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Wind Energy Transition: asymmetric strategies between Brazil and China[1]

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Introduction

The sharp development of renewables in both Brazil and China has different points of departure and arrival. On the one hand, Brazil stablished the role of renewables in its energy matrix as the very basis for its accelerated economic growth during the thirty-five years following the second world war and, therefore, well before external constraints caused by oil price shocks in the 1970s. China, on the other hand, has introduced the need for renewables as a means of correcting the harmful effects of its energy-intensive and highly carbonized economy, which has been the foundation for unbridled economic growth over the past 35 years. In this sense, the structural incentives to move forward into the decarbonized economy are deeply asymmetric between the two countries.

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Brazil is almost an energy self-sufficient country whereas China is heavily dependent on imported fossil fuels. Brazil bases already 45.3 percent of its total energy demand on renewables whereas China struggles to diminish its reliance on fossil: although the share of coal in China's electricity generation mix is declining (from 76 to 62 percent between 2010 and 2019), total coal generation is still increasing – more 41 percent from 2010 to 2019 (Kahrl et al., 2021). China is the world's largest energy consumer and greenhouse gas emitter (Liu and Wei, 2020) whereas Brazil ranks as the seventh largest GHG global emitter, with 46 percent of 2015 emissions coming from land use sector while energy sector accounted for 23.6 percent (Azevedo et al., 2018).

Comparing the way how Brazil and China have implemented its energy efficiency and environmental conservation policies it seems that China has shown a better institutional capacity to tackle those issues. According to International Energy Agency, China was able to reduce the carbon intensity in both economy and energy supply by 31.8 and 36.2 percent, respectively, between 2003-2016 whereas Brazil increased those rates by 2.8 and 3.4 percent during the same period. The updated data reinforces the above figures. On the one hand, shows that China overcame last year its carbon intensity target with an 18.8 percent decrease from 2015 levels. Although the China's energy intensity fell slightly short the original target, it also decreased an approximately 13.7 percent from 2016 through 2020 (Lewis & Edwards, 2021). On the other hand, despite the carbon intensity of the Brazilian economy and carbon emissions from the country's power generation still being ones of the world's smallest, the evolution of total CO2 emissions associated with energy matrix jumped from 288.4 to 419.1 MtCO2eq between 2000 and 2019, according to data from Brazil's Energy Research Office (EPE, 2021). Besides, Amazon deforestation has resumed growth since 2012 and currently reaches an area nearly three times larger, according to Brazil's National Institute for Space Research (INPE), undermining the forest's role as an important carbon sink.

This article will narrow down the topic and aims to assess the differences in the institutional trajectory of renewable transition policies and its effects on the implementation of the wind power between Brazil and China. The main focus will be on domestic institutional variables governing the challenges of renewable transition. In other words, socio-technical energy systems developed by both Brazil and China don't seem to fit into simplified analytical models. They demand multiple national explanatory variables such as economic growth, regime type, political institutions, and institutional capacity to address energy transition performance (Fiorino, 2011). Mainly, most of the asymmetries between the energy systems of Brazil and China is due to both the path dependence of its incumbent energy system and state capacities.

According to comparative analyses, most energy transitions have been path dependent rather than revolutionary, cumulative rather than fully substitutive. In other words, breaking out embedded energy systems requires long-term transformations able to alter technologies, political and legal regulations, economies of scale and price signals, social attitudes and values altogether (Sovacool, 2017). As Brazil's state capacity is interwoven with a developmental democratic state which draws on participation by organized civil society (Hochstetler and Tranjan, 2016), while China's state capacity is embedded in a type of political regime which does not involve such participation in deliberative processes (Kostka, 2016), the need for new political coalitions to push renewables transition does not have the same role for both countries. In other words, regardless the relatively well-succeeded renewable transition agendas of both countries in comparative terms, its bureaucratic capacities have different scope, that is, they are embedded in regimes and political institutions with very unlike legacies.

This means the institutional change aimed at new renewables in Brazil and China is still embedded in disputes between proponents of the new and incumbent technological systems. In that regard, instead of adopting a normative approach on what is the best institutional framework for the wind transition this article choose to understand how domestic institutions shape outcomes and how policy initiatives interact with legacy structures toward renewables in an open-ended process of experimental governance and institutional innovation (Heilmann, 2008; Davidson; Kahrl; and Karplus, 2017).

Main achievements of China's and Brazil's renewable transition

According to the data from the International Renewable Energy Agency (IRENA), in absolute terms China has become the leader when it comes to renewables. The country's efforts to increase energy efficiency have made it the largest market for smart meters. Besides, in order to meet a growing demand resulting from increased sales of subsidized electric vehicles China's investments have catapulted the country's lithium-ion battery capacity, which accounted for 77 percent of global volume in 2020 (Yu and Sumangil, 2021).

According to the latest report from the European Patent Office and the International Energy Agency (IEA), China has showed a steady increase in the number of international patent families (IPF) being filled for low carbon energy (LCE) technologies from 2000 to 2019 (Ménière et al., 2021). Although China is still behind leading countries in LCE technologies, like Japan, Germany and U.S., this lag shouldn't last for long considering the country's leadership as the largest manufacturer, exporter and installer of solar panels, wind turbines, batteries and electric vehicles. In that sense, the China's big push to renewables shouldn't be seen just as an environmental strategy but also as developmental and business ones. The aforementioned renewables industries have become pillars and export platforms for the country's economy, able to create a domestic industry that provides future-oriented jobs, mitigate pollution and enhance energy supply security as well as reduce the costs of its domestic industry's supply chains (Korsnes, 2020; Mathews and Tan, 2015).

