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LESSONS LEARNED FROM THE AUCTION-BASED APPROACH TO INTEGRATE WIND GENERATION IN THE BRAZILIAN ELECTRICITY MARKET

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SUMMARY

Since 2009 Brazil has been using energy contract auctions to integrate wind energy in its power system. Wind energy has been participating in both technology-specific auctions (where wind plants compete among themselves) and in technology-neutral auctions in which it competes with other technologies, such as natural gas. In the light of a renewed worldwide debate on the role of auctions as a mechanism to foster the development of non-conventional renewable generation (as opposed to other mechanisms, such as administratively-designed feed-in tariffs and/or renewable energy certificates), an in-depth analysis of the Brazilian experience could provide powerful insights for future applications.

The results of the Brazilian auctions have been undeniably impressive: they will be responsible for increasing the wind capacity in the country nine-fold between 2009 and 2016, and has allowed distribution companies to contract this energy at prices as low as 50 US$/MWh. On the other hand, as the commercial operations date for the newly contracted plants approaches, other issues and concerns arise – especially with regards to the possibility of systematic delays and/or underperformance. This paper aims to carry out an unbiased evaluation of the Brazilian auctions' results so far, and to cross-evaluate them with elements of the auction design in order to verify our hypothesis that the policymakers' choices can have a central role in magnifying inherent strengths and weaknesses of the auction scheme.

We expect our analysis to provide valuable insights to the task of designing energy contract auctions, in Brazil or elsewhere.

KEYWORDS

Electricity auctions, renewable generation, wind energy.

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1 INTRODUCTION

1.1 Auctions as renewable energy fostering mechanisms

Auctions aimed at introducing new non-conventional renewable energy (NCRE) generation capacity are not a new concept: some countries (notably the UK, Ireland and France) experimented with such mechanisms in the late 90s, with mixed results [1] [2] . With a lukewarm international reception of these first auction experiences, several countries moved towards other fostering mechanisms – however, despite this early setback, auctions have been growing strongly in popularity in recent years. A "second wave" of interest in NCRE auctions, largely led by emerging countries, has been gaining momentum ([3] [4]) and we may highlight the experience in Brazil, India, China, South Africa, Peru and Uruguay as successful auction-based initiatives for fostering NCRE development.

While each possible choice of instrument for fostering NCRE development has inherent strengths and weaknesses that make them more or less adequate in some circumstances, the authors highlight the important role that instrument design can have in maximizing the policy's impact. In particular, some of the greatest issues met by the NCRE auctions carried out in the '90s – namely, the excessive delays and risk of underbuilding – could potentially be avoided if the auction design imposed more credible and effective enforcement mechanisms, preventing speculators or financially insolvent companies from participating.

The main objective of this paper is to provide an in-depth analysis of the Brazilian experience with wind power auctions, both in terms of design elements and in terms of the results obtained so far, assessing the effectiveness of the choices made by the policymakers. We expect this analysis to provide valuable insights on how to maximize the mechanisms' strengths and minimize its weaknesses, for application in Brazil or elsewhere.

1.2 Why NCRE auctions?

As several countries face a policy-driven need to increase participation of carbon-free electricity generation in their energy mix, a key concern is how to efficiently explore non-conventional renewable resources while ensuring reliability, security of supply, cost efficiency, and timeliness of construction. As it is well-documented in the literature ([5] ,[6]), many different approaches to procure NCRE have been attempted in the past, with three of the most widespread mechanisms being feed-in-tariff (FiT) programs, renewable energy certificate (REC) schemes, and auction mechanisms.

Simply defined, an auction is a selection process designed to procure (or allocate) goods and services competitively, where the allocation is awarded based on financial offers from pre-qualified bidders. When competition is feasible and desirable, auctions have proven to be a very effective mechanism for attracting new players and efficiently matching supply and demand, and they have played major roles in several economic sectors. An auction also increases the competition and transparency of the procurement process, making the resulting obligations less likely to be challenged in the future as the political and institutional landscapes change.

