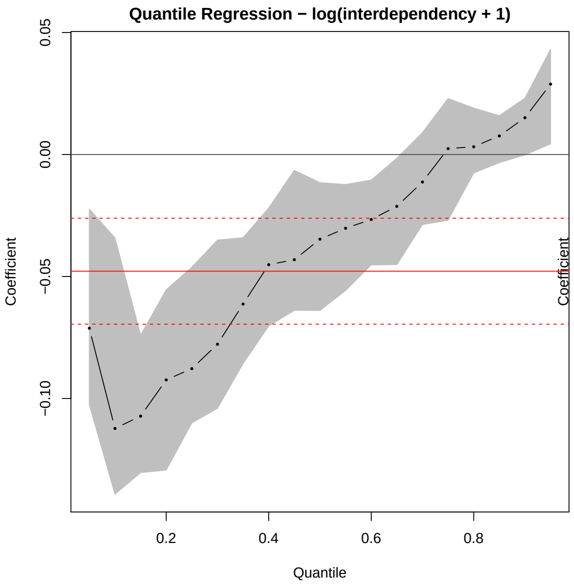

Figure 2.3 Quantile Regression for Interdependency
Source: Author

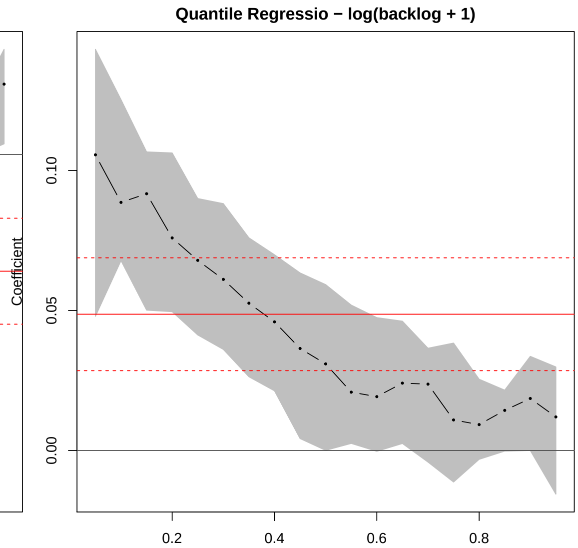

Figure 2.4 Quantile Regression for Backlog
Source: Author

to the Brazilian transmission auctions results, *bid* and *discount*. Therefore, the interdependency between the transmission projects are related to lower investment costs and are strategically utilized by bidders in this auction. On the opposite direction, the capacity constraint is related to higher and less competitive bids. Consequently, the capacity constraint is associated with lower winning probabilies and the interdependency is associated with higher winning probabilities.

We can't confirm the existence of "morning effect" between the same-day auctioned contracts. We believe that, by presenting the long term national expansion plans, the regulator diminishes the effect in favor of interdependency effects over several other auctions.

The implications of the above conclusions for policy makers are: 1- Capacity constraint is affecting the Brazilian transmission auction, and may be one source to induce companies lack of interest; 2- Interdependency and Capacity constraint affects bidders behavior and should be introduced to the methodology of specification of the reserve price. 3- Plans to rapid expand the grid can be frustrated if these effects are not considered; 4- Competition can minimize backlog effects and induce companies to bid lower.

CHAPTER 3

Failures on the Brazilian Transmission Auctions

Abstract

Most of the empirical auction literature assess auctions that, well or not, allocate objects. Auctions that fail in doing so tend to be misrepresented in the literature. As a consequence, the reasons behind the allocation failure or, in another way, the measures to guarantee allocation, don't get the necessary attention. In this paper we investigate the reasons behind the growing rate of failures observed in the Brazilian Power Transmission Auctions (BPTA). More specifically, we analyze the cases of Empty auctions and Removed projects in the BPTA. We also analyze the policies utilized by the regulator as a measure to deal with the issues and enhance the objects attractiveness. We attempt to answer the following question: "How well are auctions allocating projects in the Brazilian Transmission Sector (BTS)?". We show that, in several cases, the regulator was willing to adjust the price cap to ensure the presence of bidders. Furthermore we show the regulator policy to modifying the object in a combinatorial auction sense. Finally we empirically check for reasons that are affecting bidders participation. We verify that Interdependency and Capacity Constraint affects participation decision and winning likelihood.

Keywords: Auction Failures, Interdependency, Capacity Constraint, Procurement, Sequential Auctions, Combinatorial Auctions.

3.1 Introduction

Most of the empirical auction literature assess auctions that, well or not, allocate objects. Auctions that fail in doing so tend to be misrepresented in the literature, despite the fact that among several ways an auction could be inefficient this may be the most extreme one. As a consequence, the reasons behind the allocation failure or, in another way, the measures to guarantee allocation, don't get the necessary attention.

In the better-represented group of the literature, an often made question is "how well are auctions allocating objects?". An expected answer would involve efficiency analysis, i.e. would involve checking whether the bidder with the highest evaluation wins the auction or not. This kind of procedure requires some sort of allocation and, thereby, is not appropriated for auctions that have failed in allocating some/several objects. In this case, the verification of whether the object is allocated or not takes the place of the efficiency analysis.

In this paper we investigate the reasons behind the growing rate of failures observed in the Brazilian Power Transmission Auctions (BPTA). More specifically, we analyze the cases of empty and removed auction in the BPTA. We also analyze the policies utilized by the regulator as a measure to deal with the issues and enhance the objects attractiveness. By doing so we contribute to the small literature of auctions with allocation failures and to the so far not-analyzed issue in the Brazilian transmission sector.

We attempt to answer the following question: "How well are auctions allocating projects in the Brazilian Transmission Sector (BTS)?". We show that, in several cases, the regulator was willing to adjust the price cap to ensure the presence of bidders, so the cases of non-allocation of an object represent not just an efficiency issue but a case of auction failure. Furthermore we show the regulator policy to modifying the object in a combinatorial auction sense.

Finally we empirically check for reasons that are affecting bidders participation. We verify that Interdependency and Capacity Constraint affects participation decision and winning likelihood.

3.2 The BPTA Environment and Failures

According to EPE (2007) the actual Brazilian power matrix is highly concentrated in hydro-power generation. The national plan seeks for diversifying it, lowering the dependence on hydrological cycles. Therefore, many auctions for clean energy plants, including solar, wind and biomass thermo power have been conducted, enhancing reliability by renewable complementary pattern. In this context, higher investments in power transmission are required, as renewable plants locations can be disperse and far from costumers.

In the actual setting, the Government is entitled to plan the transmission sector expansion and to promote public tenders to contract the investments, which are carried by both private and public initiatives.

For contracting, the regulator uses a hybrid auction in a pay as bid manner. It has two phases: starts with a sealed bid auction and, if necessary, follows to an open descendant auction. As a procurement auction, the regulator sets a Revenue Cap (RC) so offers must be smaller than it. After bid submission in the first phase, all bids are revealed. In case there are bids in a range up to 5% higher than the best one, companies with bids in the range are conducted to the second phase, otherwise the lower bid company is the winner. At the second stage bids are open and start from the best offer in the previous phase.

Since the auction implementation, in 2001, about 61.000 km of power lines and more than 220 substations have been contracted, through 211 projects[1]. The average discount between ANEEL's reserve price and the final winner bid is about 24%. The figure 3.1 shows the discounts and number of offered contracts evolution by year.

The figure 3.2 shows the evolution of the number of offered contracts along the years, represented by the black line. A pattern change is noticeable after 2007. In the first period the number of contracts offered is around 10 per year. In the second period, the government offered a higher number of contracts,

[1] from 2001 until the second auction of 2015

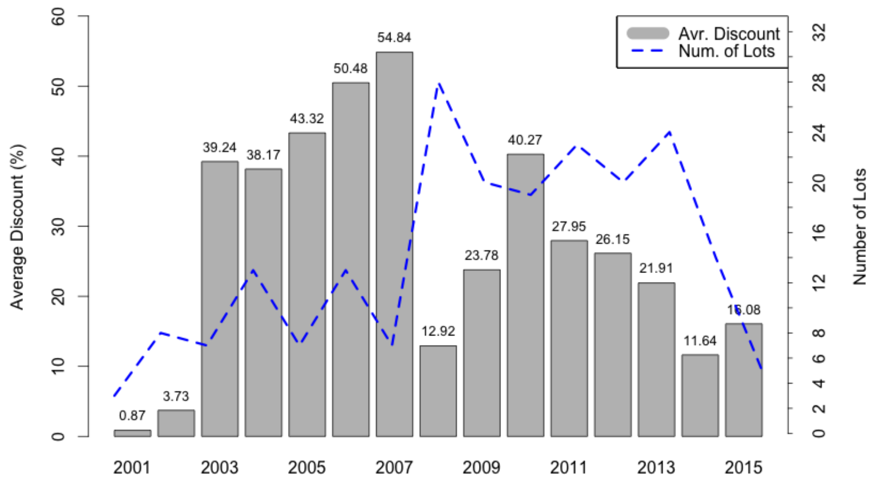

Figure 3.1 Average Discounts and Number of Contracts per year
Source: Author

reaching 38 contracts in 2013. As the difference could emerge from a policy of smaller contracts, we also check the length and investment per contract. it is also noticeable that, in the second period, both the length and investment per contract are higher, suggesting that the government decided for a faster grid expansion.

The figure shows that part of this faster growth was frustrated, as some of the contracts did not find a bidder or was removed before the auction. While the red line represents the number of "empty" auctions, i.e. offered contracts without bids, the blue stands for the removed contracts. The green line represents the number of successfully signed contracts. The figure shows that the growth of "empty" auctions started in 2010 and had its highest point in 2013. Also, in 2015[2], for the first time, the number of "empty" auctions exceeded the number of actually signed contracts.

In some situations, the regulator has removed some of the contracts after publishing the auction call. Although the regulator doesn't explain the reasons it has pulled off contracts, it could happen for reasons as: lack of bidders' registration for the auction; mistakes on the call for auction; changes in the expansion plan. In all cases the auction cancellation represents a failure in following the expansion plan or, as in the third, a failure in planning correctly before publishing the call. Furthermore, government's resources are spent to plan and publish an auction call, as well as private ones to get ready for the competition. it is worth noting that changes in the expansion plan can affect bidders expectation.

Contracts Removed before Auction

In 2006 companies brought a lawsuit against one call for auctions which was later canceled by the regulator. The companies claimed they couldn't compete for a contract without previous definition of revenue adjustment. The contracts were submitted for auction again in the same year without changes in the maximum allowed revenue and found interested bidders.

[2]By the submission of this paper, just the auctions 001/2015 and 007/2015 had been concluded.