China's renewables industry has been beaconed by three central government industrial-policy documents: the strategic emerging industries catalogue, the 'Made in China 2025', and the 13th Five-Year Plan (Kenderdine, 2017). When setting national specific targets for energy transition to renewables, China stipulated in its 12th Five-Year Plan for Energy Development a target of 100 GW of installed wind power capacity by 2015, but surpassed the original target by reaching 131 GW that year. In the following Five-Year Plan, the China's government was expecting to reach 210 GW of installed wind capacity by 2020 but, according to National Energy Administration, the country reached the astounding mark of 281.5 GW that year, leaving far behind all competing countries in the renewable transition. European Union and United States, for instance, have amassed 220 GW and 122.48 GW till the same year, respectively, according to WindEurope and American Clean Power Association. To summarize this unprecedented transformation in a nutshell, while the China's coal installed capacity has multiplied by 1.75 times over the past decade, the country's renewable sources have multiplied by 3.68 times in the same period, which allowed some analysts to predict that China's electric power system should be greener than brown by 2026 (Mathews and Huang, 2021). In other words, China's renewable sources have been continuously increasing its share in total installed electric power capacity from 25 to 43.5 percent between 2010-2021, while the share of the wind accounts for 13 percent, according to the National Energy Administration (NEA). That explains why Chinese manufacturers were able to capture almost half of the global wind market since 2018 (Lacal-Arántegui, 2019).

Despite the asymmetries of structural incentives vis-a-vis China, the overall picture of Brazil's energy transition is no less striking. In the last ten years, the country's electric power system has slightly reduced the hydropower share, increased the dependence on gas-fired power plants, and stepped up energy transition based on wind, solar and biomass sources (Table 1). In addition to the country having the world's second largest volume of jobs coming from the renewable energy industry, behind only China, the share of renewable sources in the Brazil's total energy demand still holds the unmatched 45.3 percent (IRENA, 2020). When observing only the electricity supply, renewable sources reached 83.2 percent in 2021, with the hydropower accounting for 58.7 percent, bioenergy 8.3 percent (mostly from sugarcane biomass), wind 10.4 percent, and solar 5.8 percent, according to Brazil's National Agency of Electric Energy (ANEEL). Considering those figures, it is still surprising to come across scholarly works making bold claims that European Union has become the world's greenest electric power system since 2009 (Mathews and Huang, 2021).

(Table 1)

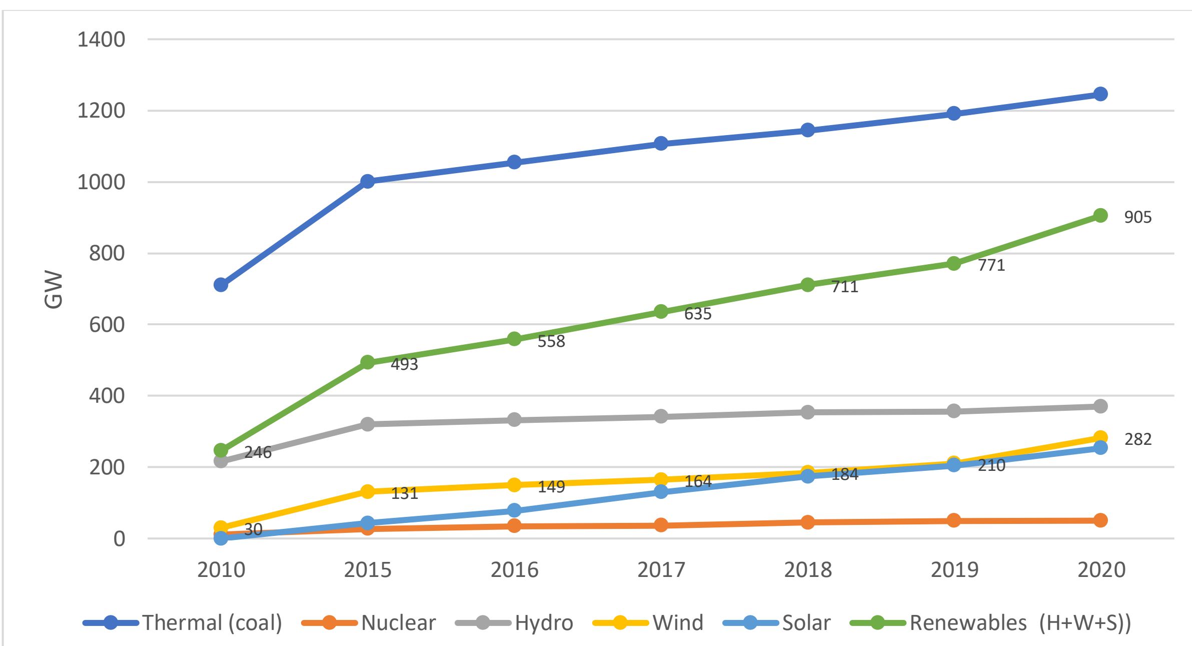
Brazil's Installed Power Capacity (MW)

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	% of Installed Capacity (2021)	Δ% (2021-2017)
Hydro	83,335	85,557	87,970	90,440	95,819	99,418	102,300	106,899	109,277	109,489	58.7	10.13
Biomass	9,754	11,111	12,210	13,149	13,845	14,247	14,729	14,880	15,187	15,532	8.3	9.02
Wind	1,667	2,109	3,840	6,629	9,507	11,460	13,381	15,155	16,317	19,479	10.4	69.97
Solar	1	3	15	21	23	419	1,750	3,482	6,906	10,912	5.8	2,604
Natural Gas	13,382	13,620	12,581	12,915	13,018	13,004	13,003	13,445	14,953	16,261	8.7	25.05
Oil	7,331	7,459	9,093	10,052	10,205	10,200	9,965	9,050	9,147	9,035	4.8	-11.42
Coal	1,944	3,024	3,593	3,614	3,613	3,713	3,718	3,597	3,583	3,582	1.9	-3.53
Nuclear	2,007	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1,990	1.1	0.0

