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Research Proposal: Fostering the Development of a Business Ecosystem: The Experience of the Brazilian State Investment Bank and the Local Wind Energy Sector.

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1. Introduction

State Investment Banks (SIBs), also known as Development Finance Institutions (DFIs), are public state-owned finance organizations that provide credit to specific economy sectors in the regions they operate. Due their access to financially substantial public funds, they have been part of important progressive social agendas worldwide, especially, after the second half of the 20th century (Griffith-Jones & Ocampo, 2018). More recently, the social challenge to reduce global warming effects motivated these organizations to heavily support clean energy generation, mainly through the financing of infrastructure, such as wind power plants (Mazzucato & Penna, 2015b). Their active role funding energy generation projects, led some SIBs to be among the top global clean energy lenders between 2009 and 2018, considering both public and private financiers (Bloomberg New Energy Finance, 2019b). However, the kind of concessional support provided by these institutions is expected to be reduced or withdrawn once benefited sectors evolve and should be able to generate viable options to fossil-fueled energy generation (Deleidi, Mazzucato, & Semieniuk, 2020). Thus, the provision of sizeable funds seems to be paired with the purposeful design of a conducive environment aimed to catalyze investments and roles of other actor (Mazzucato et al., 2018). Such a catalytic role is precisely what a development bank should do to kick-start a major structural transformation by funding and show-casing new technologies and sectors (Ramos & Studart, 2018).

In this sense, credit conditions can be used by SIBs as tools to push the development of other actors and relationships in incipient clean energy generation sectors (Geddes, Schmidt, & Steffen, 2018). Through adapted credit terms crafted considering the specific characteristics of these areas, SIBs can attract private investors interested in taking the credit to build power plants, giving an initial push to clean energy markets and technologies (Mazzucato & Penna, 2015b). The experience SIBs acquire with initial cases can be used in subsequential co-financed operations with private banks, which leads to sharing of knowledge in types of projects that these private banks lack track records and, thus, would generally decline to participate (Geddes et al., 2018). As clean energy sectors develop, credit conditions may also evolve to get closer to what is offered by the private capital market, signaling other actors that these sectors are in more mature stages (Geddes et al., 2018; Plattek, Ferraz, & Ramos, 2021). SIBs also implement industrial policies, conditioning the credit to minimum local content requirements, in which case, investors must source part of the power plants from companies located in the regions where SIBs operate (Hansen, Nygaard, Morris, & Robbins, 2020). Such policies also change over time to push the development of certain areas within a clean energy sector (Plattek et al., 2021). This way, SIBs help to spur an important regional industrial base that contributes to sustain investments and to promote technological innovations (Rennkamp & Westin, 2013). Therefore, credit conditions may stimulate the evolution of a whole business ecosystem, reducing perceived risks of the market, and pushing the development of other actors which, in turn, support ongoing and future investments (Mazzucato, 2018; Plattek et al., 2021).

Considering the context presented, this study evaluates credit conditions undertaken by the Brazilian state investment bank while supporting wind energy power plants, investigating its effects in the development of the related business ecosystem. The Brazilian National Development Bank (BNDES) has been leading investments in clean sources of energy, being the biggest financier of clean energy generation in the world considering the period between 2009 and 2018, lending US$ 23.5 billion in total, with almost US$ 15 billion directed to wind energy projects in Brazil (Bloomberg New Energy Finance, 2019b). BNDES stimulated the participation of commercial private banks in subsequential funding operations and the cooperation between international wind turbines producers and local component manufacturers. Besides, BNDES also developed with other energy institutions some important parameters for energy purchase contracts from wind parks, which helped to reduce perceived risks from investors in wind power plants and from private capital market. These measurements changed over time, being adapted as other actors in the business ecosystem reached different stages of development. This behavior suggests that SIBs may not only reactively offer credit to an underfunded area, but strive to coordinate efforts of different actors, assuming seminal and central roles in the development of business ecosystems related to clean energy generation (Mazzucato & Semieniuk, 2018).