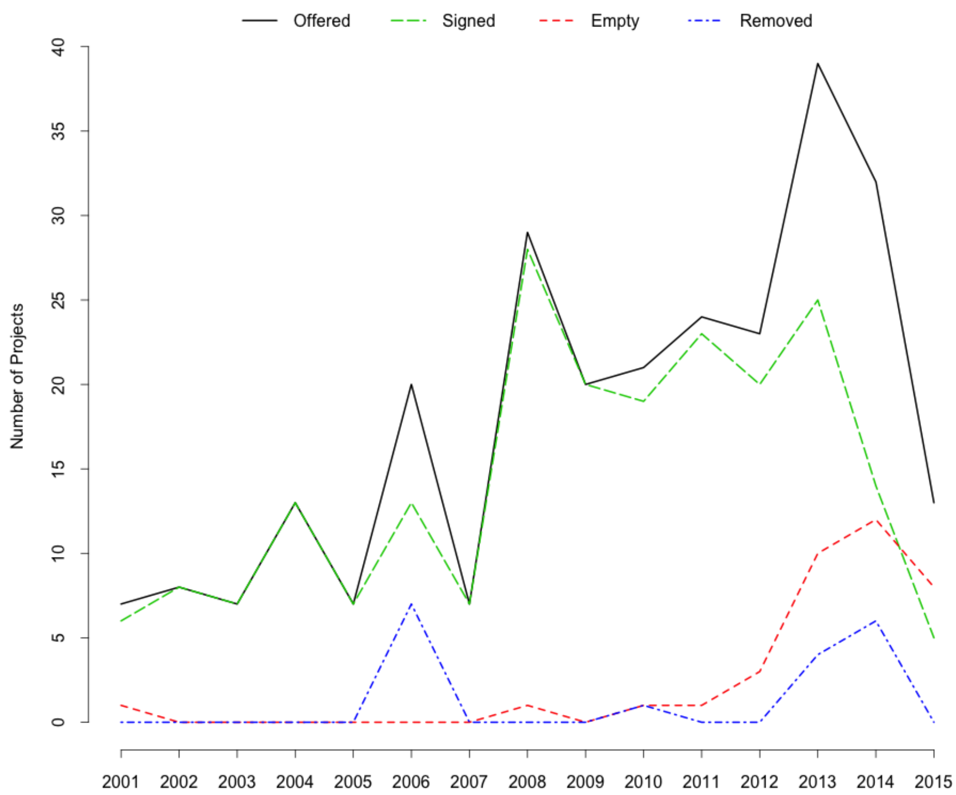

Figure 3.2 Number of Offered Contracts
Source: Author

For an apparent mistake on the call, in 2010 one contract was removed, offered again and successfully allocated in the following year. The interesting fact is that, although the relaunched contract requested the same infrastructure to be build, the maximum allowed revenue was decreased in about 28% and still got a bid from a private national and state companies acting as a consortium. Although this was the only contract which RP decreased, it shows that other contracts could require revenue revision but haven't been canceled.

For either a lack of registration or mistakes on the call, in 2013 two contracts were launched on auction 013/2013 project B and D, but were removed before the auction start. Although neither of the contracts got any additional structure, the contract D receive 136% RAP increase while the contract B had a raise of 1,49% in the Reserve Price. After that, the contract D received a bid and the structure B went to auction two additional occasions, both after additions to the contract, when it was finally contracted.

Projects C and M were removed from auction 007/2013, both after previous allocation attempts. The former was identically put to auction twice in 2012 and did not receive bids from companies. The latter did not receive bids in the first auction of 2013, so it was offered again, this time with 56% RP increase and another power line in the structure.

The lower degree of competition is noticed for both allocated and not allocated contracts. Figure 3.3 shows the number of subscribed companies per auction and the number of subscribed companies that actually bid per auction. The variables are strongly related, growing until 2006 and then decreasing in the

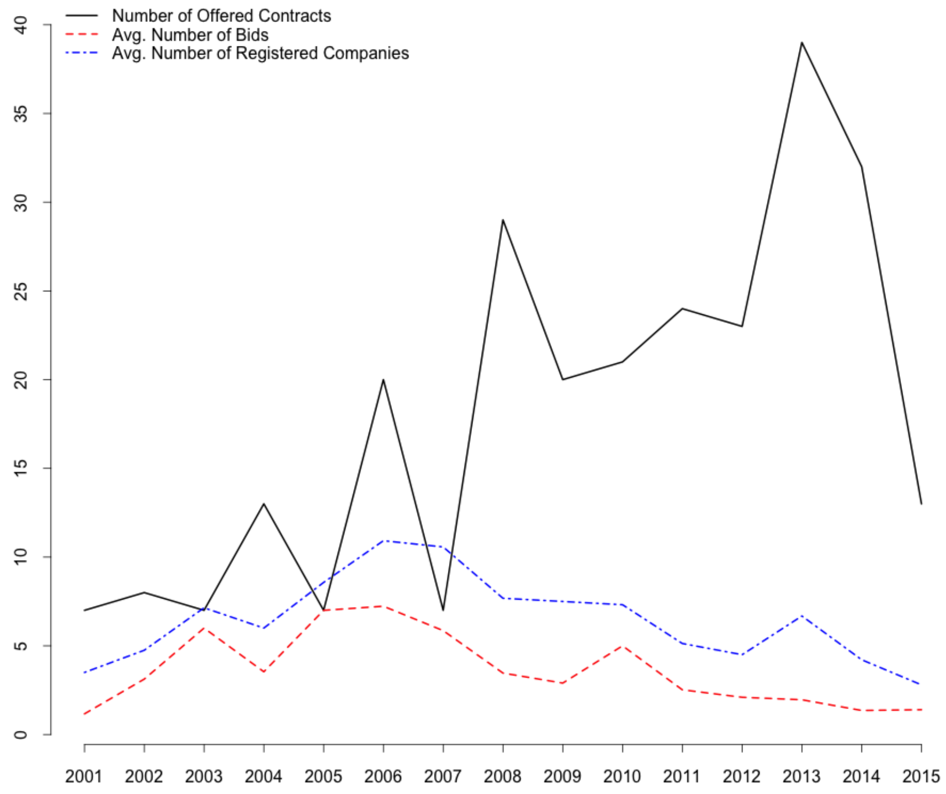

Figure 3.3 Number of competitors per auction
Source: Author

following period.

The decrease of competition per auction may be the result of a raise in the number of offered contracts per year. If it is the case, for a limited number of eligible companies in the market, it is expected less competition as the number of contracts grows. Indeed, the green line in the figure highlights this pattern. As the number of offered contracts per year remains around 10, the average number of subscribed companies grows from 5 to 10 in 2006. The great increase of offered contracts in 2008 is followed by a decrease in the average number of subscribed companies.

As verified by Jofre-bonet & Pesendorfer (2000) and De Silva *et al.* (2005) companies building infrastructure may be affected by capacity constraint, causing a temporarily increase in costs during the construction. In this scenario, remuneration decreases can repel transmission companies and even higher remuneration per contract would be necessary to keep the contracts attractive and competition degree. The figure 3.4 shows the evolution of the ratio of Revenue Cap by estimated Investment, as a measure of the project return. We also categorized the projects by its result as: "Contracted", "Empty" and "Removed".

Relaunched Without Changes

Although some structures are not contracted in a first opportunity, it is still part of the expansion plan and a solution must be found. In several occasions the ANEEL relaunched identical contracts in later auctions, while in others the structures were bundled together, modifying the relaunched contracts.

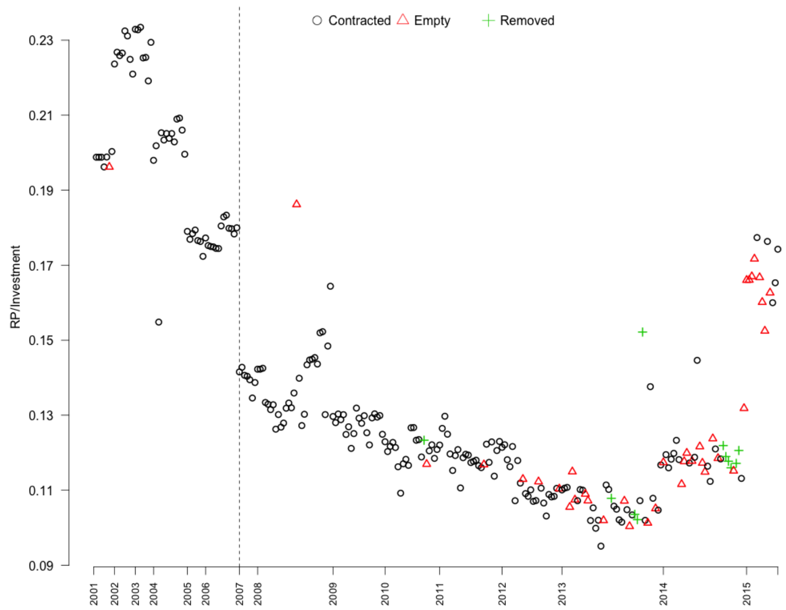

Figure 3.4 Ratio Revenue Cap by Investment
Source: Author

Since 2001 the ANEEL has relaunched 19 contracts featuring the exact same structures, with changes on schedule and/or in the maximum allowed revenue. While some of those relaunched contracts did not get offers from the companies, others haven't gone for auction. The table 3.1 shows the original contracts and the respective relaunched contracts for the same structure, and changes between the two auctions.

The first thing to highlight is that the entire auction 001/2006 was removed as the Brazilian justice, they understood that there were missing information about the periodic revenue revisions, causing miss information about the winner revenue. Later in the same year, all contracts were identically relaunched without changes in the revenue or construction schedule and successfully allocated.

Another four announced contracts have been removed before auction start and relaunched with identical structure. The auction 008/2010 contract D faced an unusual situation in which the ANEEL decide to relaunch it with a decrease in the allowed revenue of 28%. As the contract have been successfully allocated with a lower allowed revenue, it is very likely it could have been allocated in the first situation but at much higher prices.

The three other removed contracts received increase in the allowed revenue, but 1,49% for the 007/2013 contract L resulted in another failure for the regulator and ended up without offers.

In 2001 a 179km extension power line, to be build in the North of the country, did not receive offers from the companies. The agency relaunched it in the following year rising the allowed revenue in about 31%, as a way to make it more attractive to potential competitors.

The ANEEL utilized the same procedure to higher attractiveness to contracts that end up without offers, as happened in the auction number 008/2010 contract E that faced a 18% increase in the reserve price and 33% in construction time. The auction 001/2013 contract D have also received increase in revenue and time limit, 21% and 36% respectively, and was effectively contracted on the second offer auction.

The fact that represents one of the largest evaluation failures made by the agency happened to the auction 007/2014 contract J. The initial offer made was a R$ 3 million revenue limit, that afterwards was raised to R$ 21 million for the same structure. The relaunch of the structure faced a 591% allowed revenue increase and a 50% raise in the construction time limit.

Although some empty auction contracts ended up signed at the relaunch auction, the higher revenue wasn't enough to ensure competition for all them. The ANEEL faced a second failure on attempting to contract identical structures under the auctions 003/2012 contract D, 007/2012 contract H, 001/2014 contract A and 001/2014 contract G. The revenue raise for those relaunched contracts range from 3,6% to 68%. Out of those contracts, two of them were signed in the third auction, one is still not announced and one went to a fourth announcement, and revenue review, when it finally received an offer.