Compared to a feed-in-tariff scheme, an auction-based approach has the benefit of allowing a better price discovery – since setting an adequate FiT level can be a challenge in an environment of rapidly changing technological and economic parameters and incomplete information on the policymakers' side. While FiTs have the advantage of involving lower transaction costs and facilitating the participation of smaller players, the past experience of countries such as Spain and Germany ([7] [8] [9]) has shown that the risk of overshooting the desired expansion target can result in significant costs to society.

Compared to a renewable energy certificate scheme, auction mechanisms have the benefit of offering more stable financial guarantees for investors in NCRE. While the classic economic theory suggests that in the long term RECs would provide correct price signals to reach the desired capacity targets

(much like energy auctions), an auction-based approach could result in a "steadier" NCRE capacity expansion, avoiding boom and bust cycles that could potentially arise [10] .

In general, there is no single instrument of choice to promote NCRE in any given implementation – the one that will prove most adequate tends to be highly context-dependent. This paper aims to evaluate the strengths and weaknesses of the NCRE auction mechanism in a real-world implementation.

1.3 Background: the Brazilian electricity market

It is not the main objective of this paper to provide an extensive review of the Brazilian system – for a more detailed description, the authors direct the readers to [11] and [12] . This section is intended to highlight the main aspects that have motivated the choice of Brazil for this analysis, and that had an influence in the wind auction design.

Brazil has historically relied on hydropower for generation expansion: over 70% of the country's 120 GW of generation capacity come from hydro sources. The regulatory framework instituted in 2004 is largely designed with these characteristics in mind, namely seeking to ensure adequate system expansion to meet demand growth and maintain security of supply [12] . Consumers must back up their load with firm energy certificates issued by the government, which in turn are backed by physical support. In the case of distribution companies, suppliers of 75% of the market, such certificates are acquired via periodic energy auctions bundled with an energy contract. With energy contract auctions backed by firm energy certificates at the core of the Brazilian regulatory framework, the country has gathered significant experience in this area: between 2005 and November 2013, Brazilian auctions have resulted in the contracting of 72 GW of new capacity (46% of which is conventional hydro, and 29% NCRE), awarding US$ 375 billion in long-term contracts. This experience motivated this paper, as a case study of the Brazilian experience, allowing for an evaluation of the auction framework and results over time.

Another important aspect of the Brazilian system is the importance of taking full advantage of synergies involved in the hydrothermal system operation. In order to take advantage of hydrological complementarity between the several river basins and to optimize water usage in the various available reservoirs in multiple hydro cascades, the generation system is centrally dispatched by an independent system operator according to an optimization model, and energy spot prices are calculated as byproducts. In particular, wind power can benefit very much from such synergies [13] : while in many other countries wind production intermittency is an obstacle, requiring back up from fast-ramp (usually less efficient) thermal units, hydro plants' operational flexibility greatly facilitates their technical and economic integration. As a consequence, by jointly operating wind and hydro plants the Brazilian system could fully exploit the two sources' seasonal complementarity with relatively little downside, as long as wind penetration is not too large [14] . This concept had a strong influence in the design of the Brazilian wind power auctions, motivating the design of a product that would allocate more risks to the consumer rather than to the generator – under the justification that it would be cheaper to allow hydro plants to absorb that risk rather than letting investors price them.

In terms of NCRE policies, Brazil does not have a formal target for NCRE penetration. Instead, the government's support has been for the most part geared towards technologies that are already competitive or close to competitiveness in some way – the relatively small carbon footprint of the Brazilian electricity sector (due to large hydro participation) likely plays a role in this policy trend. The main exception was the 2002 Proinfa program, a feed-in tariff program which promoted the contracting of 3.3 GW of wind, small hydro, and biomass plants in equal proportions. In contrast, the first Brazilian NCRE auctions allowed the technologies to compete among themselves in price, with wind power being excluded due to its significantly higher prices at the time. However, because fiscal and financial benefits play an important role in "nudging" NCRE plants towards competitiveness and the representation of additional costs imposed to the system is imperfect, there are concerns the so-called "competitiveness" of NCRE is overstated.