To guide the research, the following primary research question (PRQ) was postulated:

PRQ: *How did the involvement of the Brazilian SIB influence the development of a local clean energy business ecosystem?*

In order to drive the research towards a deeper understanding, four sub-questions (SQs) are developed to complement the main question:

SQ1: *What are SIBs and how is their involvement with clean energy sectors?*

SQ2: *How does a business ecosystem develop?*

SQ3: *How did the role of the Brazilian SIB (BNDES) influence the local wind energy business ecosystem?*

SQ4: *How did BNDES influence the wind energy ecosystem's health and coevolution in Brazil?*

The view of an energy sector as a business ecosystem allows the assessment of the interactions of organizations from different areas and industries which must coevolve their strategies for the development of the whole network (Moore, 1993). In this study, it is postulated that such coevolution is closely related to the ecosystem health, which can be measured by the ecosystem total productivity, robustness, and niche creation (Iansiti & Levien, 2002). When important central actors in the ecosystem increasingly dominate other actor's roles and enforce their individual strategies despite collective damage, the network struggles. In the opposite, when they work to positively influence the ecosystem health, all the participants thrive and evolve (Iansiti & Levien, 2004). Therefore, health measurements present important features for the analysis of an ecosystem development, considering that a healthy environment leads to adaptation and coevolution of the participants (Iansiti & Levien, 2002).

Moreover, differently from other network related concepts, as clusters, value chains, and value networks, business ecosystems also include participants from outside the traditional chain of suppliers and distributors, such as public and financial organizations (L. Thomas & Autio, 2014). Though SIBs can be considered part of a business ecosystem, little has been researched about their role in the ecosystem development. In a broader context, Clarysse, Wright, Bruneel, and Mahajan (2014) showed the importance of public banks for the emergence of a knowledge ecosystem in a technology hotspot. Still, in general, public finance organizations are placed in the periphery of the ecosystem boundaries, having low influence in core contributions that explain how a business ecosystem unfolds (Moore, 1996).

For clean energy sectors, as the wind generation, the assessment of business ecosystems dynamics can assist the understanding about how to catalyze investments in these areas, as many interdependent organizations must align their strategies to succeed (Alam & Ansari, 2020; International Renewable Energy Agency & Climate Policy Initiative, 2020). This is notably relevant in developing countries, such as Brazil, where late industrialization of certain areas and risk aversion in private capital markets are recognized characteristics, which can hinder relationships that are important for the development of business ecosystems (Mazzucato & Penna, 2015b). In this case, SIBs seem to be well positioned to craft holistic policies that stimulate the complex interactions needed in energy sectors, also addressing the long-term landscape that energy infrastructure investments are inherently inserted (Geels, 2014; Lewis & Wiser, 2007; Mazzucato & Penna, 2015b).

From a practical standpoint, further understanding about the development of business ecosystems related to clean sources of energy is critical for the viability of investments in the area, to accelerate the increase of their participation in the energy mix, and for the development and deployment of innovations (International Renewable Energy Agency & Climate Policy Initiative, 2020). At the same time, SIBs can perform important roles in this context, influencing directionality of techno-economic systems by, for example, financing certain innovations or withdrawing support to specific areas (Geddes et al., 2018). Therefore, the results are expected to contribute to policymakers involved with public finance to cleaner energy sources, clarifying possible pathways to support them, based on the case study.

In relation to the theoretical background, the contributions of this research are twofold. First, although pointed as an important characteristic, the evolutionary aspect business ecosystems can benefit of further understanding, which is corroborated by calls for deeper analysis (Chen, Rong, Xue, & Luo, 2014; Gawer & Cusumano, 2014; L. Thomas & Autio, 2014). This is commonly questioned as the metaphorical relation with natural systems many times disregards the influence of conscious choices in opposition to random variation, or critic differences in adaptation processes (Peltoniemi, 2005; Scaringella & Radziwon, 2018). In this study, this is dealt by bringing together coevolution and the ecosystem health to the same framework. The concept of health focuses on the influence of a central actor, a keystone specie, that take actions in order to increase health measures and pushes the whole network to other stages (Iansiti & Levien, 2002). Second, it offers a different point of focus by exploring the role of SIBs in the process. Due their proximity to several other public institutions that take part in the design of the business environment, and their access to sizeable financial resources, these institutions may exert strong influence over markets and sectors (Griffith-Jones & Ocampo, 2018). Still, although their relevance in the countries and regions they operate, their role in the development of a business ecosystem is yet to be explored, and, as such, this study attempts to contribute to the topic.

To provide in depth assessment of the case, an exploratory qualitative study was conducted among specialists on the BNDES. More specifically, the research was conducted through semi-structured interviews and complemented with secondary data from policy papers, market studies related to the wind energy sector, databases containing financial information about wind energy projects, gathered from Brazilian institutions related to the energy market. The current status of the market as well as the mechanisms and policies of the Bank impacting the development of a business ecosystem in the wind energy market were examined.