Relaunched with Changes

Although the regulator interpretation that raising the allowed revenue could enhance competition, it also adopted different strategies. In some specific situations, the regulator reorganized the structures to be build in different ways: 1- bundling some structures into just one contract; 2- or, in the opposite direction, unbundling structures into smaller contracts.

This strategy was first utilized after the lack of offers in the auction 006/2008 contract D. The contract featured 81km extension including an underground part for the capital city of the Rio Grande do Sul province. The ANEEL managed to unbundle the on air and the underground parts in two different contracts. Comparing to the first situation the contracted also featured an extra substation and higher maximum allowed revenue.

The unbundling approach was also adopted for the structures included in the contract 001/2014 I. As it did not reach the expected results, the regulator faced a new failure and submitted the expansion to a third attempt for contracting.

The ANEEL attached contracts for three times. In every situation the bundled contracts were regionally connected, allowing the winner to benefit from a bigger scale contract. In two of them the regulator also added extra structures and in all three raised the allowed revenue and time limit for construction.

Despite several strategies and attempts for contracting and keeping the expansion plan, after auction 001/2015 the Brazilian power transmission sector still has 9 not allocated contracts, totalizing more than R$ 1 billion in maximum allowed revenue.

Starting at auction 007/2012, the ANEEL decided to restrict the participation of companies with long delays in the construction of previous contracts. Companies with more than 180 days of average delay in the construction schedule or with more than 2 delay notifications would be restricted from competing.

The decision intended to avoid those companies to add new projects to its backlog and to retard the grid expansion even more. Figure 3.5 shows the number of days delayed per company at 09/31/2012 and the red line represents the 180 days participation criteria for auction 007/2012. Figure 3.6 shows the companies not allowed to participate in the auction due to number of delays notifications.

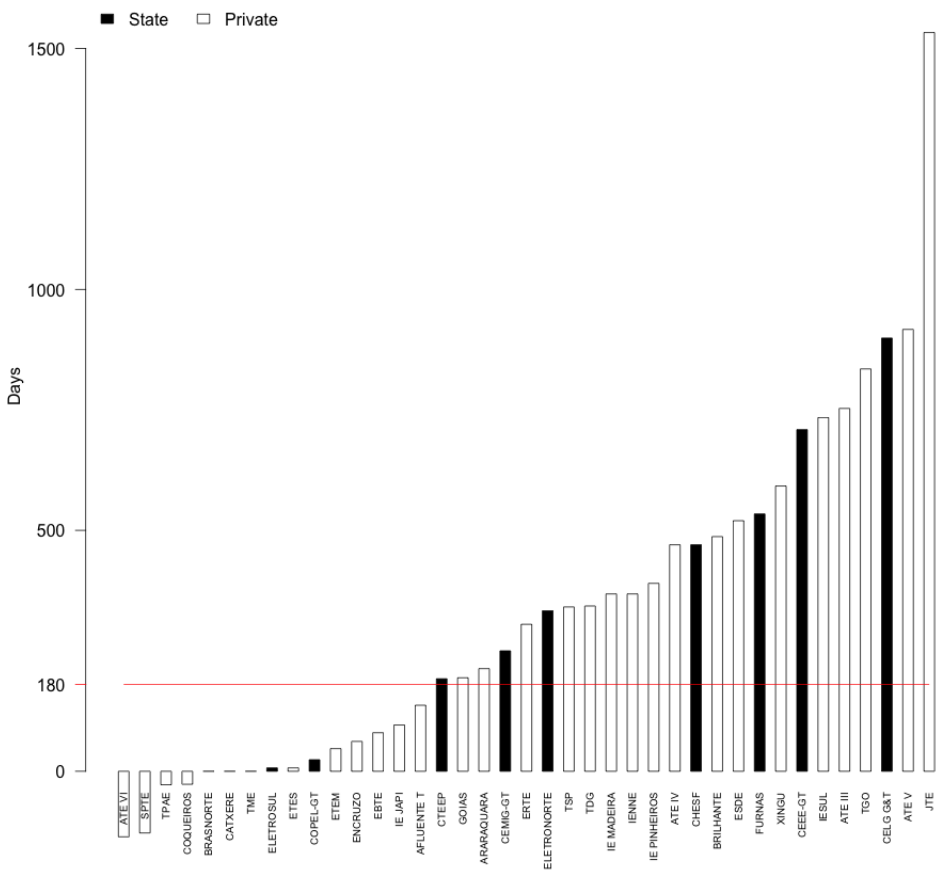

Figure 3.5 Companies with Participation Restriction due to Average Delay Policy
Source: Author

By imposing this new rule, the auctioneer reduced the pool of eligible companies and possibly[3] the number of competitors for the objects. More specifically, the participation rule removed several state companies from this pool. Black bars on figure 4.1 represent state companies.

State companies have been related to aggressive bidding by Rocha (2007) in the Brazilian Transmission Auction (BTA). Indeed between 2001 and 2015[4] state companies won 116 projects out of 211, representing a significant participation in the grid expansion. Figure 3.7 shows the percentage of contracts won by state companies along the years and the number of auctioned projects by year.

Figure 3.8 shows the main delay reasons on transmission projects. According to SFE (2015), in the last 5 years more than 71.2% of the transmission projects have schedule retarded due to Environmental

[3]we can't confirm that this rule was the only responsible for the reduction of competition in the auctions, as the facts described bellow could also have affected it.

[4]auction 001/2015

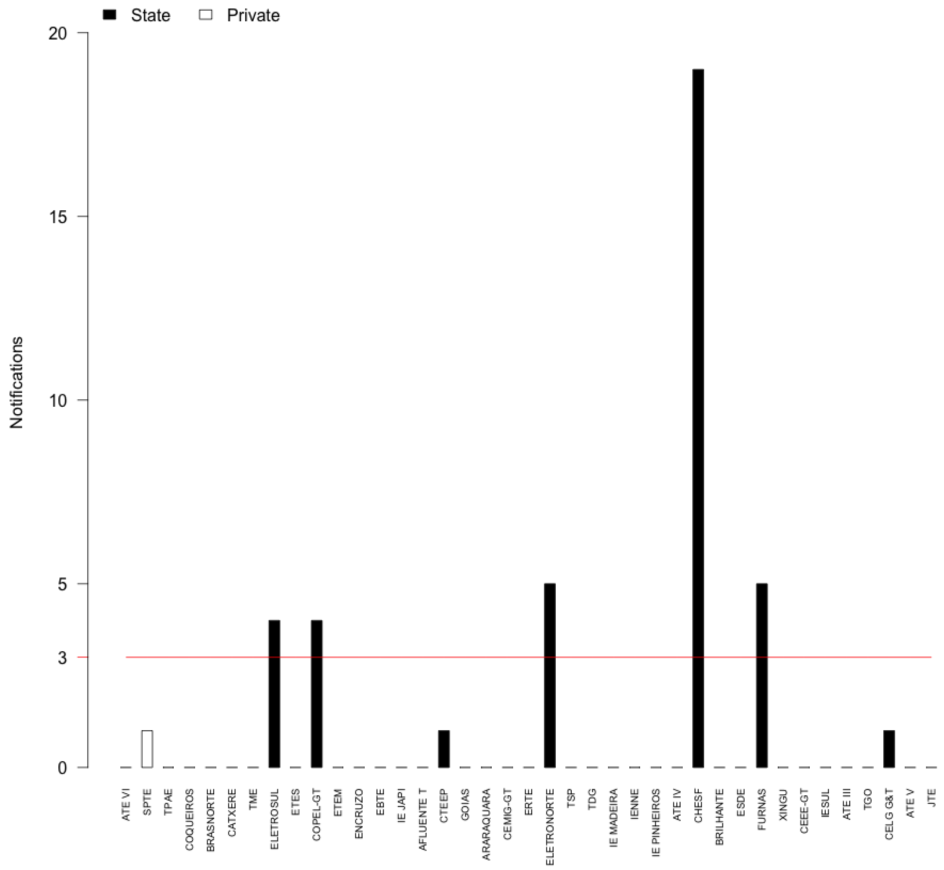

Figure 3.6 Companies with Participation Restriction due to Notification Policy

Source: Author

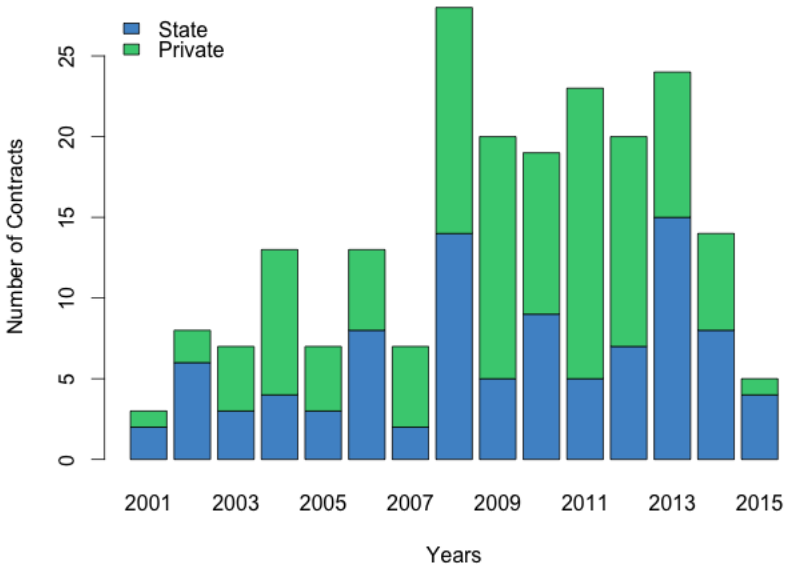

Figure 3.7 State Companies Participation on Contracted Projects
Source: Author

Licenses, 66.7% due to projects and contracts issues, 66.5% due to buying equipment process and 39.2% due to problems on the building phase.

Figure 3.9 shows the average project duration of the transmission projects, highlighting the duration of Execution and issuing Licenses. The Figure shows that the licenses issuing duration represents a significant part of the total during all the analyzed years, and that it was longer than the execution itself in 2011 and 2012. Also, in 2012 projects delayed on average 581 days due to Licenses, and reached the peak of 1012 days on average for project finalization in 2014.

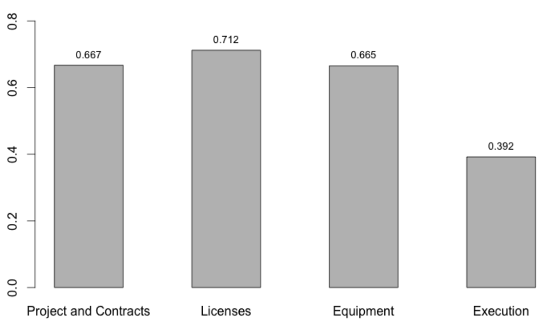

Figure 3.8 Percentage of Companies with Delay in the Project Step
Source: Author

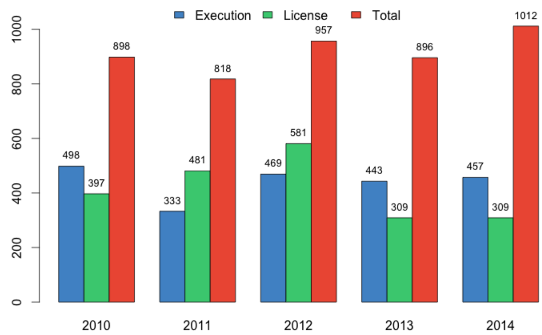

Figure 3.9 Average Project Duration (Days) per Project Step
Source: Author

Project delay can affect auction participation for reasons other than the auctioneer participation policy. The transmission contract establishes that project remuneration will only start after its conclusion.