Source: Table crafted by the author based on data from "Boletim Mensal de Monitoramento do Sistema Elétrico Brasileiro" extracted from Sistema de Informações de Geração (SIGA) - the former Aneel's Generation Information Bank (BIG)

(Figure 1)

China's Power Installed Capacity (GW)



Source: Prepared by the Author based on data from Mathews and Huang (2021)

Additionally, Brazil has attracted an unprecedented volume of new clean energy investments that added up to USD $60.6 billion between 2010-2019, according to Bloomberg New Energy Finance. Such investments helped to catapult the country's wind capacity from 0.6 GW to 19.5 GW between 2010 and 2021, increasing its share on total installed capacity from 7.4 to 10.4 percent only in the last five years. Still according to forecasts from the Brazilian Wind Energy Association (ABEEólica) and considering only the auctions already carried out, the wind capacity will advance to around 28 GW by 2024. Additionally, solar PV sources gave an exponential leap from 0.3 to 5.8 percent on the country's installed power capacity since 2017. Although natural gas has also gained ground, it was the new renewables that have obtained a greater enlargement in the Brazil's installed capacity share. Comparatively, while Brazil's PV and wind combined share has reached 16.2 percent of the country's total installed power capacity, China has managed to forge from scratch a combined installed capacity of those new renewables of 606 GW in the last twenty years, whose share on the country's installed capacity has already reached 26 percent, according to China's National Administration Energy. In other words, despite the lag on accumulated wind capacity between Brazil and leading countries both growth pace and share of wind in the country's installed capacity have been able to keep up with those countries.

Path Dependency and State Capacities: institutions matter in wind transition

Both the path dependence of bureaucratic governance and decision-making deadlocks resulted from multi-level coordination may explain differences and communalities on energy transition figures between Brazil and China. Besides, *transformative policy experimentation* approach has the potential to address the main implementation hindrances presented to new renewables, such as policies strive to alter economic and administrative behavior of institutions. Contrary to the assumptions of freewheeling trial and error or spontaneous policy diffusion, policy experimentation is a purposeful and coordinated activity whose goal is to produce new policy options that are absorbed by official policymaking and then replicated on a larger scale (Heilmann, 2008).

Brazil

Brazil has a decades-long history of investing in renewable energy which precedes the current climate change debate. Throughout the 1950s, 1960s, and 1970s, the Brazilian developmental state built almost one hundred large hydropower dams each decade (Khagram, 2004). It was driven by both economic and social reasons, that is, as a means of ensuring power supply security and subsequently also for reducing Brazil's dependence on imported oil rather than purely climate concerns (Schaeffer et al., 2015; Vieira and Dalgaard, 2013; Szklo et al, 2005). Besides, both interests and *esprit de corps* of hydropower bureaucracies – forged during the golden ages of mega-dam projects - were largely absorbed by the new regulatory regime that emerged as a result of market-oriented reforms, what reinforced the path dependency of incumbent energy system (Prado, 2012; Tankha, 2009; Oliveira, 2007). In view of that, Brazil's energy transition policy has a pronounced path-dependence in its multi-level coordination mechanisms based on a divided competence to legislate energy transition: municipalities are in charge of building codes; sales taxes are in the states' jurisdiction; the Brazilian electricity grid is national (Basso, 2019).

Besides subnational energy transition initiatives have played a strong role in the learning and niche formation of new renewables that have been given less priority at the national level (Bradshaw and Jannuzzi, 2019), those local initiatives have also redistributive effects as more than 85 percent of the Brazil's wind capacity is hosted at cities with the lowest human development indexes (Yanaguizawa Lucena & Lucena, 2019). However, those subnational initiatives still facing regulatory challenges at national level to move forward renewable transition such as those relating to the deployment of centralized wind-PV hybrid power plants in Northeastern Brazil (Santos et al., 2020). As regional-level actors frame renewable energy choices primarily in terms of economic development opportunities and improving power supply security, the environmental and social issues have just benefitted as a subsidiary effect of economic viability of wind farms. In other words, path dependency of incumbent socio-technical energy system is still sidelining environmental issues in Brazil's energy transition agenda.

Such path dependency driven by a centralized hydroelectric system led to a situation of "lock-in", remaining the dominant form of energy production while resisting against alternative energy technologies and creating constraints to achieve emerging policy goals such as energy supply security (Bradshaw, 2018). Pushed by an unprecedented electricity shortage crisis that hit the country in 2001, the Brazilian government launched one year later a feed-in tariff program called Incentive Program for Alternative Energy Sources (PROINFA) aimed at increasing the share of small hydro power plants, wind power farms, and biomass thermoelectric in the energy supply (Cavaliero and Silva, 2005). Throughout this first and incipient phase of implementation, PROINFA faced bottlenecks such as the financial shortages of program eligible candidates, that is, Autonomous Independent Power Producers - which could not be under total or partial control of any power utility; besides the candidates' failure to meet the 60 percent local content requirements (Dutra and Szklo, 2008).

Until 2011, the wind energy development in Brazil was primarily driven by PROINFA but later on tenders have been the major driver of its expansion in the country (Bayer, 2018). In this context, Brazilian Development Bank (BNDES) has stood out as the main provider of subsidized loans, whether based on the feed-in tariff system or project finance models in which BNDES took equity participation up to 80 percent. Although some scholars claim that the wind farms mushrooming in Brazil was mostly a market response to the institutional changes promoted in the sector, focused on boosting private investment (Diniz, 2018), it is not possible to underestimate the role played by BNDES which has taken part in financing roughly 76 percent of the accumulated wind installed capacity between 2008 and 2016 (Esposito, 2018).