In the remainder of this research the theoretical background will be presented, followed by a contextual background about BNDES and its relation to the wind energy market in Brazil. In sequence, the appropriateness and assessment of the methodology. The results of the research will be presented, followed by the discussion with limitations, academic, and managerial implications.

2. Theoretical Framework

In this chapter the theory underpinning the research questions will be analyzed and discussed, providing foundations for the empirical research. First the concepts and aspects related to SIBs in the context of funding for clean energy will described. Then, the literature review about business ecosystems will be presented, identifying key aspects impacting this specific study. Concluding, a conceptual framework will be presented to address the variables and relationships that underlying the research, combining the concepts, and establishing the foundations to answer the main research question.

2.1. State Investment Banks and Their Involvement with Clean Energy

In this part, the origin of State Investment Banks will be briefly introduced, followed by the discussion in literature about the logic behind their agency, with focus on the context of funding to clean energy sources. This part of the study serves as a base to answer SQ1: *What are SIBs and how is their involvement with clean energy sectors?*

2.1.1. Operational History and Foundations

SIBs appeared in Europe in the mid-19th century. However, their modern versions, with structures and missions more similar to the ones seen today, have roots in the period of post-World War II (Mazzucato & Penna, 2015a). The German Kreditanstalt für Wiederaufbau (KfW – meaning 'reconstruction credit institute'), and the Japan Development Bank, were founded, respectively, in 1948 and in 1951, with clear mandates to help in the reconstruction of industries and infrastructure of their nations. During the same period, the Industrial Development Bank of Canada, and the Brazilian Banco Nacional de Desenvolvimento Econômico e Social (BNDES – literal meaning 'National Bank of Economic and Social Development') were also created in order to provide economic aid to specific markets and to accelerate industrial development in their countries. Since then, these kind of organizations have been a relevant public tool to direct investments in scenarios of both stability and crisis, besides contributing to the socioeconomic development of the regions where they act (The Brazilian Development Bank, 2020).

Throughout time, other SIBs were created around the world. Luna-Martinez and Vicente (2012) identified 286 of them, 29.7% in Asia, 24.5% in Africa, and 17.8% in Latin America and Caribe. Griffith-Jones and Ocampo (2018) reported 520 national development banks in 185 countries, with some countries having more than one. Although, the creation and pervasiveness of these organizations are in general attributed to the existence of market failures (Griffith-Jones & Ocampo, 2018; Mazzucato & Penna, 2015a), they are not only present and relevant in underdeveloped or developing economies. The KfW is one example of a resilient SIB from a developed country, that recently performed an active role in the transition process of the German energy infrastructure, known as 'Energiewende' (Griffith-Jones, 2016). Even in developed countries market failures may be present as well, at least to a certain degree, also varying among different sectors (Griffith-Jones & Ocampo, 2018). Notwithstanding, it is important to observe that the presence of SIBs providing long-term credit is deemed especially relevant for economies with less developed capital markets (Panizza, Yeyati, & Micco, 2004), and even more for industries with high capital intensity (Mazzucato & Semieniuk, 2018).

Credit coordination problems during economic crisis is one case of market failure where SIBs can actively address. They may use their credit instruments to operationalize political and fiscal countercyclical measures, channeling resources to short- and long-term financing with different goals

(Gutierrez, Rudolph, Homa, & Beneit, 2011; Panizza et al., 2004). For instance, in the period between 2008 and 2009, The European Investment Bank played a critical role providing funds to promote long-term focused investments in fixed assets and, at the same time, short-term loans to sustain employment (Mazzucato & Penna, 2015a).

While problems related to economic cycles may be related to liquidity, access to substantial amounts of funds, and capacity to timely inject them in economy, other market failures can lead to structural gaps, as information asymmetries and externalities (Gutierrez et al., 2011). The first raises transaction costs especially to first time borrowers, and the latter relates to outcomes that spillover in unpredicted ways and to unforeseen areas. Both are hard to be internalized by the private market, and thus, they are not reflected in financial analysis of infrastructure projects (Gutierrez et al., 2011). The lack of track records and the inability to assess positive externalities of new sectors (or negative externalities of traditional ones), hinder private players to divert resources from one area to another (Griffith-Jones & Ocampo, 2018).