Therefore, delays direct affect the project cash flow and companies will require higher return rates to accommodate that change. Also, hence capital is stucked in projects it cannot be utilized in others projects, in other words, companies have less liquidity to invest in new projects. So, due to delays, companies can face higher risks and financial capacity restriction.

The power transmission contract requires the winner company to build, maintain and operate the transmission facility. The construction of power lines and substation can request the following steps: topography and environment study, deforestation and area cleaning, land and rock excavation, and construction. These activities require specialized machinery and labor, which can be a source for capacity constraint. Also, the contract set specific schedules for the construction and operation start, varying from 18 to 36 months. These contracts characteristic allow the bidding strategies to be affected by capacity constraint.

Several works assess the impact of capacity constraint in auctions environments (Ashenfelter, 1989; Saini & Suter, 2015, see). Jofre-bonet & Pesendorfer (2000) verifies the presence of capacity constraints and that capacity constrained companies are 50% less likely to submit a bid in the California Highway Auction. Saini & Suter (2015) experimentally assess capacity constraint effects and affirms that it affects bidding behavior, although firms tend to do not fully account for those inter-temporal effects. De Silva *et al.* (2005) utilizes the companies backlog as proxy to infer capacity utilization.

We define *backlog* as the number of not finalized projects, in a specific date, hold by a company. Our hypothesis is that bidders are accounting for projects not finalized in the day the new project is supposed to start, not the numbers of projects in the day of the auction. Figure 3.10 shows the average number of submitted bids per auction in each year. We classified bidders by the following backlog intervals: [0, 4], [5, 9],[10, 15].

Until 2007 all bidders have maximum of 4 projects in execution, from 2008 companies with at least 5 projects start participating more often and represent a significant part of the total number of bids, representing almost 50% in the first auction of 2015. Moreover, between 2009 and 2013 even companies with more than 10 participated in the auction.

Figure3.11 presents the number of projects won by companies in categories of backlog level. The figure shows that, despite the small participation rate, companies with more than 5 unfinished projects won several projects, overcoming companies with less than 5 projects in 2009, 2011, and 2012.

The auction participation could have been affected by another government policy that lead to an increase in the regulatory risk. In 2012 the ANEEL established new procedures in the market and defined new indemnity for not yet amortized investments. According to Bragança *et al.* (2015) the change in the market produced a significant and persistent risk increase in the market.

As a natural reaction to the perception of higher regulatory risk, investors can require higher return rates, or in an auction framework, it may require higher Revenue Cap. For that matter and to enhance contracts atractivity, the Revenue Cap should be, in some degree, sensitive to changes in the regulatory risk perception. Nevertheless, the regulatory risk and several auction characteristics are not included in the

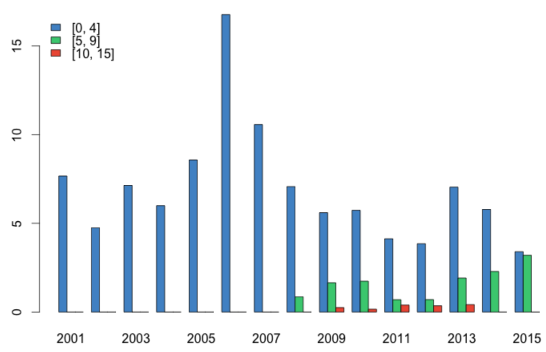

Figure 3.10 Evolution of Number of bids per auction by Backlog levels
Source: Author

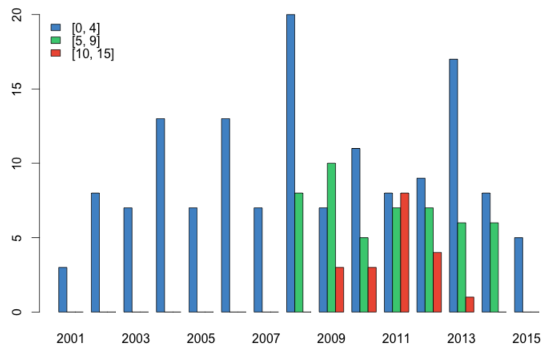

Figure 3.11 Number of Victories by Backlog levels
Source: Author

method ANEEL utilizes to set the Revenue Cap. The regulator describes its method in Aneel (2015b).

One of the main characteristics of the BTA is not properly included in the methodology for setting the RC, its repeated auction framework. Although the auction clearly follows this structure, the method considers it as an one-shot game. This simplification prompts to the not inclusion of issues like synergies effects between objects or capacity constraint faced by competitors. Furthermore, for not allowing the Revenue Cap to adjust to the auction environment, the auctioneer may incur in errors and not achieve expected results.

For definition, the Revenue Cap is the maximum the auctioneer is willing to pay for a specific service. So, the Revenue Cap should also signal the auctioneer's preference about the object, as its importance for the system reliability and for assuring electricity supply.

3.3 Conclusion

Besides the initial success of the Brazilian Transmission Auctions, several cases of contracts non-allocation emerged in a later phase. While the former contracts could often find several bidders, the later ones saw a drastic decrease in the number of bidders, reaching the extreme of no bidders at all and therefore a striking case of auction failure. These cases revealed the regulator's inability to keep the projects atractiviness, in despite of the several plans to develop the transmission grid.

Recognizing its failure, the ANEEL used two different procedures to enhance project attractivity for relaunch: 1- Raise of the Revenue Cap; 2- Change in the project composition, bundling and/or separating structures included in a contract. Again, some contracts found a positive result while others did not, suggesting that the changes were not deep enough in some cases. it is worth noting that besides successfully contracted, some projects found only one bidder in opposition to a desired auction with high degree of competition.

We conclude that policy makers should stimulate the participation in the auction and, specially mitigate the factor that may reduce it as: the participation rule, regulatory risk, capacity constraint (financial constraint and environmental licenses). Therefore, the ANEEL should introduce the interdependency and capacity constraint into the Revenue Cap specification method, specially when a fast expansion is required. By not doing so, the capacity constraint can direct affect companies interest on projects. This issue can be even more notorious in a market with a small pool of companies. Also, the auctioneer should obtain environmental licenses before the auction, mitigating a strong source of delays and risk and, therefore, preventing the raise in firm's capacity constraint.

3.4 Appendix

Table 3.1 First Contracting Attempt

ID	Auction	Project	RP	Reason	Location	Extension (KM)	Substation	Technology (KV)	Cutoff (Months)
1	003/2001	D	R$9.804.540,00	Empty	PA	179	0	230	24
2	001/2006	A	R$66.118.680,00	Removed	MT/RO	-	-	-	18
3	001/2006	B	R$56.073.530,00	Removed	MG/SP	-	-	-	22
4	001/2006	C	R$38.422.490,00	Removed	MG/SP	-	-	-	22
5	001/2006	D	R$17.949.780,00	Removed	MG	-	-	-	18
6	001/2006	E	R$8.736.260,00	Removed	BA	-	-	-	18
7	001/2006	F	R$7.338.760,00	Removed	ES	-	-	-	18
8	001/2006	G	R$8.707.570,00	Removed	PR	-	-	-	20
9	006/2008	D	R$9.074.790,00	Empty	RS	81	0	230	18
10	008/2010	D	R$12.860.250,00	Removed	PR	130	1	230	24
11	008/2010	E	R$2.727.120,00	Removed	GO	50,5	0	230	18
12	006/2011	C	R$1.988.950,00	Removed	AM	30	0	230	20
13	003/2012	D	R$8.816.000,00	Removed	MG	78	0	500	22
14	007/2012	H	R$25.969.920,00	Removed	AC	657	2	230	36
	001/2013	E	R$54.661.170,00	Empty	SP/PR	399	0	500	36
15	001/2013	F	R$38.963.870,00	Empty	SP	241	1	500	30
	001/2013	J	R$39.051.190,00	Empty	SP	207	2	500	30
16	001/2013	D	R$2.522.940,00	Empty	GO	69	0	230	22
17	002/2013	G	R$10.648.300,00	Empty	MA	203	1	230	30
18	007/2013	Q	R$1.864.480,00	Empty	SP	0	1	345	36
19	007/2013	O	R$3.500.120,00	Removed	CE	65	1	230	22
20	007/2013	L	R$1.864.480,00	Removed	RO	0	1	230	24
21	007/2013	H	R$1.928.840,00	Empty	PA	0	1	230	24
	007/2013	J	R$7.327.720,00	Empty	MG	0	2	230	24
22	001/2014	L	R$15.312.180,00	Empty	MG	191	1	230	36
	007/2014	B	R$183.537.503,00	Removed	MG	717	3	500	36
23	001/2014	J	R$5.516.700,00	Empty	MA/PI	95	0	230	36
24	001/2014	I	R$21.652.470,00	Empty	MT	262	3	500	36
25	001/2014	H	R$33.591.630,00	Empty	PA	136	1	500	42
26	001/2014	A	R$38.745.780,00	Empty	PA	436	1	230	36
27	004/2014	I	R$5.212.075,54	Empty	PA	0	1	230	31
28	004/2014	G	R$28.796.174,58	Empty	TO	90	2	500	31
29	007/2014	J	R$3.054.178,00	Empty	GO	0	1	500	24
30	007/2014	H	R$12.614.597,00	Removed	RS	158	0	230	36
31	007/2014	C	R$125.125.967,00	Removed	SC	484,5	1	525	36
	007/2014	E	R$20.807.139,00	Removed	RS/SC	152	1	230	36
32	007/2014	D	R$32.917.214,00	Removed	AL/PE/SE	307	0	500	36

