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

Área 4 - Teoria Econômica e Métodos Quantitativos

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Resumo

O Setor Elétrico Brasileiro adotou mecanismos de leilão para alocar projetos de transmissão de energia. Os resultados dos leilões são impactados por interdependência e restrição de capacidade. Inicialmente, nos desenvolvemos um modelo teórico para avaliar essas questões em um ambiente de leilão de procura sequencial. O modelo teórico mostra que a ação conjunta da interdependência e da restrição de capacidade diminui a competitividade dos participantes e o *payoff* do leiloeiro. Utilizando os modelos econometricos *Switching Regression* e *Quantile Regression*, observamos que interdependência e da restrição de capacidade afetam a probabilidade de vitória e o comportamento dos lances. Por fim, sugestões são feitas com base nos resultados obtidos.

Palavras-Chave: Falha nos Leilões, Interdependência, Restrição de Capacidade, Regressão Quantílica, Leilão Sequencial. **JEL: D44, C34, C31**

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. First, 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. Second, 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. **JEL: D44, C34, C31**

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 sector, operating and maintaining structures in the same region can be an 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 failure 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 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   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.

According to EPE (2015) 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 pay-as-bid auction adopted 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: bids start from the first phase best offer and finishes when no company wants to lower the currently offer. The winner then submits a power transmission project and signs a contract for 30 years.

After building, and during the operation phase, the contracted company is punished in case of power transmission failures, and the fine is proportional to the reasons for interruption 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.

There is a remarkable 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 1 shows the discounts and the number of offered contracts evolution along the years.
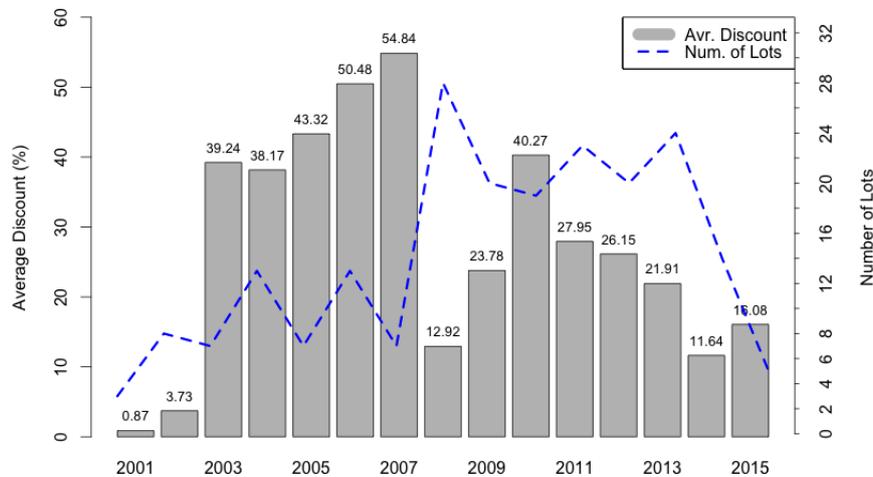

Figure 1: Average Discounts and Number of Contracts per year
Source: Author

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. Castro (2006) shows a model to explain the growing discounts: they are related to the country risk reduction. 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 also be taken in account.

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 bid strategies 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.

3 Interdependency and capacity constraint

According to Pitchik & Schotter (1988), in sequential auctions, objects can be interdependent, mostly 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.

In what concern 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.

ˆ 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.

4   Theoretical model

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 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

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

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 $B \leq R$.

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 $C^0 - \epsilon$. In the second round we have the following

   Round 2

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

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

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

   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 $s'2$: $B_j = C(0) - \epsilon$ in the first round. In such case

   Round 1

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

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

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

The competitors can keep on reducing the first round bid until its final payoff equal zero. Adopting this strategy $s^{\cdot *}$ the auction happens as following

Round 1

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

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

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

$$\boxed{\pi_1 = C(1) - C(0) + \epsilon + C(0) - C(1) - \epsilon = 0, \qquad \pi_2 = 0 + 0 = 0}$$

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 1 shows the expected payoffs related to the available strategies. $[P_1][P_2]$

Table 1: Normal Form Matrix

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

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.

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 $B_1 = C(0) - \epsilon$ while player

2 bids $B_2 = C_2$. The auction result is

Round 1

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

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

Round 2

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

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

Round 3

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

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

Final Payoff

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

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

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

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

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,

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

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

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,

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

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

Suppose player 1 is drawn,

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

Final Payoff

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

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.

4.3 Interdependency and capacity constraint

Now, we add 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.

4.3.1 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

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

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

Round 2

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

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

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

$$\pi_1 = C(1) - C(0) + 0 + R - \epsilon - C(1) = R - \epsilon - C(0)$$
$$\pi_2 = 0 + R - \epsilon - C(0) + 0 = R - \epsilon - C(0)$$
$$\text{Auctioneer:} R - C(1) + R - R + \epsilon + R - R + \epsilon = R - C(1) + 2\epsilon$$

Comparing with the no capacity constraint situation

Δ: Without - With

$$\Delta\pi_1 = 0 - [R - \epsilon - C(0)] < 0, \qquad \Delta\pi_2 = 0 - [R - \epsilon - C(0)] < 0$$
$$\Delta\text{Auctioneer} = 3R - C(0) - C(1) - C(2) + \epsilon - [R - C(1) + 2\epsilon]$$
$$\Delta\text{Auctioneer} = 2R - C(0) - C(2) - \epsilon > 0$$

4.3.2 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

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

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

Round 2

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

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

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

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

Comparing with the extreme high constraint case

Δ: "E. High" - "2 Degrees"

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

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.