Infrastructure investments in the energy sector have some relation to the previous presented types of market failures, which justifies the actions of SIBs (Rennkamp & Perrot, 2016). In the case of externalities, as an example, health problems caused by the pollution originated during the burn of fossil fuels can be considered as a negative externality of investments in coal or oil based thermoelectric power plants. Such example is informative, as differently than other energy transitions or revolutions in history, the recent option towards more sustainable sources rely less in cutting edge innovations – that deliver way higher performance or extremely reduced costs compared to more pollutant options – and more in social and ecological visions of desirable outcomes (Fouquet, 2016). In the transition from wood, animal power and natural sources (still primitive mills based on hydro and wind power) to coal, the combination with steam engines boosted productivity and added flexibility in the industrial sector (Fouquet, 2016). Similar process was seen in the combination of petroleum and internal combustion engines (Sovacool, 2016). Thus, the process of sensing and weighing externalities are increasingly more important in the decisions of resource allocations of private and public players in the current energy infrastructure landscape (Unruh, 2000).

The aforementioned combination between energy sources and related innovations, can also be connected to information asymmetries, as a parallel is traced from the current state of the industry following Meadowcroft (2009):

> *The modern fossil fuel economy displays characteristics of a mature sociotechnical domain, with close integration among the components of the hydrocarbon industry (exploration, extraction, transport, combustion, retail); interdependence with support and supply*

enterprises (finance, insurance, maintenance, equipment manufacture, training, and research); co-evolution with other functional subsystems (chemical industry, electricity distribution, transport, agricultural production); and with broader patterns of human activity and settlement (the design of cities, patterns of international trade). (p. 329)

This symbiotic evolution with other social, technological, and economical structures, lock-in investments into a self-reinforcing loop (Unruh, 2000). Participants of the market have increasingly more information and incentives to maintain exchanges within the paradigms already known, while projects which cannot be assessed adequately or for which the risk profile is beyond the market's risk appetite, usually face higher barriers to receive credit (Lazzarini, Musacchio, Makhoul, & Simmons, 2017). This scenario forms strong path dependencies, likely embedding energy transitions in an extended time frame of resources competition and resistance from entrenched actors connected to the current dominant sociotechnical design (Fouquet, 2016; Sovacool, 2016).

Thus, solely relying in Schumpeterian entrepreneurial forces and its 'creative destruction' to provide new options in the energy sector may be myopic if it disregards the incentives and inertial pressures related to the prevalent logic (Geels, 2014). Meanwhile, the 'invisible hand' of the market may fail to provide new directions even when the *laissez-faire* is socially counterproductive or suboptimal in comparison to other trajectories with more positive outcomes (Mazzucato & Penna, 2015a). This view leads to the claim for more state intervention in energy transitions and in the support to new less polluting technologies (Meadowcroft, 2009).

Market failures introduce the basic and initial logic for the agency of SIBs in different sectors of economy. However, as it will be presented next, when financing clean energy generation, they operate in contexts where the design of the sociotechnical system, built in conjunction with fossil-fuel technologies developments, requests the consideration of other aspects, such as the resistance by the current prevalent logic and actors (Unruh, 2000).

2.1.2. Funding to Clean Energy Generation

In relation to funding to clean energy generation projects, it is important to contextualize that the commitments from several nations to reduce production of carbon dioxide and other greenhouse gases, are striving to steer current pathways from causing irreversible damage to nature and society due overexploitation of fossil fuel sources of energy (Newell & Taylor, 2020; United Nations Framework Convention on Climate Change, 2015). As part of the solution, actors from the financial market are expected to provide substantial funds to projects of clean sources of energy (Bloomberg New Energy Finance, 2019a). In turn, these investments may help to limit global warming to 2 degrees Celsius by the end of the century when compared to pre-industrial levels. Yet, it is recognized that current volume of investment would have to increase drastically throughout the next decades for this goal to be achieved, let alone the main target of 1.5 degree Celsius. In fact, investment in low-carbon energy, which from 2013 to 2018 were on average below USD 300 billion per year, would have to level up to USD 800 billion annually until 2050 (International Renewable Energy Agency & Climate Policy Initiative, 2020). Financial support to bridge this gap cannot be expected to be provided solely by private sector, especially due to short-termism present in the capital market in opposed to long-term commitments usually related to energy projects (Mazzucato & Penna, 2015b). At the same time, while such kind of societal challenge requires involvement of a multitude of independent actors, the urgence of the matter demands resourceful institutions to assume central roles coordinating part of the process (Mazzucato & Penna, 2015b).