Table 3.2 Second Contracting Attempt

ID	Auction	Project	RP	RP %	Contracted	Object Change	Registered	N. Bids	Cutoff (Months)
1	002/2002	D	R$12.895.690,00	31,53%	Yes	No	3	3	20
2	005/2006	A	R$66.118.680,00	0,00%	Yes	No	10	10	18
3	005/2006	B	R$56.073.530,00	0,00%	Yes	No	9	9	22
4	005/2006	C	R$38.422.490,00	0,00%	Yes	No	9	8	22
5	005/2006	D	R$17.949.780,00	0,00%	Yes	No	9	6	18
6	005/2006	E	R$8.736.260,00	0,00%	Yes	No	13	8	18
7	005/2006	F	R$7.338.760,00	0,00%	Yes	No	13	10	18
8	005/2006	G	R$8.707.570,00	0,00%	Yes	No	13	7	20
9	001/2009	A	R$9.896.316,26	108,02%	Yes	Separated	9	4	20
	001/2009	B	R$8.981.176,53		Yes	Separated	10	1	24
10	004/2011	E	R$9.167.260,00	-28,72%	Yes	No	8	1	24
11	004/2011	D	R$3.235.160,00	18,63%	Yes	No	6	2	24
12	002/2012	C	R$7.779.310,00	291,13%	Yes	Expansion	4	2	20
13	005/2012	F	R$9.135.910,00	3,63%	Empty	No	4	0	22
14	002/2013	A	R$32.953.840,00	26,89%	Empty	No	5	0	36
15	007/2013	A	R$174.447.720,00	31,48%	Yes	Merged	4	1	48
16	007/2013	D	R$3.066.690,00	21,55%	Yes	No	9	2	30
17	007/2013	M	R$16.650.500,00	56,37%	Removed	Expansion	-	-	30
18	001/2014	C	R$30.383.460,00	1529,59%	Yes	Expansion	3	1	36
19	013/2013	D	R$8.288.080,00	136,79%	Yes	No	5	1	22
20	013/2013	B	R$1.892.225,00	1,49%	Empty	No	4	0	24
21	001/2014	B	R$102.161.430,00	5196,52%	Yes	Expansion	4	2	42
22	004/2014	D	R$52.535.460,18	132%	Empty	Merged	5	0	37
23	007/2014	G	R$15.920.717,00	188,59%	Removed	Expansion	-	-	36
24	004/2014	C	R$165.702.651,39	665,28%	Empty	Expansion	5	0	37
25	Not relaunched								
26	004/2014	B	R$65.311.636,90	68,56%	Empty	No	3	0	43
27	Not relaunched								
28	001/2015	I	R$40.669.044,00	41,23%	Empty	No	2	0	36
29	001/2015	K	R$21.123.287,99	591,62%	Yes	No	3	2	36
30	001/2015	J	R$17.743.999,93	40,66%	Yes	No	2	1	36
31	001/2015	E	R$218.348.404,44	49,62%	Empty	Merged	2	0	48
32	001/2015	F	R$98.537.258,78	199,35%	Empty	Expansion	2	0	42

Table 3.3 Third Contracting Attempt

ID	Auction	Project	RP	RP %	Contracted	Object Change	Registered	N. Bids	Cutoff (Months)
13	007/2013	C	R$11.539.910,00	26,31%	Removed	No	-	-	36
14	007/2013	N	R$38.913.860,00	18,09%	Yes	No	4	1	36
17	013/2013	C	R$17.063.980,00	2,48%	Yes	No	7	1	24
20	007/2014	F	R$28.380.584,00	1399,85%	Empty	0	1	0	28
22	001/2015	A	R$387.739.142,06	64%	Empty	Merged	1	0	48
23	001/2015	G	R$28.355.645,37	78,11%	Empty	Checar	2	0	
24	001/2015	B	R$234.162.214,23	70%	Empty	Separated	3	0	48
	001/2015	C	R$48.290.038,81		Empty	Separated	3	0	48
26	001/2015	D	R$119.083.697,68	82,33%	Yes	No	2	1	48
28	Not relaunched								
31	Not relaunched								
32	Not relaunched								

Fourth Contracting Attempt

ID	Auction	Project	RP	RP %	Contracted	Object Change	Registered	N. Bids	Cutoff (Months)
13	013/2013	A	R$11.539.910,00	0,00%	Yes	No	4	1	36
20	001/2015	H	R$96.116.617,30	238,67%	Yes	Expansion	4	1	42
22	Not relaunched								
23	Not relaunched								
24	Not relaunched								

CHAPTER 4

Brazilian Power Transmission System: Expansion Challenges

Abstract

The Brazilian Power Transmission Sector faced an intense expansion in the last decade. Since 2001 more than 61.000 km of power lines was contracted. Winning the auction for the project is only the initial step for the company. In this paper we study what happens after the projects are contracted. Is the Power Transmission Expansion carried as planned by the government, so it can ensure electricity supply? More specifically, what are the differences between the planned and executed expansion? How is it evolving? We conclude that the transmission sector is facing a management issue as the government has difficulties to contract and the contracted projects are not usually delivered in time. We verify a significant and increasing gap between the planned and the executed projects.

Keywords: Power Transmission; Electricity Sector Planning; Project Delay; Brazilian Environmental Licensing

4.1 Introduction

Since 2001 more than 61.000 km of power lines was built and high discounts on initial prices was obtained. In spite of that, the system expansion *per si* is not the ultimate government goal, which seeks to ensure the electricity supply. In this paper we review the expansion plans of the power transmission sector and analyze how is the expansion implementation evolving after the contracts are auctioned.

In the late 90s, the Brazilian Electricity System went through a deep reform with the goal of promoting competition and, therefore, enhancing power supply, reasonable prices and country-wide access to electricity. The need of a reform was clear by the end of decade when the country suffered blackouts and power rationing.

In this paper we aim to answer the questions: Is the Power Transmission Expansion carried as planned by the government, so it can ensure electricity supply? More specifically, what are the differences between the planned and executed expansion and how is it evolving?

We conclude that the transmission sector is facing a management issue as the government has difficulties to contract and the contracted projects are not usually delivered in time. We verify a significant and increasing gap between the planned and the executed projects. Furthermore, the participation policy, designed to combat the average delay, may affect the expansion through the allocation phase.

4.1.1 Auctions

As mentioned in the previous chapter, starting in the auction 007/2012, the ANEEL decided to restrict the participation of companies with long delays in the construction of previous contracts. Companies with more than 180 days of average delay in the construction schedule or with more than 2 delay notifications would be restricted from competing. The decision intended to avoid those companies to add new projects to its backlog and therefore to retard the grid expansion even more. Figure 4.1 shows the number of days delayed per company at 09/31/2012 and the red line represents the 180 days participation criteria for auction 007/2012. Figure 4.2 shows the number of notifications for the same auction.

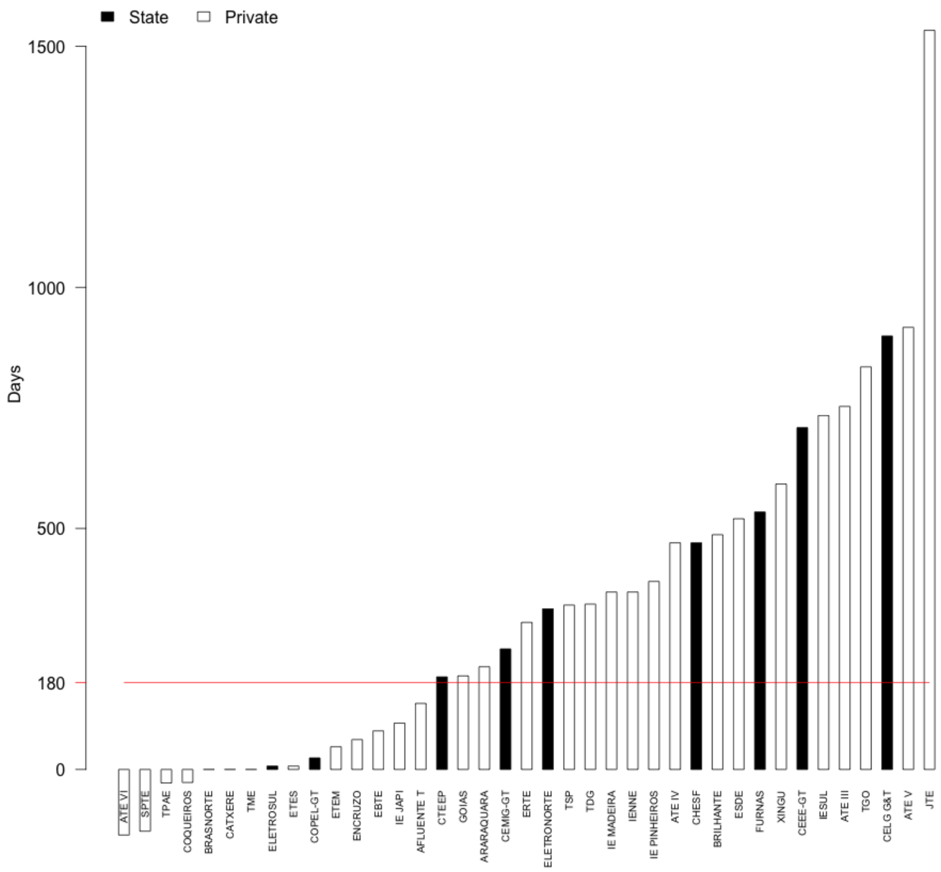

Figure 4.1 Average Delay (Days)
Source: Author

By imposing this new rule, the auctioneer reduced the pool of eligible companies and possibly[1] the number of competitors for the objects. More specifically, the participation rule removed several state companies from this pool. Black bars on figure 4.1 represent state companies.

Although the majority of upcoming companies was private, the state owned companies have a significant representation among the auctioned projects. State companies have been related to aggressive

[1] we can't confirm that this rule was the only responsible for the reduction of competition in the auctions, as the facts described bellow could also have affected it.

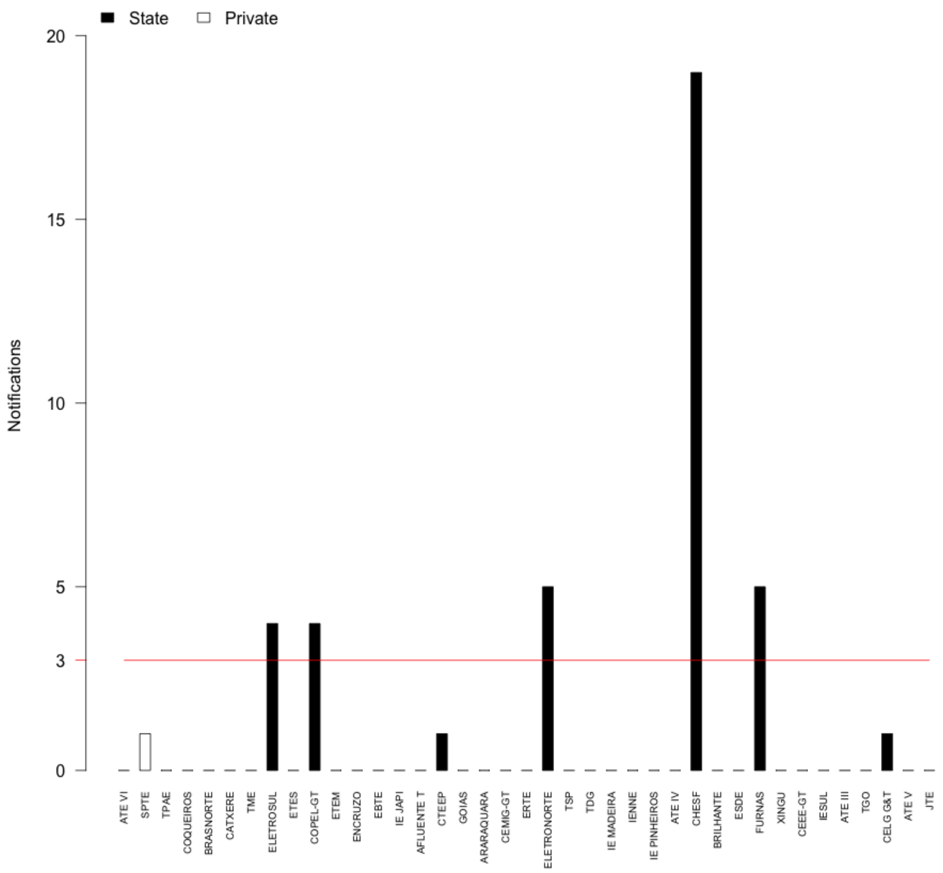

Figure 4.2 Number of Infractions Notifications
Source: Author

bidding by Rocha (2007) in the BTA. Indeed between 2001 and 2015[2] state companies won 116 projects out of 211, representing a significant participation in the grid expansion. Figure 4.3 shows the percentage of contracts won by state companies along the years and the number of auctioned projects by year.