2 BRAZILIAN WIND POWER AUCTIONS

2.1 Auction scheme

There are several types of energy contract auctions that can be carried out in Brazil, including auctions for procuring energy contracts from existing plants and single-project auctions for megahydro projects. This paper will focus on the two types relevant for contracting new wind capacity:

- Regular new energy auctions, which are regularly carried out twice per year for delivery 3 and 5 years ahead: their main goal is to procure energy contracts (supported by firm energy certificates) to back up the distribution companies' load growth. The counterparty of the contract is the distribution company, who passes all costs through to regulated consumers.
- Reserve energy auctions, which are carried out sporadically, and function as a mechanism for the government to contract surplus energy to increase the system's reserve margin. Reserve auctions have often been used as a NCRE fostering mechanism. The counterparty is the electricity trading chamber, who collects a fee from regulated and free consumers to cover contract costs.

Even though in practice each auction has an auction committee and may redefine several design elements, the authors believe the distinction described above to be sufficient for the purpose of this paper. The main design elements of the two types of auction are summarized in the Table below, highlighting similarities and differences. The 2013 auctions have introduced a few important changes, which are indicated in the Table (regulations before the change are described in the bottom). The motivations for these changes and their consequences are discussed in more detail in section 3.

Table 1 – Main characteristics of the Brazilian wind power auctions

	Common ground	**Regular new energy auctions**	**Reserve energy auctions**
Basic scheme	- Centralized procurement processes organized by the government - Auction mechanism follows a two-phase hybrid scheme: descending price clock rounds followed by a pay-as-bid final round	- Carried out regularly twice per year, for delivery 3 to 5 years ahead - Bids are compared in terms of an index that aims to represent economic costs and benefits to consumer related to the seller's expected generation profile	- Carried out whenever the government calls for it, usually for delivery 3 years ahead - Bids are compared on a simple least-cost basis
Requirements from bidders	- Only new generation projects may participate - Participants must present extensive documentation, including environmental license, wind certification, land use rights documents, grid access statement, etc. - Participants' net worth must be at least 10% of project investment cost	- The government sometimes restricts suppliers by either (i) choosing parameters to split demand among several technologies or groups of technologies, (ii) specifically excluding some generation sources, or (iii) effectively excluding some thermal plants by introducing a limit to plants' operating variable cost	- Usually bidding is restricted to one to three NCRE technologies
Demand	- Demand given in energy terms (MWh/y): annual energy delivery	- Demand is determined by distribution companies' load growth expectations	- Demand is determined by the government (security of supply criteria)

Product characteristics	- 20-year energy contracts indexed to local CPI - The seller's contracted amount remains constant throughout the contract [1] - Maximum volume that a plant can offer in the auction (firm energy) is its P90 certified generation [2]	- Joint products: obligation to provide (i) electricity, (ii) firm energy, and (iii) firm capacity - The generator retains its right to surplus firm energy unsold at the auction, and may trade it freely	- Energy-only product - The consumer retains the right to surplus firm energy unsold at the auction for the reserve contract's duration
Settlement mechanism	- Partial settlements (with tolerance) are carried out once a year; full settlement every four years - If the generator has a deficit in the 4-year settlement, it must "buy back" this difference at a 6% premium over the settlement price [3]	- Generation is allocated to the contract in proportion to the fraction of the plant's firm energy that was sold in the auction - If the tolerance upper bound is surpassed, surplus generation is not allocated to the contract and is settled at the spot market - If the tolerance lower bound is violated, the generator must "buy back" this difference at the higher of (i) contract price and (ii) mean spot price	- The entire generation of the plant is allocated to the contract - If the tolerance upper bound is surpassed, surplus energy is purchased by the contract counterparty at a 30% discount on the contract price - If the tolerance lower bound is violated, the generator must "buy back" this difference at a 15% premium over contract price - Plants sold in the same auction may negotiate their deficits and surpluses to avoid penalties in the 4-year settlement
Penalty for delays	- Potential execution of the completion bond - 5% of project investment cost - Potential contract termination by regulator if project is severely delayed (typically ~1.5 years)	- Contract payment is reduced by at least 10% (up to 3 month delay) to 50% (delay>1 year) - Seller must procure contracts in the market to meet its obligations, even if the plant is operational but not its connection [4]	- The generator's contract revenue is delayed until COD - Seller cannot compensate for its unmet obligations, and is likely to be penalized in the settlement mechanism (violating the lower bound)
Transmission coordination	- Wire tariff is calculated before the auction and kept constant for its duration	- Generators must coordinate grid access at their own risk [5]	- Separate "sub-auctions" are carried out for access to substations [5]