In this scenario, SIBs demonstrate willingness to make use of their position to strategically address this situation (D'Orazio & Valente, 2019; Geddes et al., 2018). Their access to substantial capital resources, patient finance, and propensity to participate in high-risk projects can provide directionality towards particular innovations that offer different options to the dominant fossil fuel-based energy industry (Mazzucato & Semieniuk, 2018). Moreover, considering the presented logic based on market failures, SIBs also display high capacity to internalize positive externalities of clean energy projects (Lazzarini et al., 2017). In other words, they are able to better capture social and environmental values, translating them in favorable financial conditions to projects where the private capital market decline support by solely focus on financial and risks aspects (Mejia-Escobar, Gonzalez-Ruiz, & Duque-Grisales, 2020). This behavior can be seen in subsidized interest rates offered by different SIBs to projects of clean energy generation with incipient technologies, as wind and solar energies (Bloomberg New Energy Finance, 2019a). By championing these technologies, a way is paved for them to move from the experimental to the deployment level, giving them the possibility to be evaluated, compared and, eventually, competing with more traditional and pollutant sources of energies (Park, 2007). According to Griffith-Jones (2016) show-casing new technologies and sectors in initial phases of deployment is precisely the role development banks should assume to start major structural transformation.

SIBs also address the current sociotechnical regime resistance by diverting resources from fossil-fuel energy generation projects to cleaner options (Mazzucato & Penna, 2015b). This can be observed by the refraining to provide funds to energy generation projects that result in high-carbon production, as BNDES did in 2017 when adapted its policies to no longer support coal-fired thermoelectric plants (The Brazilian Development Bank, 2018). This way they signal actors in the energy sector which path they will follow, ensuring their long-term commitment, while also stimulating others to pursue the same. This behavior is aligned with practices in energy transition management, where besides promoting new pathways, confronting incumbent inertial pressures that aim to maintain the status quo are part of the efforts (Geels, 2014).

To support these new sectors that steer away from the prevailing energy sources, SIBs might have to engage into more than providing sizeable resources, as they face a societal challenge (Mazzucato & Penna, 2015b). In this case, the sole offer of substantial funds with favorable conditions might not meet an enough developed market or it might not spur the dynamic interactions between other actors, which give support to major social changes (Mazzucato & Penna, 2015b). Social structures and procedures needed for the development of certain sectors may have to be crafted cooperatively with other organizations. This can be seen in partnerships between academia, industry, and government – in this case public financing channeled by SIBs – focusing on knowledge generation, applied R&D, and education for skilled labor, aiming to support the evolution of clean energy sectors (Chen et al., 2014).

In the financial area, the development of specific contractual agreements, tailored to the specificities of new energy sectors, can serve as benchmark for the market in subsequential projects. Credit instruments as project finance, where the loans are backed by the projected cash flows rather than the balance sheets of its sponsors, is an example of a mechanism used by SIBs to fund clean energy projects which was followed by the private capital market (Ramos & Studart, 2018; Steffen, 2018). Co-financing – when different organizations participate in loan operations and share operational and financial risks – also can be used to stimulate the private capital market, as private banks, through sharing of knowledge and experience, acquired by SIBs in initial projects (Geddes et al., 2018).

Industrial policies can also be addressed in the process, through minimum local content requirements. Although criticized for having a protectionist characteristic (Stone, Messent, & Flaig, 2015), this type of policies can contribute to stimulate local component production, mainly in developing countries (Hansen et al., 2020). In general, these regions are behind in technical knowledge and application of clean energy generation technologies, making it difficult to operate when fully depending on imported items and services, let alone to locally develop subsequential technological improvements (Lewis & Wiser, 2007; Rennkamp & Perrot, 2016). Therefore, where there is no market or incentives for other players to commit their resources, SIBs may have to assume seminal roles to create a conducive environment and to reduce barriers faced by other actors.

Geddes et al. (2018) summarize some of the actions taken by SIBs into specific roles, when these institutions invest in clean energy innovations. Accordingly, SIBs assume different roles to successfully address barriers faced by other actors and stimulate their participation in the development of both the financial sector and the technology system:

- Capital provision role: projects with very large upfront capital costs may configure important barrier to entry, discouraging possible investors, which can be addressed by

SIBs through their access to substantial large governmental resources or international funds.