Figure 4.4 shows the main delay reasons on transmission projects. According to SFE (2015), in the last 5 years more than 71.2% of the transmission projects have retarded schedule due to Environmental Licenses, 66.7% due to projects and contracts issues, 66.5% due to buying equipment process and 39.2% due to problems on the building phase.

Figure 4.5 shows the average project duration of the transmission projects, highlighting the duration of Execution and issuing Licenses. The Figure shows that the licenses issuing duration represents a significant part of the total during all the analyzed years, and that it was longer than the execution itself in 2011 and 2012. Also, in 2012 projects delayed on average 581 days due to Licenses, and reached the peak of 1012 days on average for project finalization in 2014.

As previously mentioned the auctioneer Revenue Cap can be strategically modified and/or be affected by external variables, therefore resulting in changes in the projects return. The Revenue Cap by

[2] auction 001/2015

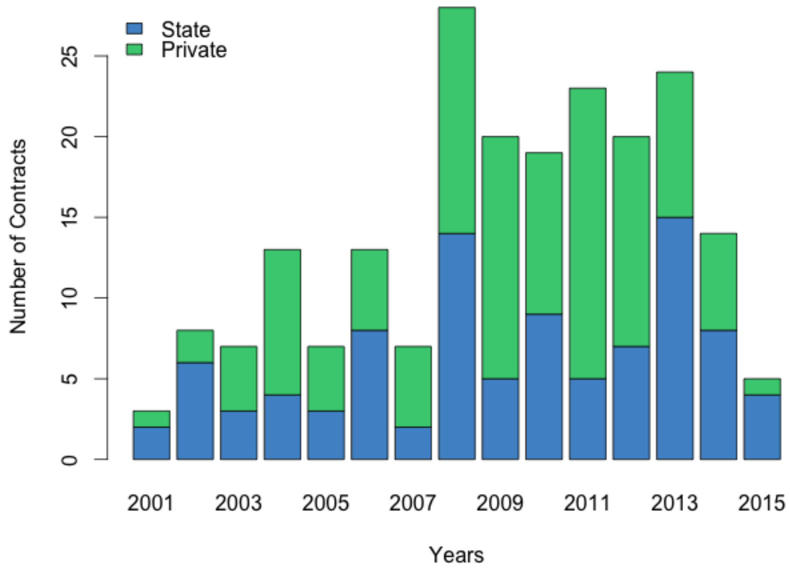

Figure 4.3 State Participation on Contracted Projects
Source: Author

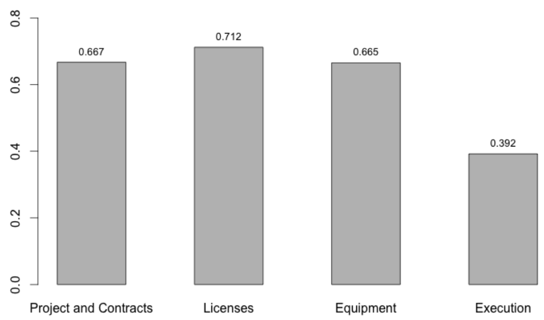

Figure 4.4 Percentage of Projects Delayed in Each Phases
Source: Author

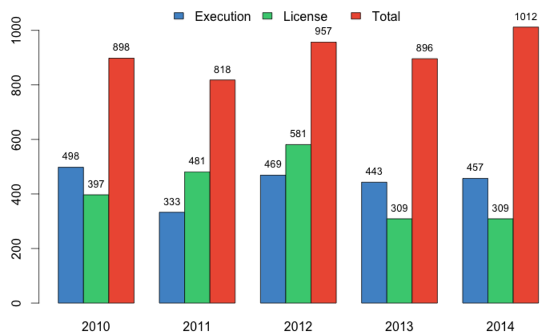

Figure 4.5 Evolution of Average Delay (Days)
Source: Author

Investment ratio can be used as a return measure. The Figure 4.6 shows the variable pattern along the years. Although before and after 2007 periods are not comparable[3], a reducing pattern can be seen in both of it, followed by a raise in 2014. The Figure also highlights that the number of not contracted projects gets significantly higher since 2012.

Environmental License

According to SFE (2015) there are three licenses to fulfill the environmental requirements: the

[3]Up to 2007 the bid was the company revenue until the 15th year, after that the revenue was reduced to 50% of the bid. From 2008 this rule changed and the annual revenue is the company bid for the contract extent.

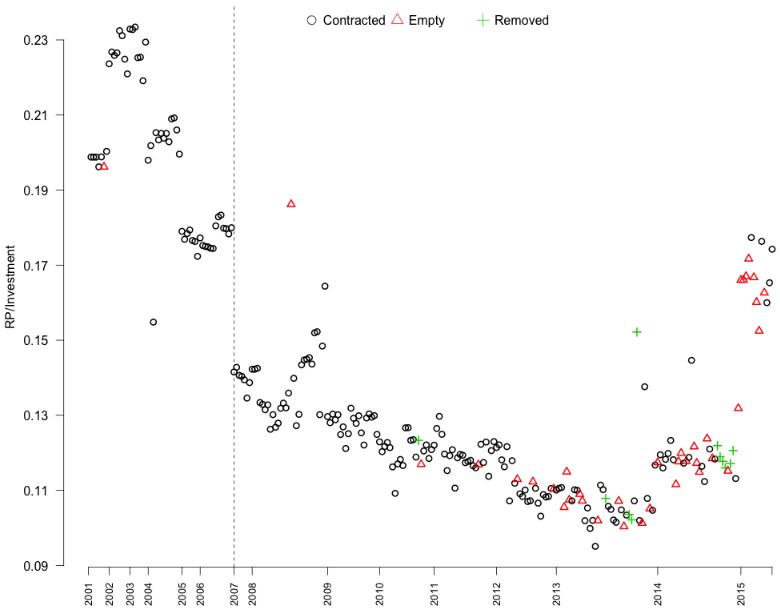

Figure 4.6 Ratio Price Cap by Investment
Source: Author

Initial License (LicenÃ§a PrÃ©via in Portuguese), the Construction License (CL) and the Operation License (OL). The second one has the potential to delay the infrastructure implementation as the construction cannot start before the CL is issued. The OL expedition, otherwise, usually happens close to the end of the construction and is required for the line operation.

The environmental licensing may occur in three ways: based on a "simplified environmental report" (Relatório de ambiental simplificado); based on an "environmental assessment report" (relatório de avaliação ambiental); or based on an "environmental impact study" (estudo de impacto ambiental) and associated "environmental impact report" (relatório de impacto ambiental) (Júnior *et al.* , 2014).

The IBAMA decides the way the licensing may occur depending on the project complexity and what can be affected, what can require the participation of other institutions, as presented in table 4.1.

Júnior *et al.* (2014) also claims that both the construction license and the authorization to suppress vegetation should be jointly issued, as the first phase for the construction is clearance of vegetation along the route.

4.2 Expansion delays

To further evaluate issues related to the delays, we utilize Transmission Projects Monitoring Reports (TPMR), issued by the ANEEL between Sept 2015 and Sept 2016. We accessed the system between the 11th and the 13th of each month in this period, excluding October 2015, January 2016 and August 2016. The report is automatically generated and presents all the ongoing transmission project in the date of access, based on the

Table 4.1 Actor involved in environmental licensing

Actors involved in environmental licensing	Main attributions
Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA)	Federal environmental agency, with responsibility for licensing of undertakings that involve more than one state;
State Environmental Agencies	Responsible for environmental licensing of projects that only involve one state;
National Indian Bureau (FUNAI)	Responsible for overseeing actions and projects that can affect indigenous peoples;
Palmares Cultural Foundation	Responsible for preserving the heritage and socioeconomic viability of quilombolas;
National Institute of Historic and Artistic Heritage (IPHAN)	Responsible for managing and preserving historic and cultural heritage (e.g., archeological sites);
Health Surveillance Secretariat	Entity of the Ministry of Health responsible for minimizing the incidence of communicable diseases, such as malaria and dengue fever;
Chico Mendes Biodiversity Institute (ICMBIO)	Responsible for managing federal conservation units (protected forest areas - Law 9985/2000).

Source: Júnior *et al.* (2014) (*Adapted*)

updated data in the SIGET. The collected data includes the due date of the project, the conclusion forecast and the project status: advanced, regular or delayed.

The table 4.2 shows the percentage of contracts in each status along the analyzed period. it is clear that the percentage is mostly unchanged along the period for all status, with a small decrease of the *In Advance* projects and increase of the *Delayed* projects. This pattern is explained by the simple fact that projects ahead of schedule tend to conclude before the delayed projects. The table also shows the number of conclusions and inclusions in the period, justifying the decreasing number of expansion projects.

Table 4.2 Number of Monitored Projects by Status Along the Period

Status		Sept 15	Nov 15	Dec 15	Feb 16	Mar 16	Apr 16	May 16	Jun 16	Jul 16	Sept 16
# of Projects		373	363	352	340	342	339	344	347	325	342
In Advance		9%	10%	10%	8%	7%	9%	8%	6%	6%	6%
Regular		28%	27%	28%	31%	32%	32%	31%	33%	29%	30%
Delayed		63%	64%	63%	61%	61%	59%	61%	61%	66%	64%
Conclusions	#		22	16	23	13	9	10	17	13	15
	%		6%	5%	7%	4%	3%	3%	5%	4%	4%
Inclusions	#		12	5	11	15	6	14	20	1	22
	%		3%	1%	3%	4%	2%	4%	6%	0%	6%

Source: Author

The table 4.3 shows an interesting pattern about the expansion projects status. The first series presents the number of projects that was *Delayed* in the previous report and became either regular or ahead of schedule. The second series presents exactly the opposite, the number of projects that was ahead of schedule or regular and became delayed. The difference of the two series shows that there is an inflow of companies into the delayed status.