In other words, the institutional drivers behind such a new renewable trend in Brazil have found in BNDES and regulatory role played by ANEEL its main actors. Those institutions constitute part of a complex network of interaction between stakeholders who form the broader regulatory space and play a role of collaborative actors in the regulatory process, defining the Brazil's updated state capacity (Bradshaw, 2017). In this sense, scholars have underlined the political construction of the wind power transition in Brazil relied on a restricted style of formulation in which both representation of economic interests and the interaction among bureaucrats, politicians and interest groups dominate the political process (Soares; Gava; and Puppim de Oliveira, 2021). In other words, as the scale of technology adoption moves from niches towards systems, both new political coalitions and multi-level dynamic were necessary to push complementary technology over the incumbent energy system (Geels, 2019; Breetz; Mildenberger; and Stokes, 2018).

Whether the path dependence of Brazil's incumbent power system was able to constrain the scope for both the system marketization and the renewable transition itself, its bureaucracy does not seem to have been able to mobilize both organizational reputation and networks (Carpenter, 2001) to prevent disruptive privatization of remaining instruments of state capacity over power system. The privatization of the main state-owned power company, Eletrobras, sealed by an Act of Congress signed into law by President Bolsonaro in 2021, promises to further deteriorate the state capacity to coordinate energy transition policies in Brazil.

This new round of State divestment should repeat the results of the privatization of power distributors in 1990s when the financial indicators of sold companies improved, benefiting their shareholders, but the quality of service provided to consumers did not (Silvestre et al., 2010). Responsible for most electrical power interconnection and controlling approximately 45 percent of the transmission lines, the Eletrobras holding company also accounts for 30 percent of the country's electricity generation. One of the most insidious effects of this privatization Act is the decotization. A significant part of the energy currently sold by Eletrobras is cheaper due to the fact that it is produced by old hydropower plants, whose debt for its construction is already amortized. For this reason, Eletrobras dams sell power at half the price of private producers. As part of the prize to attract private investors, the privatization establishes decotization, that is, the end of the cheaper sale of power from Eletrobras and its alignment with ‘free market prices’. Experts have pointed out that this will have a cascading effect, increasing the costs of production chains and depressing the income of consumers mostly wage earners.

In addition to regressive effects of decotization on disposable income, the loss of state control over Eletrobras will also have environmental consequences. This new privatization law makes it mandatory to contract 8 GW from new gas-fired thermoelectric plants between 2026 and 2030. These power plants should operate full time with a minimum capacity of 70 percent for at least fifteen years. Consequently, it is estimated that annual emissions of greenhouse gases would increase 60 percent compared to the volume already emitted by current gas-fired thermoelectric plants in operation. The forecast of accumulated emissions arising from the operation of new gas-fired power plants determined by the Eletrobras privatization law should add another 260.3 $MtCO_2e$, more than the emissions of the entire Brazil’s transport sector in 2019 (Iema, 2021).

China

Renewables transition in China is also embedded in path dependence driven by a multi-level governance of networked actors, operating through formal and informal mechanisms. The legacy of fiscal reform also provided incentives that led to the development of a local state corporatism which increased authority of regional governments (Qian and Xu, 1993; Oi, 1992). Often named by neo-institutionalist scholars as a “regionally decentralized authoritarian system” (Xu, 2011), such institutional architecture has played a significant role beaconing the reach of China’s energy transition policies. It is worth mentioning that between 2003 and 2011 over 90 percent of wind farms were approved by local governments driven by inter-provincial competition whose purpose was to induce market agents to focus more on meeting quantitative targets for installed capacity rather than provide qualitative outputs (Kirkegaard, 2018).

Indeed, the leading role of local governments in forging a renewable transition market was made possible as the performance of local economies emerged as the principal yardstick for cadre evaluation under both the Communist Party's *nomenklatura* system and the state's administrative hierarchy (McNally, 2006). In other words, China still holds a central agency and a powerful bureaucracy in charge of binding targets for renewable energy policies, underpinned by a cadre management system which has persuasive schemes of incentives to assure the performance of its officials (Kostka, 2016). As it enables not only the adaptation of national-level models to specific locations but also the incorporation of local implementation lessons in national policymaking, policy-makers and policy stakeholders deliberately adjust the goals, rules and techniques of renewable policies in response to experiences and new information, forging a dynamic of policy learning (Lo and Broto, 2019).

Such policy learning has been underpinned by an institutional pendulum movement from China's energy bureaucracy which features as simultaneously hierarchical and heterarchical, undergoing at least four rounds of fragmentation and centralization (Cai and Aoyama, 2018). While the Chinese decision-making system concerning wind energy policy was relatively open during the early stages of its experimentation, the system remained closed towards the final stages when the National Development and Reform Commission (NDRC) decided to choose the tendering policy for nation-wide implementation in 2006 (Mah and Hills, 2014). Such transformative policy experimentation has been based on hands-on experimentation delegated to local officials but China's central government plays an indispensable role in scaling up and generalizing local innovations, thereby providing coordination to the reform process (Heilmann, 2008).

Even though China has been able to steadily decrease national energy intensity and slash the share of fossil fuels in its primary energy mix, administrative policy instruments aimed at the low-carbon energy transition have faced ever-diminishing returns due to excess capacity from uncoordinated inter-provincial and central-local planning. Despite being ruled by a central authoritarian government, local implementation is pushed by an uncoordinated energy governance driven by bargaining, vested interests, and local experimentation of provincial governments, state- and party-agents (Kirkegaard & Caliskan, 2019; Korsnes 2014). While having the world's largest installed wind capacity, in turn, China also faced a severe forced spillage of available wind electricity by the grid operator owing to economic or grid stability reasons (Davidson; Kahrl; and Karplus, 2017). Most of that spillage has been associated with coordination problems driven by conflicts related to both a high degree of fragmentation in the electric power regulation and multiple axes of institutional misalignments stemming from China's fragmented energy bureaucracy, which makes analysis based on multi-level perspective relevant (Qi et al., 2019; Cai and Aoyama, 2018). While international experiences indicate that wind curtailment[3] rate typically ranged between 1 and 3 percent of the potential wind power generation (Bird et al., 2016), in China as much as 15 percent of overall wind generation was curtailed from 2009 to 2017 (Xia; Lu; and Song, 2020).