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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
  $J_L : C_1 = C(1) \rightarrow B_1 = C(0) - \epsilon \rightarrow \pi_1 = C(0) - \epsilon - C(1) > 0$
  $J_H : C_2 = C(0) \rightarrow B_1 = C(0) \rightarrow \pi_1 = 0$

- In case L loses the second round, the third is
  Round 3
  $J_L : C_1 = C(2) \rightarrow B_1 = C(-1) - \epsilon \rightarrow \pi_1 = C(-1) - \epsilon - C(2) > 0$
  $J_H : C_2 = C(-1) \rightarrow B_1 = C(-1) \rightarrow \pi_1 = 0$

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 $x+C(0)-\epsilon-C(1) \geq C(-1)-\epsilon-C(2)$. 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

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

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

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

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

  $J_H : C_2 = C(1) \to B_2 = C(0) - \epsilon \to \pi_2 = C(0) - \epsilon - C(1) > 0$

- In case L loses round 2

  Round 3

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

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

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

Minimum bid

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

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

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

Round 2

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

$J_H : C_2 = C(0) \to B_2 = C(0) - \epsilon - C(1) + C(-1) - \epsilon \to \pi_2 = 0$

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

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

Player H wants object 1 in case

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

5   Empirical

In this section we assess empirically 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, and interdependency. 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)[1].

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 reports descriptive statistics of the data base.

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

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[1]For further descriptions of the model, see Fiebig (2007)

Table 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

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[2].

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

Before running the Switching regression model, we present OLS estimation for the log(bid) in Table 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 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 adapted 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

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

Table 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

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 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 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 con-

Table 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

tracts 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 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 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 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 **??**. 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 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 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 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 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 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 quantiles, with the exception of the last quantile. The figures 5 and 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.

Table 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*

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.

Table 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.
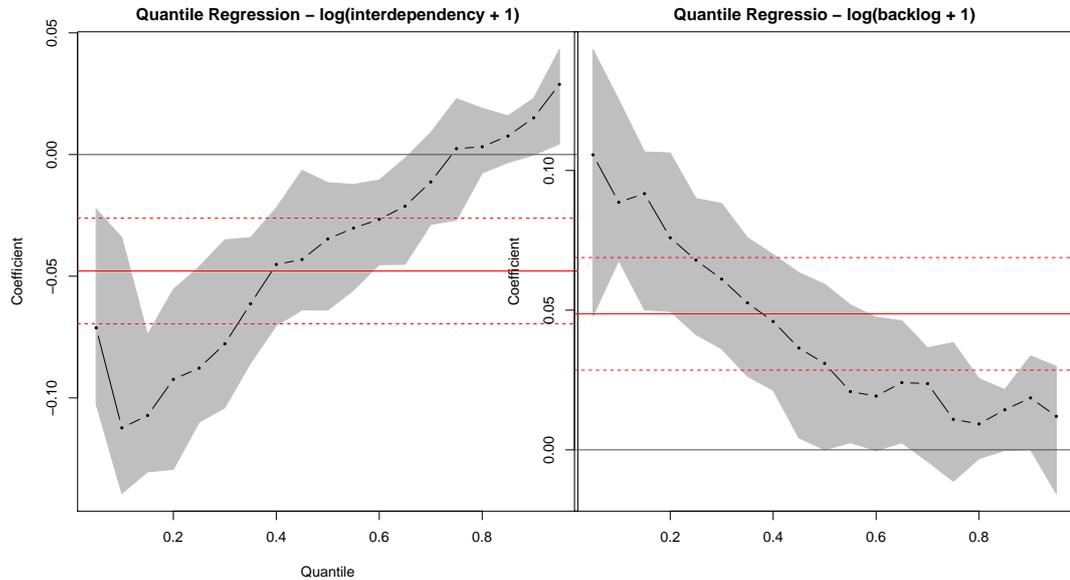
Source: Author

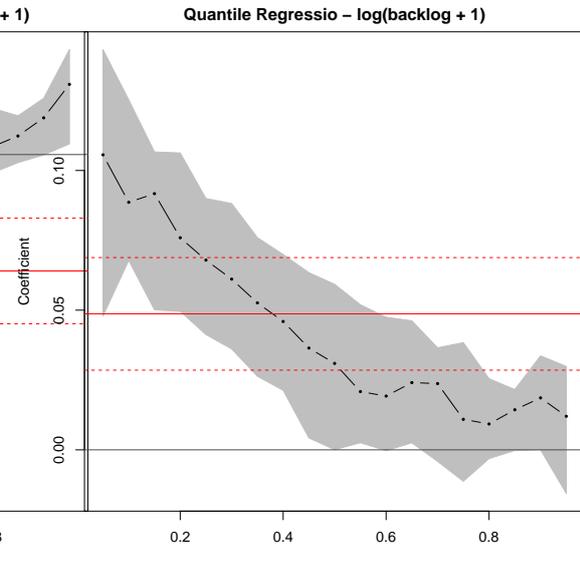Figure 2: Quantile Regression for Interdependency
Source: Author

Figure 3: Quantile Regression for Backlog
Source: Author

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 to the Brazilian trans-

mission 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. Furthermore, the use of the Switching Regression Model reduced the auto-selection bias of the estimations and reinforced the directions of the correlations previously estimated.

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.

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