Table 4.3 Number of Changes in Project Status: Out of and Into *Delayed* Status

Comparing to Projects in	Status Change	Nov 15	Dec 15	Feb 16	Mar 16	Apr 16	May 16	Jun 16	Jul 16	Sept 16
t-1	Out of	1	1	1	0	2	0	1	0	6
		0,43%	0,43%	0,45%	0,00%	0,96%	0,00%	0,47%	0,00%	2,79%
	Into	10	5	5	8	3	15	7	14	15
		7,25%	3,79%	3,82%	6,11%	2,24%	10,87%	5,26%	10,29%	12,50%
Sept 15	Out of	1	0	1	0	1	0	1	0	5
		0,43%	0,43%	0,43%	0,00%	0,85%	0,00%	0,43%	0,00%	2,55%
	Into	10	5	5	5	3	8	7	11	10
		7,25%	3,62%	3,62%	5,80%	2,17%	10,87%	5,07%	10,14%	10,87%

Source: Author

The reported expansion projects can be separated in two different groups according to how the regulator requested it. The regulator can either require the expansion of a specific facility to its operator or can auction a expansion project. While the former usually features small expansions or adjustments in a facility, the later is associated to more significant grid expansions. In the table 4.4 we present the number of projects by status and type. it is noticeable that although the expansion types have significant different characteristics, it still have similar status representation.

Table 4.4 Number of Projects by Status and Type

	Total	Delayed	Regular	Advanced
New Concession	1194	61%	29%	10%
Additional to Concession	2283	63%	31%	7%
Total	3477	62%	30%	8%

Source: Author

Despite the similarity of status frequency, the expansion types presents significantly different average monthly delay. The table 4.5 presents the average increases in the conclusion date forecast. For instance, the first column shows that, in relation to Sept 15, the conclusion date of the auctioned projects increased in 33 days in average while in 14 days for the other type. it is noticeable that the auctioned expansions consistently expands its conclusion date longer than the adjustment expansions. This pattern can be related the sizes of the expansions, as the bigger auctioned expansions are more likely to suffer from a delay, due to its complexity, size and length.

it is worth mentioning that the average delay increases[4] over time, in despite of the decreasing number of monitored projects. To check if the increase is the result of a general increase in the delay or if few cases are driving the results, we removed the contracts with extreme increase between May and Jun. We verify that all results still holds, excluding the hypothesis that few cases are driving the results.

[4]see table 4.2

Table 4.5 Average Monthly Delay by Project Type (Days)

	Sept 15	Nov 15	Dec 15	Feb 16	Mar 16	Apr 16	May 16	Jun 16	Jul 16	Sept 16
New Concession										
All Projects										
Avg Delay	498	522	536	566	568	575	598	778	809	806
Increase		33,12	14,79	24,95	11,50	10,78	27,97	151,83	33,71	19,28
		7%	3%	5%	2%	2%	5%	25%	4%	2%
Holding Projects in Sept 15										
Avg Delay	498	523	540	567	586	593	619	820	862	864
Increase		33,13	15,11	25,86	12,92	11,08	25,77	168,28	37,40	8,81
		7%	3%	5%	2%	2%	4%	27%	5%	1%
Additional to Concession										
All Projects										
Avg Delay	434	450	466	471	484	473	500	508	516	518
Increase		14,88	7,34	15,82	9,89	14,21	38,12	20,39	18,76	12,63
		3%	2%	3%	2%	3%	8%	4%	4%	2%
Projects in Sept 15										
Avg Delay	434	455	479	503	521	535	574	618	643	671
Increase		14,88	13,10	16,39	10,30	15,57	37,66	25,56	22,68	15,84
		3%	3%	3%	2%	3%	7%	4%	4%	2%

Source: Author

To analyze the Average Monthly Delay for the auctioned expansions, we match the expansion data in TPMR with data of auction environment and company characteristics. We extract the quantiles of several variables based on the full sample of transmission auctions[5], then categorize the expansion projects in the quantiles and plot the monthly increase on the average delay.

For the figure 4.7, we categorize the projects by quantiles of Revenue Cap. The figure 4.8 presents the monthly increase in the average delay of projects, categorized by quantiles of line Extension. The line Extension and the Price Cap are closely related and both can be used as measures of the size and complexity of a project. Therefore, we expect that the delay increase tend to be bigger for higher Revenue Cap and for longer Extensions.

The figure 4.7 shows that the estimated average increase in the delay for the first quantile is statistically different from the third and fourth quantile. This result are in line with the expected positive correlation between the increase of the average delay and the project size and complexity. Moreover, the differences in the increase of average delay between *Concessions* and *Additions to Concessions* projects can likely be associated to this positive relation, as the size and complexity are the major differences between the two types of projects.

Although we consider the power line extension a better proxy for the project size and complexity, the averages for the analyzed sample, shown in figure 4.8, doesn't support the expected positive relation.

[5]We observed all transmission auctions until the auction 001/2015.

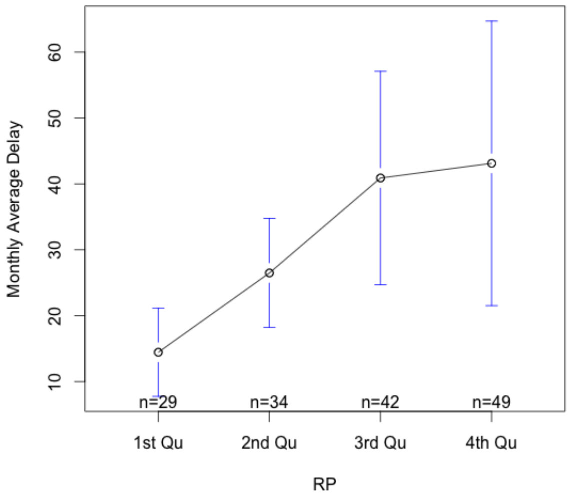

Figure 4.7 Average Monthly Delay by Price Cap Quantile
Source: Author

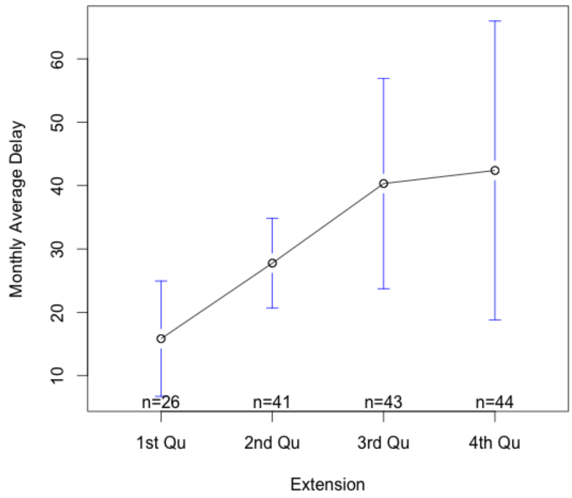

Figure 4.8 Average Monthly Delay by Extension Quantile
Source: Author

The figure 4.9 plot the average delay separating the projects by location. No significant difference is observed between regions. Here again, it may be the result of the sample selection.

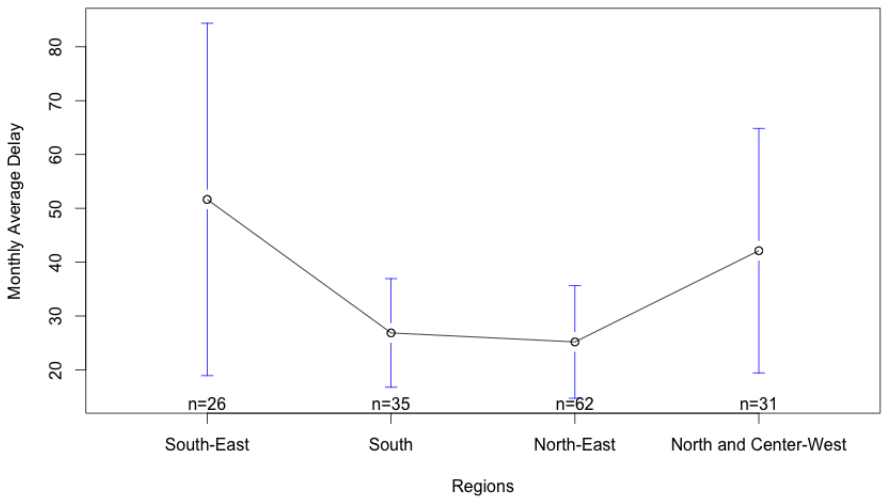

Figure 4.9 Average Monthly Delay by Region
Source: Author

The power transmission contract requires the winner company to build, maintain and operate the transmission facility. The construction of power lines and substation can request the following steps: topography and environment study, deforestation and area cleaning, land and rock excavation, and construction. These activities require specialized machinery and labor, which can be a source for capacity constraint. Also, the contract set specific schedules for the construction and operation start, varying from 18 to 36 months. These contracts characteristic allow the bidding strategies to be affected by capacity constraint.

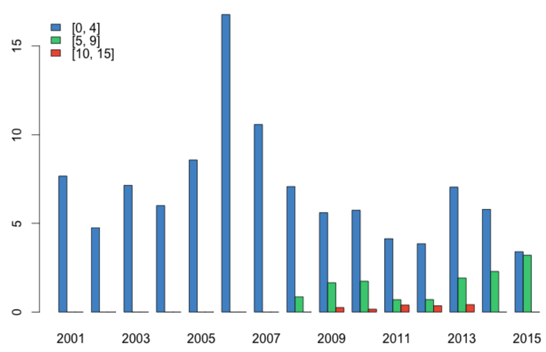

Figure 4.10 Number of bids per auction by Backlog levels
Source: Author

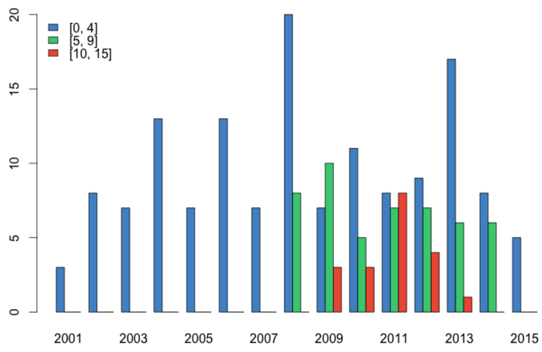

Figure 4.11 Number of contracted projects by Backlog level
Source: Author

Project delay can affect auction participation for reasons other than the auctioneer participation policy. The transmission contract establishes that project remuneration will only start after its conclusion. Therefore, delays direct affect the project cash flow and companies will require higher return rates to accommodate that change. Also, hence capital is stucked in projects it cannot be utilized in others projects, in other words, companies have less liquidity to invest in new projects. So, due to delays, companies can face higher risks and financial capacity restriction.

Several works assess the impact of capacity constraint in auctions environments (Ashenfelter, 1989; Saini & Suter, 2015, see). Jofre-bonet & Pesendorfer (2000) verifies the presence of capacity constraints and that capacity constrained companies are 50% less likely to submit a bid in the California Highway Auction. Saini & Suter (2015) experimentally assess capacity constraint effects and affirm that it affects bidding behavior, although firms tend to do not fully account for those inter-temporal effects. De Silva *et al.* (2005) utilizes the companies backlog as proxy to infer capacity utilization.

We define *backlog* as the number of not finalized projects, in a specific date, hold by a company. Our hypothesis is that bidders are accounting for projects not finalized in the day the new project is supposed to start, not the numbers of projects in the day of the auction. Figure 4.10 shows the average number of submitted bids per auction in each year. We classified bidders by the following backlog intervals: [0, 4], [5, 9],[10, 15].