This is the context that explains the energy system's inertia that has constrained China's electricity market reform, announced in 2015 - another example of sociotechnical lock-in. The reform sought to develop competition between generating companies; introduced pilot spot markets; opened investment in and operation of new distribution networks to companies other than the two existing grid enterprises; and introduced competition in electricity retail. In other words, the reform summarized in the so-called 'n. 9 Document' was forged to address twisted pricing mechanism, irrational power system planning, inefficient utilization of renewable energy and so on (Zeng et al., 2016). However, state-owned energy companies still play the role of policy instruments for energy supply security, employment and energy pricing as about 90 percent of generating capacity, and almost 100 percent of transmission and distribution lies in the hands of the state at central or local levels. In other words, even with the marketization driven both by 'corporativization' of state-owned enterprises and regulatory liberalization, the incumbent energy system beaconed by political regime and bureaucratic capacity still call the shots. Independently or in collusion with local governments, those companies still retain the

[3] Curtailment is the abandonment of electricity generation from effective power capacity, that is, when the power grid frequently interrupts the power connection of installed wind capacity

ability to act as veto players by weakening or obstructing the implementation of central government policies such as electricity market reform (Zhang and Andrews-Speed, 2020).

The continued wind power investment by China's Central State-Owned Enterprises (CSOEs), even under wind curtailment, does not means whatsoever to attribute to its economic behavior an absence of market rationality due to political/policy burdens (Zhu et al., 2019). Indeed, scholars have claimed state control and marketization should be seen as complementary rather than contradictory as it has resulted not only in extraordinary increase of wind installed capacity but has been also able to address issues like market fragmentation and renewable energy curtailment (Yu, 2020). Notwithstanding the above, although the lack of coordination among energy stakeholders has not implied a weakening of the China's state capacity to move forward the wind infrastructure, it has resulted in greater difficulty in adjusting the 'software' of institutional and societal change or practices related to energy demand and energy efficiency (Hove; Meidan; and Andrews-Speed, 2021).

Renewable Transition, State-Owned Banks, and Development Strategy

Unlike the undermining measures lately adopted by the Brazilian government against its development bank, the official development finance undertaken by China's state-owned banks has maintained and deepened low-interest loans, preferential export credit, and equity investments for the development of energy projects domestically and abroad. With a difference in size, BNDES played basically the same role as the China Development Bank (the largest Chinese policy bank). BNDES was acknowledged as the world's third largest national development bank (after its Chinese and German counterparts) until the middle of the last decade, not just for the country's domestic market but also to international project finance in support for infrastructure (Sierra and Hochstetler, 2017).

However, the political events which led to former President Dilma Rousseff's ousting in 2016 and the election of a crypto-fascist as president in 2018 have deeply affected the role of BNDES. The institutional advantage measured by subsidized interest rates which guide development banks worldwide has been suppressed in the case of BNDES as one of the first institutional measures took by the new ruling coalition which overthrew President Rousseff in 2016 (Santana, 2018b; Martins and Torres Filho, 2020). BNDES' annual disbursement capacity has dropped from BRL $263.8 billion to BRL $66.9 billion between 2014-2020 (in constant values of December 2020). Chinese policy banks, in turn, have surpassed the leading development finance institutions (DFIs) to become the world's largest providers of development finance for all forms of energy combined, especially regarding electric power, having mobilized a total of USD $117 billion for power projects worldwide for the past two decades (Kong and Gallagher, 2021; Li; Gallagher; and Mauzerall, 2020).

The institutional bifurcation of the financial engines of the renewable transition in Brazil and China has already resulted in different effects on the deployment and diffusion of renewable technological spillover. This resonates with studies which claim the 'direction' of innovation depends on the type of financial actor, that is, public financial actors invest in portfolios with higher risk technologies besides they also increased their share in total investment dramatically over time (Mazzucato and Semieniuk, 2018). Whereas China has used its state-owned banks and industrial policies to drive its domestic companies to capture the value associated with the development of clean energy technologies as well as replacing imports by developing a domestic supply chain, Brazil has let such spillover slip despite the significant increase of new renewables share in the country's installed capacity.