[1] In reserve auctions until 2012, contract obligation was automatically reduced whenever the observed generation at the time of the 4-year settlement was lower than the contracted amount

[2] In all auctions until 2012, firm energy was calculated based on average generation (P50) instead

[3] In all auctions until 2012, there was no 6% premium

[4] This rule was briefly changed in 2012 to remove the seller's obligation, and then changed back

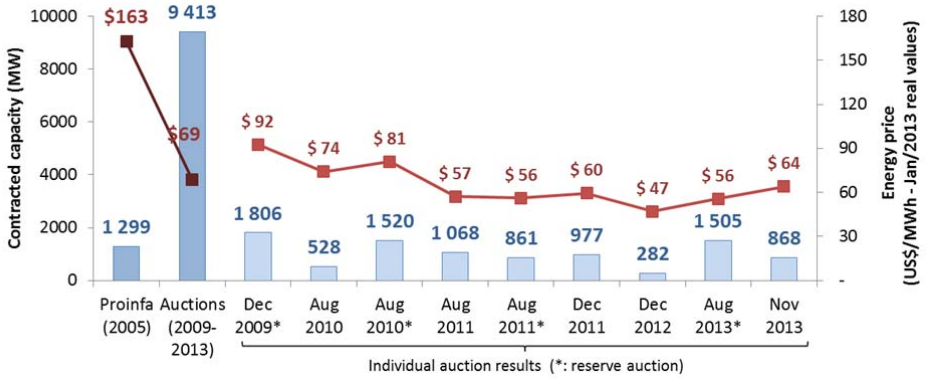
[5] Until 2012, the government had centrally coordinated the planning of shared collection substations in both types of auction.

2.2 Auction results and long-term consequences

In 2009, the first wind power-exclusive reserve auction took place in Brazil, instituting several of the design elements described in section 2.1 – in particular, the product included a settlement mechanism catered to wind technology's needs, in an attempt to exploit hydro-wind synergies (see section 1.3). This auction was organized under expectations that the international conjuncture would allow for especially low prices, since the 2008 economic crisis had strongly reduced demand for wind equipment in Europe. The auction was very successful in attracting a large number of investors to the country – including local and foreign private generators, wind equipment manufacturers and government-owned companies –, and prices were reduced even further in subsequent auctions, suggesting that the new price level is a consequence of structural rather than temporary aspects.

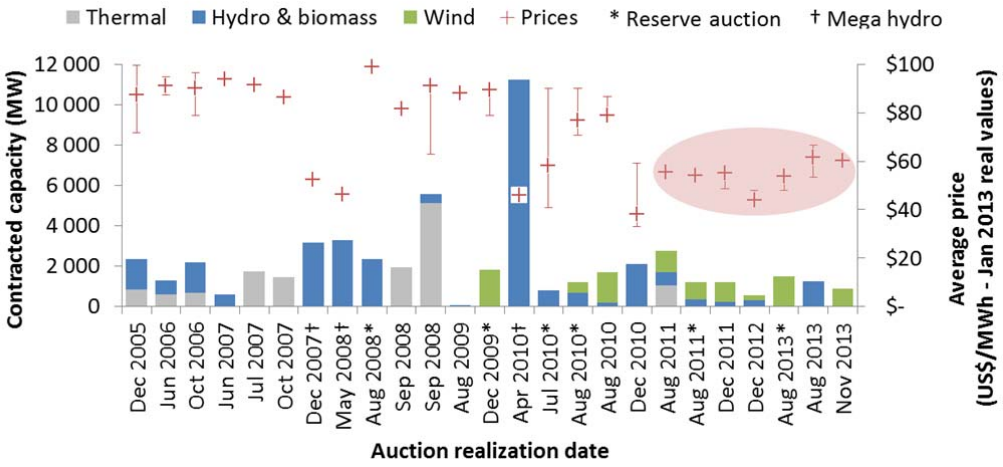
Figure 1 shows the wind capacity contracted via auctions in Brazil since 2009 and compares the auctions outcome with those of the Proinfa program. The rapid price reduction in the wind auctions is generally attributed to the fierce competition among equipment suppliers (several of which have started manufacturing wind equipment in Brazil) and generators (more than 13 000 MW in wind power projects, from various companies, were enlisted to participate in the 2009 auction, of which only 1 800 MW were finally contracted. Similar capacity amounts have been enrolled in more recent auctions as well).