Until 2007 all bidders have maximum of 4 projects in execution, from 2008 companies with at least 5 projects start participating more often and represent a significant part of the total number of bids, representing almost 50% in the first auction of 2015. Moreover, between 2009 and 2013 even companies with more than 10 participated in the auction.

Figure 4.11 presents the number of projects won by companies in categories of backlog level. Figure B shows that despite the small participation rate, companies with more than 5 unfinished projects won several projects, overcoming companies with less than 5 projects in 2009, 2011, and 2012.

Among the delayed contracts, it is worth mentioning the case of the Spanish company Abengoa that declared bankrupt. What makes this case relevant is that the company won important contracts to expand the connection between different regions of the country, some of the lines should delivery power from new wind and solar power plants in the north-east region and from the Belo Monte hydro power plant. As a result, according to ONS (2016) the lack of this grid expansion can highly impact the power delivery from those power plants between 2016 and 2020.

There are several other issues related to the delays, as the price difference between regions, the cost of related projects that cannot connect to the grid and start being in use (while the government needs to start making payments), system reliability, power supply, new planning efforts and re-contracting the projects. The last one can be specially high when the auctions face a high failure rate.

For the Abengoa case, ONS (2016) has made an specific study to evaluate its impact. To minimize the damage, the report suggests that some infrastructure under the Abengoa responsibility that must be recontacted. Furthermore, it also highlights projects that should be closely monitored due to the risk of bigger damage to the system in case of delays.

According to Aneel (2015a), to reduce the number of delays incidents and the impact to the system, the ANEEL closely follows several of the ongoing projects. The projects are selected according to its system impact risk, i.e., to its forecast delay, the importance to the system, the need of environmental licenses and the importance of related power generation plants.

According to Energia (2016) the ANEEL invited wind power investors to participate in the power transmission auctions, specially for contracts directly connected to power plants. The gesture is an attempt to attract foreign investors to the sector and increase the contracting rate of the previous auctions.

4.3 Conclusions

After going through a quick expansion, it is clear that the Brazilian transmission system faces a management issue: the government doesn't succeed in contracting the necessary projects and a significant part of the contracted ones face long delays. Furthermore, there is an increasing delay on the already contracted projects, which means the actual system is getting much behind of what was planned.

Independent of the agency procedures, the long delay experienced by the grid expansion could be even more impactant. The effects were potentially minimized by the recent smaller power demand[6], induced by the slow economic growth, and the previous system expansion. The later fact, brought gains in system reliability what is notorious in the yearly sequence of the PET reports. While in the first the EPE suggested several expansions for an immediate implementation, the last one (PET 2023) lists projects with longer and more reasonable implementation schedule.

[6] The low power demand prompt to the cancellation of power contracting auction - see MME (2016)

This facts reinforce the notion that todays failure in expanding the system may have a greater impact in the future, specially if the country faces a desired stronger economic growth.

To reduce the effects of the participation policy and attract interested participants to the auctions the government should raise the projects return by raising the price cap, specially when: the biggest "money lender", the BNDES, is restricting its participation on the sector; and several companies are forbidden of participating in the auctions due to project delays.

Furthermore, the environmental bureaucracy, in addition to the low return, may be inducing the competitors to a winners course. To mitigate this possibility, the ANEEL should previously issue the environment licenses before the auction, as it does for power generation plants, and as a matter of lowering the winners risk; Furthermore, it should jointly work with the environmental agency and regulator to align their policies.

Bibliography

Amemiya, T. 1985. *Advanced Econometrics*. Harvard University Press.

Aneel. 2008. *Relatório Aneel 10 anos*. Tech. rept. Aneel, Agência Nacional de Energia Elétrica, Brasília.

Aneel, Agência Nacional de Energia Elétrica. 2015a. *Acompanhamento Diferenciado de Empreendimentos de Expansão da Rede Básica*. Tech. rept. Ministério de Minas e Energia, Brasília, Brazil.

Aneel, Agência Nacional de Energia Elétrica. 2015b (Feb). *Nota Técnica n 27/2015 SRM-SCT-SGT/ANEEL*. Tech. rept. Aneel - Agência Nacional de Energia Elétrica.

Ashenfelter, Orley. 1989. How Auctions Work for Wine and Art. *Journal of Economic Perspectives*, **3**(3), 23–36.

Ashenfelter, Orley, & Genesove, David. 1992. Testing for Price Anomalies in Real-Estate Auctions. *American Economic Review*, **82**(2), 501–05.

Ausubel, Lawrence M., Cramton, Peter, McAfee, R. Preston, & McMillan, John. 1997. Synergies in Wireless Telephony: Evidence from the Broadband PCS Auctions. *Journal of Economics & Management Strategy*, **6**(3), 497–527.

Bragança, Gabriel, Pessoa, Marcelo, & Rocha, Katia. 2015. *Medidas Regulatórias, Volatilidade e Contágio: um estudo dos casos da energia elétrica e das telecomunicações no Brasil*. Discussion Papers 2127. Instituto de Pesquisa Econômica Aplicada - IPEA.

Carlos, Amanda Pimenta, & Saraiva, Joisa Dutra. 2008. Strategic behaviour of winning bids in the brazilian transmission auctions. *In: Anais do XXX Brazilian Econometric Society Congress*.

Castro, N. J. 2006. Leilões de Linhas de Transmissão e o Modelo de Parceria Estratégica Pública-privada. *Revista GTD*, **V. 2**(Out), p. 62–63.

De Silva, Dakshina, Jeitschko, Thomas, & Kosmopoulou, Georgia. 2005. Stochastic synergies in sequential auctions. *International Journal of Industrial Organization*, **23**(3-4), 183–201.

Energia, Canal. 2016. *Governo convoca geradores eólicos para participar de leilões de transmissão*.

EPE, Empresa de Pesquisa Econômica. 2015a. *Plano Decenal de Expansão de Energia 2006 - 2015*. Tech. rept. Ministério de Minas e Energia, Brasília, Brazil.

EPE, Empresa de Pesquisa Econômica. 2015b. *Plano Decenal de Expansão de Energia 2015 - 2024*. Tech. rept. Ministério de Minas e Energia, Brasília, Brazil.

EPE, Empresa de Pesquisa Econômica. 2015c. *Plano Decenal de Expansão de Energia 2024*. Tech. rept. Ministério de Minas e Energia.

EPE, Empresa de Pesquisa Energética. 2007. *Matriz Energética Brasileira 2030*. Tech. rept. Ministério de Minas e Energia.

EPE, Empresa de Pesquisa Energética. 2016. *Nossa História*. Tech. rept. Empresa de Pesquisa Energética.

Fiebig, Denzil. 2007. Microeconometrics: Methods and Applications - by A. Colin Cameron and Pravin K. Trivedi. *The Economic Record*, **83**(260), 112–113.

Francelino, R. C., & Polito, R. 2007. *O Segredo Flamenco*. Brasil Energia, MÃdia Online, 01 Junho de 2007.

Gandal, Neil. 1997. Sequential Auctions of Interdependent Objects: Israeli Cable Television Licenses. *The Journal of Industrial Economics*, **45**(3), pp. 227–244.

Hirota, Heitor Hiroaki. 2006. *O mercado de concessão de transmissão de energia elétrica no Brasil*.

Instituto Acende, Brasil. 2013. *Transmissao de energia sem ideologia*. Tech. rept. O Estado de São Paulo.

Instituto Acende, Brasil. 2015. *O TCU e os atrasos do setor elétrico*. Tech. rept. O Estado de São Paulo.

Jofre-bonet, Mireia, & Pesendorfer, Martin. 2000. Bidding Behavior in a Repeated Procurement Auction. *European Economic Review*, 44.

Jofre-Bonet, Mireia, & Pesendorfer, Martin. 2003. Estimation of a Dynamic Auction Game. *Econometrica*, **71**(5), 1443–1489.

Júnior, Ricardo Abranches Felix Cardoso, Magrini, Alessandra, & da Hora, Antonio Ferreira. 2014. Environmental licensing process of power transmission in Brazil update analysis: Case study of the Madeira transmission system. *Energy Policy*, **67**, 281 – 289.

Klemperer, Paul. 1999 (Jun). *Auction Theory: a Guide to the Literature*. CEPR Discussion Papers 2163. C.E.P.R. Discussion Papers.

Krishna, Vijay. 2002. *Auction Theory*. Academic Press.

Maddala, G. S. 1983. *Limited-Dependent and Qualitative Variables in Econometrics*. Cambridge University Press. Cambridge Books Online.

Milgrom, Paul. 2004. *Putting Auction Theory to Work*. Cambridge University Press.

MME, Ministério de Minhas e Energia. 2016. *MME divulga cancelamento do leilão A-3*.

Motta, L., & Ramos, F. 2011. Efeito estrateǵico sobre os leilões de linhas de transmissão brasileiros: o caso da interdependência. *In: XLIII Simpośio Brasileiro de Pesquisa Operacional*.

ONS, Operador Nacional do Sistema Elétrico. 2016. *Análise do Impacto do Atraso das Obras da Abengoa e Priorização de Obras*. Tech. rept. Ministério de Minas e Energia, Rio de Janeiro, Brazil.

Pitchik, Carolyn, & Schotter, Andrew. 1988. Perfect Equilibria in Budget-Constrained Sequential Auctions: An Experimental Study. *RAND Journal of Economics*, **19**(3), 363–388.

Rasmusen, Eric. 2006. *Games and Information: An Introduction to Game Theory*. 4 edn. Wiley-Blackwell.

Reiss, J., & Schondube, Jens. 2010. First-price equilibrium and revenue equivalence in a sequential procurement auction model. *Economic Theory*, **43**(1), 99–141.

Rocha, Katia, Moreira, Ajax, & Limp, Rodrigo. 2013. Determinantes dos Altos Deságios nos Leilões de Transmissão de Energia Elétrica no Brasil entre 1999-2010. *Revista Brasileira de Economia*, **67**(2).

Rocha, Paulo G. 2007. Leilões para os ativos de Transmissão no Brasil: uma análise da possibilidade de contratação do mercado. *Seminário Nacional de Produção e Transmissão de Energia Elétrica*.

Saini, Viplav, & Suter, Jordan F. 2015. CAPACITY CONSTRAINTS AND INFORMATION REVELATION IN PROCUREMENT AUCTIONS. *Economic Inquiry*, **53**(2), 1236–1258.

Serrato, Eduardo. 2006. *Fronteiras Paramétricas de Eficiência para o Segmento de Trasnmissão de Energia Elétrica no Brasil*.

SFE, Superintendência de Fiscalização dos Serviços de Eletricidade. 2015 (Dec). *Acompanhamento Diferenciado de Empreendimentos de Expansão da Rede Básica*. Tech. rept. Aneel - Agência Nacional de Energia Elétrica.

Silva, Dakshina G. De. 2005. Synergies in Recurring Procurement Auctions: An Empirical Investigation. *Economic Inquiry*, **43**(1), 55–66.

Tozei, Nayara Peneda, Vieira, Wilson da Cruz, & Mattos, Leonardo Bornacki de. 2014. Efeitos da participaç de consórcios nos lances e deságios em leilões de transmissão de energia elétrica no Brasil. *Economia Aplicada*, **18**(03), 91 – 116.