BNDES and New Renewables: from backbone to elusive institution

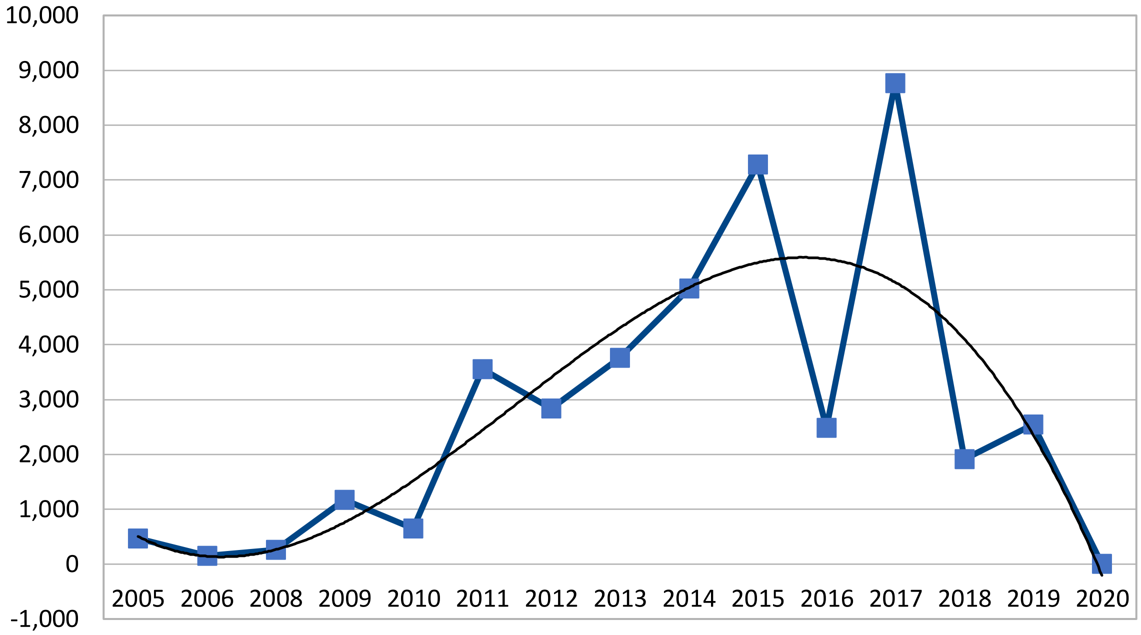
BNDES's total accumulated loans to power infrastructure projects have declined by half between the first and second half of the past decade, with no evidence that such a sharp drop has been proportionately offset by other sources of funding (Figure 5). Besides those constrains over its financing capacity, the major turn over BNDES' policy was the alignment of its interest rates with those from open credit market and the decreasing the institution's equity participation in wind farm development costs from 80 percent to not more than 50 percent. It made Bank's competitive loan interest rates no longer available. Based on domestic content requirements of 60 percent, BNDES's subsidized credit policy was being responsible for driving import-substitution moves on wind supply chains, drawing wind turbine manufacturers and assemblers to Brazil from 2009 onwards (Adami, Verschoore and Sellitto, 2021). It is not possible to be surprised, therefore, when stakeholders' perception regarding to wind implementation barriers in Brazil attributes to the high cost of capital its main cause, driven both by the increase in financing interest rates and by the decrease in equity participation from BNDES (Diógenes; Claro; and Rodrigues, 2019).

In line with those findings, scholarly works have underlined that delays in grid connection, local content requirements, the red tape associated with environmental feasibility studies, late delivery of wind turbines, supply bottlenecks, poor project management, and relatively short deadlines for implementation are some of reasons for only 14 percent of wind contracted capacity was completed within the deadline (Bayer, 2018). Indeed, 30 per cent of wind and 50 percent of biomass power plants are with the contract timetable behind schedule, mostly due to hinders to obtain financing (26 per cent), delays in connecting to the transmission system (20 per cent), construction cost overruns and difficulties in obtaining the permits (18 per cent each one) (Tolmasquim et al., 2021). As it is possible to see in the chart below (figure 2), BNDES lending towards wind infrastructure showed a steady growth until 2015 but it became erratic and declining after that year.

(Figure 2)

BNDES Disbursements for Wind Farms

(BRL million)