Figure 1 – Highlight on wind power auctions and Proinfa: Contracted capacity and prices



It is remarkable to observe that the direct competition of wind power plants with conventional generators seems to have brought a new price paradigm for all other technologies, by forcing other investors to adapt. As shown in Figure 2, typical auctioned prices before the emergence of wind power as a major player have been significantly higher (except for a few mega hydro auctions).

Figure 2 – Prices in Brazilian new energy auctions since 2005: a change in paradigm



3 THE UNSOLVED CHALLENGES

3.1 The true cost of wind power

Wind power's participation in the regular energy auctions (as opposed to the reserve auctions) implies that the technology is a full-fledged contributor to the Brazilian system's needs (in terms of generation, firm energy, and firm capacity), and effectively that wind expansion can substitute capacity additions from conventional sources, rather than acting strictly as a complement. While this assumption is true for small wind penetration due to the synergies described in section 1.3, it might not hold for high levels of wind in the system and when considering the impact of transmission constraints and of the high uncertainties associated with a system expansion based on run-of-river hydro plants. These issues might pose a limit to integrate wind capacity in the system without threatening the security of supply and the system operation, implying a few hidden costs of wind power.

To the authors' best knowledge, [14] was the first reference to calculate the impact of wind in the Brazilian system's operations and to assess a first estimate of the maximum penetration of this technology in the country. A maximum penetration of 60 GW was reached. However, this study did not take into account network constraints and analyzed the impacts under an "energy-only" standpoint, i.e., ignoring short-term effects and focusing on the ability of the system's hydro reservoirs to support wind integration. A more detailed study representing the costs and benefits of wind power in the system considering both electric and energy issues remains to be done.

Because there is not enough information to assess this issue, several desirable attributes of the newly constructed plants are not explicitly represented in the dispatch model or in the auction mechanism (such as dispatchability, location, and peak shaving capability). Therefore, it is possible that these attributes are being undervalued in the auctions, ultimately imposing higher costs to be burdened by the consumers. Another source of distortions is the fact that NCRE are often the target of independent policies offering fiscal and financial benefits, which further contribute to conceal the technology's true costs. For example, NCRE plants are entitled a 50% discount on their wire tariff, are exempt from a mandatory contribution to the sector R&D fund (1% of the net revenue), and tend to be offered more attractive financing conditions from the Brazilian Development Bank. The large number of small benefits scattered in several legal documents increases complexity for investors, and makes it so that the "true" cost of wind power becomes even more difficult to assess.

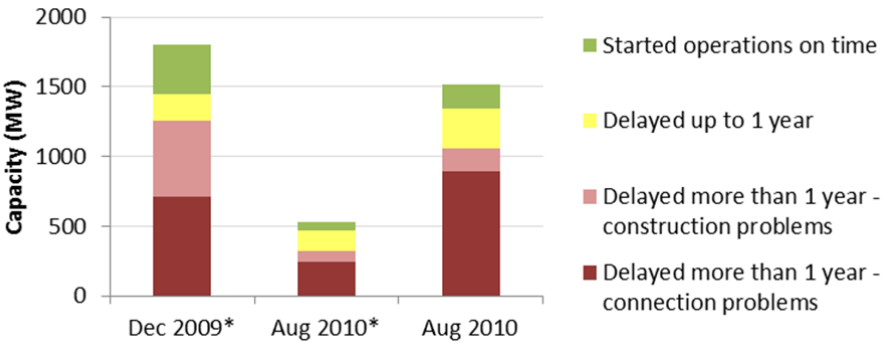
3.2 Coordination with transmission planning