- De-risking role: concessional finance with interest rates below the market and providing guarantees as operationalizing funds for eventual defaults, are some of the ways SIBs perform de-risking.
- Educational role: SIBs develop internal capabilities when engaging with technical areas and specialists of the sectors they aim to foster. The accumulated knowledge and expertise are shared with other actors as investors and other financial institutions.
- Signaling role: When SIBs develop a reputation for expertise in determined area, there is the understanding of other actors that investments in such sectors are worthy, thus they follow based on trust.
- First or early mover role: Differently from the signaling role, which results in the private sector crowding-in directly, this role crowds-in private investment to subsequent future projects, by generating initial track records to some sector.

Complementarily, Mazzucato and Penna (2015a) present the more traditional roles defined as countercyclical and developmental. While the first relates to the correction of economic cycles of expansion and retraction, the latter emphasizes the importance of funding to public goods with high social impact. The authors also explore the new venture support role, which aims in providing support especially to small and medium enterprises, entrepreneurs, and startups, that otherwise would be underfinanced by the private market. Lastly, the mission-oriented role is conceptualized as a new and different role from previous ones. While the financial gap, rooted in market failures logic, justifies the participation of a SIB in the market, in this role their engagement into coordinating the development of new technologies, firms, sectors, and markets, goes beyond the expected actions of these institutions, helping making things happen that otherwise would not (Mazzucato & Penna, 2015a). Thus, SIBs investing in clean sources of energy strive to create a conducive environment for other actors to join and deploy their resources (Mazzucato & Penna, 2015a). More than that, they act as catalyzers, accelerating the deployment of projects related to clean energy infrastructure, taking advantage of their position while shaping the energy landscape (Geddes et al., 2018; Griffith-Jones, 2016). In this process, SIBs are displaying capacity to coordinate efforts of public and private agents, occupying central roles in the process of adoption and expansion of sustainable infrastructure (Studart & Gallagher, 2016).

However, such mechanisms may produce only short-term competitiveness advantages for clean energy options if they do not develop structures that lead them to keep evolving without necessarily having subsidies (D'Orazio & Valente, 2019). Therefore, it is also recognized that such support is expected – and desired – to diminish as other sources and players step in, as the case of the KfW and the solar photovoltaic industry in Germany (Griffith-Jones, 2016). As such, they provide support for a determined period and as result it is expected that enough stability gives rise to self-sustained and perennial ecosystems. In this scenario, it can be glimpsed the importance for these organizations to increase measures of ecosystem health, where other actors can evolve and support ongoing and future investments – concept that will be presented in the next section.

2.2. Business Ecosystem

As presented in the previous section, for investments in new clean energy effectively take place, it is necessary coordination of multiple actors from a variety of areas in society. This makes the assessment of ecosystems aligned and relevant for the topic. Hence, in this section the concept of business ecosystem will be presented, along with the key aspects derived from literature that impact its evolution and consequent development. This part of the research contributes with insights to answer SQ2: *How does a business ecosystem develop?*

2.2.1. Definition

The term ecosystem in organizational management field is attributed to Moore (1993), who sought to explain how companies build interactions with other business actors as a way to successfully deploy innovations, while working both competitively and cooperatively. In his view, this complex interplay between competitive and cooperative strategies is the mechanism that explains the evolutionary characteristic of an ecosystem and differentiate it from other ways of assessing business alliances and networks. Using such biological approach instead of more mechanistic traditional views implies that the activities performed by different actors are symbiotically integrated and contribute for the prosperity of the system as a whole, not only impacting dyadic relationships nor being restrained to an unique industry (Jacobides, Cennamo, & Gawer, 2018). Business ecosystems are then defined as the multilateral relationships of many interested parts aligned around a focal value proposition, creating, sharing, and capturing value while coevolving individual and collective strategies (Jacobides et al., 2018; Moore, 1993; L. Thomas & Autio, 2012).

It is also recognized that differently from the biological counterpart, a business ecosystem is a social structure and, thus, conscious choices play an important role in evolutionary processes as variation, selection, and adaptability (Peltoniemi, 2005). As such, it can be expected that participants proactively chose environments and relationships that best serve their individual strategies and, inversely, adapt strategies to cope with external changes. Thus, the establishment of an alignment structure with other business actors is seen as a cognitive effort to combine internal and external resources and capabilities into a coherent joint value proposition (Adner, 2017; Jacobides et al., 2018; Peltoniemi, 2005; L. Thomas & Autio, 2014).