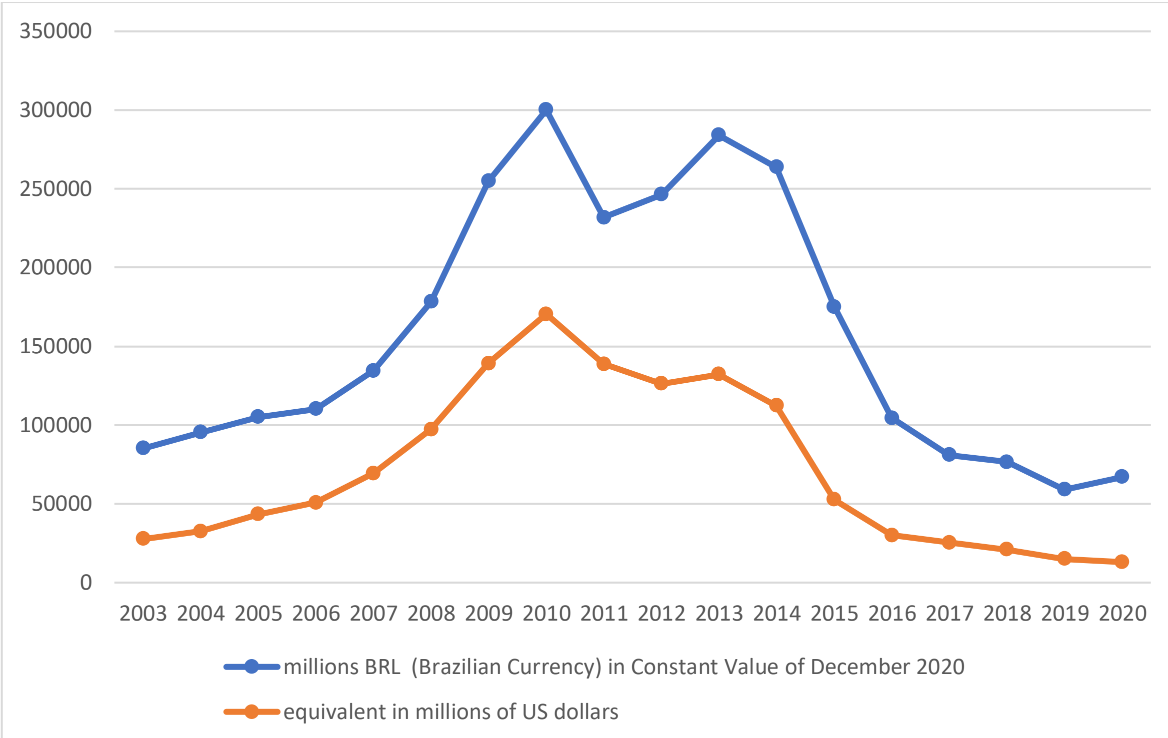


Source: Prepared by the Author

Although the BNDES having become the largest absolute provider of long-term loans for energy infrastructure until the middle of the previous decade (figure 4) – particularly toward wind (Esposito, 2018) - state support to foster new renewables has been shaped by a stronger preference for competitive auctions, public–private partnerships, and stricter financing rules (Hochstetler and Kostka, 2015). In order to overcome capital shortage and prevent a disruptive power rationing, like the one that hit the country in 2001, the Brazil's government passed a power reform Act in 2004 that adopted energy auctions as the primary mechanism to procure energy and capacity. Between December 2004 and October 2019, the Brazilian auction programme contracted 9571 TWh of energy in 82 rounds of auctions, adding 105 GW of installed capacity whose 77 GW were from renewables (Tolmasquim et al., 2021). According to the Monthly Monitoring Bulletin of the Brazilian Electric System, the country had 756 wind farms in operation by January of 2021.

(Figure 3)

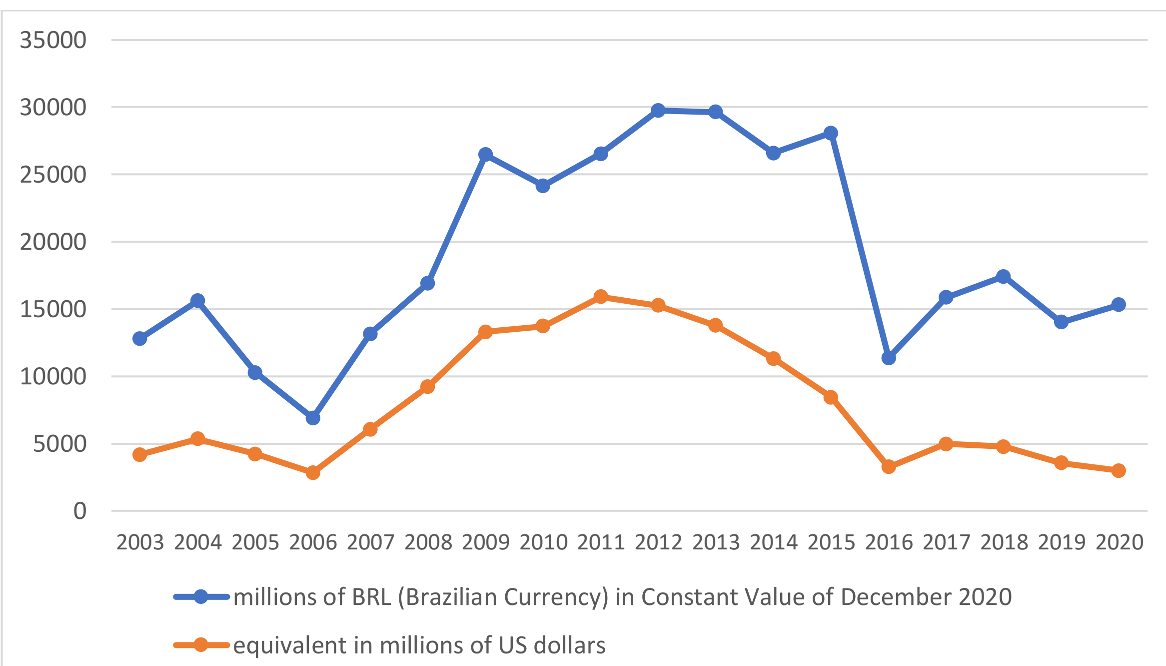
Total BNDES Disbursements



Source: Prepared by the Author

(Figure 4)

BNDES Disbursements for Electricity Infrastructure



Source: Prepared by the Author

As aftermath of the energy procurement model and capital shortages, both driven by ad hoc constrains, the erratic effects over innovation policies on renewables became palpable. Whereas technological spillover effects from Chinese industrial policy on new renewables have upgraded its domestic supply chain, mostly driven under the rubric of the Innovation-Driven Development Strategy (Naughton, 2021), wind sophisticated components in Brazil are still monopolized by foreign supply chains. In other words, the Brazilian government's approach is narrowly directed at developing wind energy as a cost-efficient alternative to other sources and still reliant on the inflow of foreign technology, even though it had managed to attract a considerable amount of foreign direct investment and built a domestic supply chain (Gandenberger and Strauch, 2018). Indeed, Brazil has developed a wind manufacturing industry specializing in the less technologically sophisticated components – such as blades, towers, bearings and castings – while till 2016 local companies accounted for only 6% of the nacelle manufacturing market (Bazilian; Cuming; Kenyon, 2020). Although there are multiple mechanisms and sectoral policies to tackle renewable transition, updated surveys have claimed Brazil does not have a coordinated and long-term national strategy for low-carbon energy innovation, which also explains the sharp decline in public and publicly-oriented investments on research, development and demonstration (RD&D) of renewable sources from BRL $966.44 million in 2014 to BRL $488.60 million in 2018 (ECLAC/CGEE, 2020). That means while China's economy has maintained an advantage in more dynamic sectors with higher levels of technological intensity, Brazil has deepened the participation of sectors with less technological content (Araújo and Diegues, 2022).

China and Wind: capturing global value chains

Although top-down state intervention played an instrumental role in upgrading the domestic wind industry, China's relative success in developing it has been also reliant on different forms of private and subnational initiatives, international interdependencies, and the flexibility of China's decision makers in adapting the mix of policies over time, that is, it’s based on transformative policy experimentation (Binz et al., 2017; Heilmann, 2008). Hence, multiple surveys have been trying to find out the driving forces behind China’s success in leapfrogging to global leadership in installed wind capacity and manufacturing, besides the role of domestic technological advancement to capture the lion share of global renewables value chain (Xu; Yang; and Zhao, 2021; Liu et al., 2018; Nahm, 2017; Groba and Cao, 2015; Lema; Berger; and Schmitz, 2013).