Because an auction-based approach involves full disclosure of the projects to be built ahead of time, it can also facilitate the coordination of generation expansion with transmission planning. The first Brazilian NCRE auctions introduced an ambitious coordination scheme [15] , allowing for layers of shared collectors substations in a network system designed by the government. In 2013, this complex scheme was discontinued: going forward, connection access will need to be secured before the auction by the bidders, who shall negotiate their own access directly with the network operator or distribution company. The government intends to help this process by pro-actively auctioning backbones of high-voltage links in the country to facilitate the connection of wind plants; but nonetheless the investors will burden more risk in the connection works.

Although seemingly advantageous on paper, the undoing to the initially proposed coordination scheme proved to be tight schedule constraints: after the NCRE auction, government representatives needed to (i) prepare the transmission plan based on the auctioned plants and calculate the resulting wire tariffs; (ii) iterate with the winning projects and obtain their binding commitment to participate in the shared facilities, redesigning the transmission plan if necessary; (iii) prepare the necessary documentation and call for the transmission auction, allowing sufficient construction time for the connection to be ready at the same time as the generator. This was clearly unfeasible in the most extreme cases, in which there was only a 24-month gap between the NCRE auction and the contract COD.

An analysis of the November 2013 inspection report, prepared by the Brazilian electricity regulator, gives an indication of the magnitude of the problem – nearly 70% of the wind capacity sold in the first three auctions (which should have started operations by July 2012, September 2013 and January 2013 respectively) are delayed by more than 12 months, and 70% of those delays are attributed to connection issues.

Figure 3 – Current status of the projects auctioned in the first three Brazilian wind auctions



Because coordination with transmission planning has proven to be more challenging than expected, it seems that the decision to change the scheme of responsibilities for the 2013 auctions has been correct. However, even ignoring the connection problems, the evidence in Figure 3 seems to indicate that systematic delays are occurring despite the harsh requirements and penalties proposed in the auction mechanism (see section 2.1) – only 15.5% of plants started operations on time. This is a standing concern that ought to be taken into account in the NCRE auction design.

3.3 Potential overestimation of the capacity factors

One early criticism of the Proinfa program was that the selection criterion used for the winning projects was the issuance date of the environmental permit – an arbitrary choice that offered little incentive to select the most efficient projects and best wind hotspots. This was reflected by the stark contrast in predicted capacity factors (CF) of selected projects: while the CF for the Proinfa plants was 31%, projects auctioned in 2009 had a certified CF of 44%. What was at first a reason for celebration soon became a source of suspicion, as over the subsequent auctions certified CFs became higher and higher, eventually exceeding 50% – until the design scheme was changed for the 2013 auctions, when investors could sell no more than the P90 of the plant's certified wind generation. Even then, the auctioned plants have claimed that they can maintain a 46% CF *in the 90% confidence interval*.

Figure 4 illustrates how the 2013 auctions represented a discontinuous shift in both the decreasing price trend and in the increasing capacity factors trend. This figure also correlates the price offers of the winning projects and their capacity factors. It is interesting to see that sometimes the lowest prices were offered by investors with projects with small load factors, might indicate some sort of aggressive bidding with implementation risk.

The possibility that investors could be (wittingly or unwittingly) reporting inflated capacity factors is a legitimate concern, since the misrepresentation of their contribution in the dispatch model could result in a suboptimal system operation that could threaten security of supply. Despite the relatively short historical record, the auctioned plants currently operational seem to have performed at a CF only slightly higher than Proinfa plants (see Figure 5). Even though the results are compatible with a "good year" for Proinfa plants and a "bad year" for auctioned plants, and even though the track record of auctioned plants is based on a relatively small sample, these preliminary results do little to ease the concern that auctioned CFs may be inflated.