Using such biological approach implies that the activities performed by different “species” – i.e., the business actors from the organizational environment – are symbiotically integrated, yet with some of them having greater impact in health, evolution, and, ultimately, success of the system as a whole (Jacobides et al., 2018). These important species or central actors, commonly labeled as leaders (Moore, 1993), keystones (Iansiti & Levien, 2004), or orchestrators (Cennamo & Santaló, 2019), sustain a stable core of interdependent actors that align their strategies, developing new capabilities which ensure present and future value generation (Adner, 2017; Iansiti & Levien, 2002). In this structure, such alignment and stability are usually furnished by the affiliation to these central actors who, in turn, coordinate other’s roles, the flow of value through the chain, positions of the other members, and governance policies. While the central figure may shift over time, their presence keeps being deemed important by other members of the community as they stimulate investments towards a common vision (Moore, 1993), strive to provide health to the ecosystem (Iansiti & Levien, 2004), and manage the coevolution of the community through a four stages process: birth, expansion, leadership, and self-renewal or death (Jacobides et al., 2018; Moore, 1993).

The openness and flexible features presented in the ecosystem initial works also provided a fruitful terrain to be used with prominent areas in management studies entrepreneurship environments (Cantner, Cunningham, Lehmann, & Menter, 2020; Isenberg, 2010), industrial networks (Best, 2015), digital business (Senyo, Liu, & Effah, 2019), and technological platforms (Cennamo & Santaló, 2019; Gawer & Cusumano, 2014). Innovation ecosystem is also a term commonly used in the field, sometimes describing the same settings found in business ecosystem studies (Järvi & Kortelainen, 2017; L. Thomas & Autio, 2014), in other cases considered as an evolution of the original concept (Granstrand & Holgersson, 2020), and also as a different stream inside the ecosystem logic (Aarikka-Stenroos & Ritala, 2017; Valkokari, 2015). One of the ways the differentiation is made regarding the intention of the community of organizations. In this sense, innovation ecosystems may be seen as the initial stages of a business ecosystem, comprised by a community of members combining research efforts, mainly on breakthrough technologies, aiming to develop a viable product or service that brings an innovation to the market (Adner & Kapoor, 2010). In this study, the concepts from other works mentioning innovation ecosystems will be considered as an exchangeable term to business ecosystem, as Moore (1993) clearly stated that “in a business ecosystem, companies coevolve capabilities around a new innovation” (p. 76). However, it is challenging to define exactly when an innovation leaves this status behind. Particularly, in the case of products that have already passed by some stages of development in industrialized countries, and after that reach developing countries, that in turn, are trying to catch up industrial lagging – which is the case of the topic of this research. That is the reason for this study to use the broader term of business ecosystems, and also its broader application.

2.2.2. Coevolution

Within this frame of reference, a first important feature to understand how ecosystems develop is the coevolution of different participants, reinforced by reciprocal cycles of change (Moore, 1993; Peltoniemi & Vuori, 2008). In natural ecology, coevolution does not necessarily lead to an enhancement of a feature or change to a condition that might be considered superior. It basically entails that a change in one species impacts the fit of another, and vice versa (Moore, 1993). However, in the context of business ecosystems, organizations are motivated by the search of advantages which indicates that changes and relationships between species are planned to attend demands usually connected to better performance, reduced costs, or specific standards, thus evolution is not a result of totally random variations (Peltoniemi, 2005). Adner (2017) complements proposing the non-decomposability of multilateral relationships, where, taken parties A, B and C as an example, a successful contract between A and B is undermined by the failure of the contract between A and C. Analyzing a relationship and the related changes of two parties in isolation may lead to a false conclusion and lack of understanding about the coevolution of these members. Hence, the concept of business ecosystems goes beyond dyadic analysis, encompassing multiple simultaneous relationships.

In his seminal work, Moore (1993) proposed that coevolution leads the development of an ecosystem through four stages, starting at birth, followed by expansion, leadership, and, finally, self-renewal or death. In the initial stage, a sound customer value proposition is crafted by a leader organization in order to introduce an innovation to the market. At this point, from the position of the leader, cooperation usually pays off as follower companies help to fulfill the value package of the focal offer (Moore, 1993). During expansion, the efforts are related to scale up and outcompeting other ecosystems. The leadership stage presents a scenario where the competition inside the ecosystem itself is intensified, as a robust community of suppliers needed for the expansion phase also provides stability, leading them to start expanding by taking over other's suppliers activities (Moore, 1993). Finally, in self-renewal the ecosystem face pressures from new innovations and must reorganize the value blueprint in order to keep its relevancy or face death. Though some resemblance can be seen with the product life cycle, the emphasis is placed on the management of interactions, relationships, and interdependences between partners, suppliers, and even customers, in a firm- and network-level (Dougherty & Dunne, 2011; Williamson & De Meyer, 2012).