Since Renewable Energy Law was passed in 2006, Chinese government has established a framework for promoting and regulating renewable energy transition. The Law defined financial arrangements for supporting renewable technologies: categorized tariffs for renewables (feed-in mechanism) which guarantees an above-market rate that the grid company will pay to the renewable generator; cost-sharing measures; a Special Fund arrangement; and subsidies and grants to renewable energy players such as manufacturers and research institutions (Andrews-Speed and Zhang, 2015). As renewable technologies are still embedded in sunk costs associated both to a huge investment and uncertainty in the early stages of its development, besides an erratic pricing mechanism, the development of those technologies rely heavily on governmental policy support in the short term (Yang; Cheng; and Yao, 2019). In other words, by combining public R&D funding with regulatory policies to increase market demand, China was able to establish a domestic renewable industry (Nahm, 2017).

The main financing sources for China’s wind and photovoltaic power developers has been both local governments and the loans provided by China’s state-owned banks. Until 2011, the loans share from state-owned banks over the total invested in wind and PV power accounted for approximately 80 percent. Ever since, China has risen as the world’s largest wind power market both in terms of manufacturing and installed capacity. It was in this context that regional wind power capacity has catapulted by 22.4 times between 2006-2011 and went on to account for 96.2 percent of the national wind power capacity, that is, an average annual growth rate of 86.2 percent (Ming et al., 2014).

Such trajectory gained new impetus when China Banking Regulatory Commission (CBRC) launched the green credit system in 2013 and later the Guidelines for Establishment the Green Financial System in 2016, when green credit and green bonds policies have emerged as the most robust sources of green financing. Such measures have laid ground across regulators and executive bodies, providing direct financial incentives through monetary policies and macroprudential assessments. They have been driven by both the removal of the 75 percent loan-to-deposit (LDR) ratio requirement by the People's Bank of China (China's Central Bank) and the decreasing size of customer deposits, making room for banks raise capital through bond issuance in international and Chinese interbank markets, and by listing on stock markets, leading to increase in LDR across China's banking sector (Choi; Escalante; and Larsen, 2020).

In this context, China's domestic bank system has kept a significant role to develop renewables throughout the 2010s as outstanding green loans from 21 major banks reached RMB 10.6 trillion (USD 1.5 trillion) by the end of 2019, more than twice the amount of 2013. Besides, China's green bond market is now the world's largest source of labeled green bonds with RMB 977 billion (USD 140 billion) outstanding at the end of 2019, averaging 30 percent annual growth (Choi and Li, 2021). Updated surveys have confirmed the significant role played by China's financial sector development to explain over 40 percent of changes in the share of renewable energy (Ji and Zhang, 2019). In other words, the role of the China's state-owned banks in supporting renewables have raised in a context in which instead of the state providing direct allocation through fiscal revenue it enhancing creditworthiness of renewable projects in order to make them viable to the market or as it has been called: "state-supported, market based" means of development finance (Chen, 2020).

As aftermath of financial support toward renewables, China has developed comparative advantages in sophisticated good exports, such as wind energy technology components, and managed to decrease carbon emission intensity (Zheng; Song; and Shen, 2021; Yu et al., 2020). As the costs of both wind and PV power have fallen alongside technological innovation, experience, scale, and grid enhancements, this cost curve allowed China to build export capability while simultaneously diversifying the domestic electricity supply (Liu and Goldstein, 2013). Throughout 2010s Chinese wind turbine manufacturers have virtually captured the absolute largest share of global market as the number of Chinese companies among the top ten global wind turbine manufacturers jumped from 4 to 7 between 2011 and 2020. Although China's renewable energy industry has experienced a spurt of development with signs of upgrading, scholarly works have underlined the growth of China's wind turbine sector has been driven by protectionist measures favoring local firms which remained both SOE-dominated throughout the value chain and uncompetitive internationally (Brandt and Wang, 2019). Besides, such trend has shown variability across China's provinces associated to subnational policy approach to industrial structure, R&D investment, and environmental regulation (Bai et al., 2020).

Conclusion

Scholarly works are still struggling to set a more comprehensive analysis of the institutional arrangements that explain the stunning pace of renewable transition in the last twenty years. When resuming the concept of state capacity as analytically formulated throughout this article it's possible to realize that Brazil's and China's central state have kept the ability to logistically implement its decisions over actual and potential opposition of entrenched social groups. However, it is evident that the scope of these capabilities has continually differentiated over the past decade, mainly due to structural constrains resulting from differences in both the level of environmental degradation and path dependence from incumbent energy systems. Whereas China's central state has deepened its implementation ability through the unmatched state-owned banks funding and bureaucratic multilevel coordination mechanisms, Brazil's central state has partially abdicated its implementing institutions since the coup d'état that ousted an elected president in 2016. This has been clearly reflected in the pace and amount of installed capacity for new renewables between the two countries.

Notwithstanding Brazil having amassed the equivalent of 16.2 percent of total installed power capacity from wind and solar sources alone, China's combined wind and solar capacity has been able to exceed 26 percent of the country's total installed power capacity. Besides, the transition policies toward new renewables seems to show a better institutional consistency in China than Brazil whether in terms of technological spillover effects or in relation to environmental mitigation. Although wind capacity growth forecasts are still optimistic and the price of the contracted wind has even declined, the institutional rupture started in 2016 have triggered an undermining of the Brazil's state capacity which has also reached the renewables transition policy. Brazil tends to lose the renewable momentum that can undergo a reversal, especially after the stranglehold of the BNDES' financial capacity and the Eletrobras privatization.

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