Figure 4 – Capacity factor scatterplot – winners of energy auctions[1]

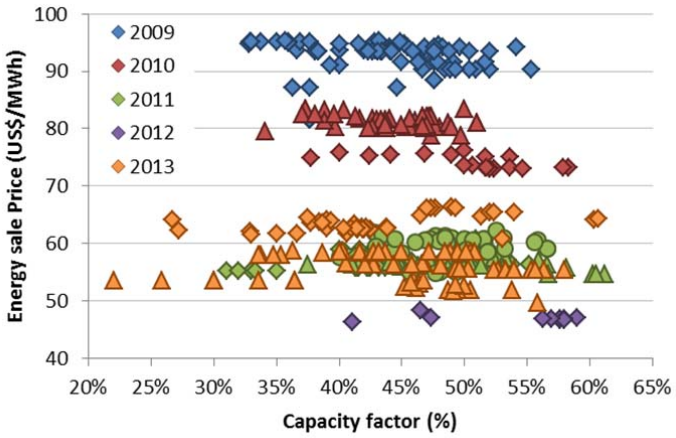
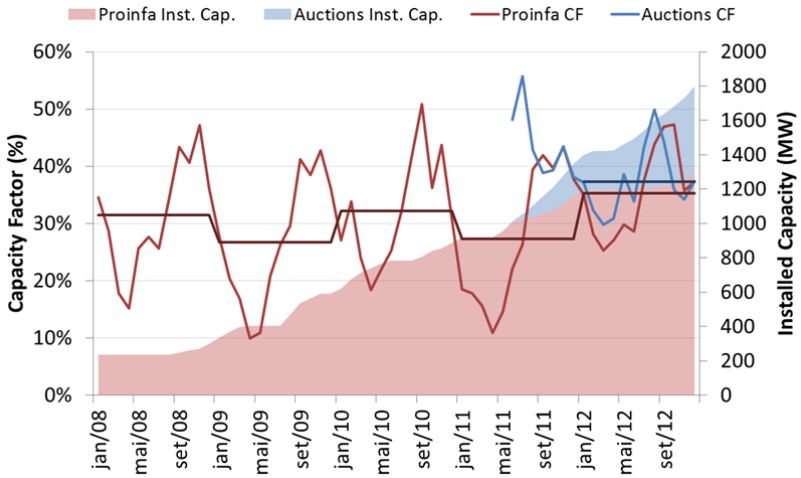


Figure 5 – Historical capacity factors for the Proinfa plants and auctioned plants



If this is indeed the case, it would seem that the contract mechanisms are not giving the correct incentives to encourage an unbiased CF declaration – however, getting rid of the favorable risk-allocation mechanisms is a controversial issue, since it would likely result in a suboptimal exploration of the wind-hydro synergies described in section 1.3. It is also important to observe that the restriction introduced in 2013 if anything offers *higher* incentives for investors overestimate the plant's CF – since the auction mechanism (see section 2.1) tends to remunerate the plant at a lower price per MWh when it overperforms relative to the quantity sold in the auction, the investors could seek to inflate their P90 generation values.

4 CONCLUSIONS

Brazil has amassed an extensive experience in organizing energy auctions, and the country's endeavors with wind power in particular have been especially beneficial, allowing nearly 9.5 GW of new capacity to be contracted at prices in the ballpark of 50 US$/MWh. Despite this undeniable success in the auction stage, other difficulties have been revealed as the commercial operations date for the auctioned plants approaches.

The penalties foreseen in the auctioned product seem to have been insufficient to avoid systematic delays and underperformance of the wind plants. Indeed, two of the main issues identified (severe delays in transmission works; overoptimistic declaration of capacity factors) have arguably been

[1] Multiple auctions in the same year are represented with different markers but in the same color

magnified by the Brazilian policymakers' careful and well-intentioned attempt to provide greater securities to the investors (centralized coordination of transmission planning; beneficial risk allocation mechanism), which has motivated the government to adjust the auction mechanism in 2013.

However, changing the auction scheme going forward will not be sufficient to combat the issue, if systematic deviations indeed materialize. The auctioned plants have been deeply integrated into the Brazilian market model when they were added to the distribution companies' portfolios and represented in the dispatch models for hydro optimization; and the misrepresentation of those plants going forward will result not only in penalties for the investors, but overcosts to be burdened by all consumers in the system.

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