It is important to note that the managerial challenges and characteristics presented in each phase may be blurred and not follow a linear pattern as the iterative process of exchanges in such complex system result in high levels of unpredictability (Moore, 1993; Peltoniemi & Vuori, 2008). Diverse conflicting views may increase internal rivalries even in initial stages and existing ecosystems may attack nascent ones, hindering them to achieve other phases. Yet, usually, at the beginning of an ecosystem there is greater technological uncertainty leading to more cooperation between actors to create value and later more competition takes place for the appropriation of that value (Adner & Kapoor, 2010; Moore, 1993). This idea suggests that despite being hard to predict how the development of an ecosystem progresses and the exact challenges in each moment of its evolution, by assessing the behaviors of the participants it is possible point out its stage of maturity and, from this understanding, promote coordinated actions to strengthen it and to increase general health.

In the initial stages, businesses compete for different sorts of resources, from financial to human, blend them in the context they are inserted, and exchange value with stakeholders, partners, competitors, and customers, spurring the dynamic interactions that characterize an ecosystem (Moore, 1993). Thus, it is recognized that businesses do not evolve in a vacuum and, logically, neither the ecosystems they create or participate. One or more leader organizations emerge right from the inception, coordinating the efforts of the other participants to sped-up the ongoing improvements and to manage the challenges related to balancing cooperation and competition during the ecosystem development (Dedehayir, Makinen, & Ortt, 2018; Moore, 1993). To do so, they exploit not only their own position and relationships in a determined value blueprint, but the positions of partners that are scattered among several different industries. Besides, they leverage their position to design a coherent collective value proposition attracting important follower organizations and hindering them from engaging into other emerging ecosystems (Moore, 1993).

2.2.3. Roles

As initially presented above, one key characteristic of business ecosystem is the presence of species playing central role for the formation of a coherent network of organizations, institutions, and other market actors. These important species or central actors are commonly labeled as leaders (Moore, 1993), keystones (Iansiti & Levien, 2004), or orchestrators (Cennamo & Santaló, 2019). Yet, there is discussion about the extent to which the leadership role is indeed central to ecosystem development. Some authors argue that it is not possible to control the actors since each one is playing for their own interests, pointing that an organization population is a self-organizing system, due to a decentralized decision making structure (Peltoniemi, 2005). Jacobides et al. (2018) seems to agree with this view when defining an ecosystem as non-fully hierarchically controlled set of actors. However, as there are multiple interests, some sort of central coordination seems needed to align different players towards a same direction and most of the main studies seem to converge towards an idea in which the leadership is a fundamental trait for the existence of an ecosystem (Clarysse et al., 2014; Gawer & Cusumano, 2008; Iansiti & Levien, 2004; Moore, 1993). Complementarily, as recognized even by Peltoniemi (2005) "in market system economies the market functions as enabler of self-organization" (p. 68), however, in any market economy "there are countless of government interventions such as business subsidies, import duties and publicly funded development projects" (p. 68), thus, in practice, strong market forces, embodied by public actors, heavily influence self-organization and, consequently, shaping the ecosystem.

To cope with the challenges of continuous changes and innovations that fuel the ecosystem development, leader companies become central ecological contributors, holding bargaining power over other members (Moore, 1993). In this position, they have a pivotal characteristic of defining not only how value is created, but also shared and captured by all the members of the ecosystem (Jacobides et al., 2018; Moore, 1993). In this sense, Moore (1993) emphasized how ecosystem leaders as Apple, IBM, and Wal-Mart occupy central positions and yet are deemed important by other members of the community as they enable the shared investments toward a common vision. Therefore, centrality requires management of tensions between developing a shared vision to influence other actors and the leader's own self-interests (Valkokari, Seppänen, Mäntylä, & Jylhä-Ollila, 2017), and between capturing value while nurturing relationships that positively impact the ecosystem as a whole (Oskam, Bossink, & de Man, 2020).

To regulate this environment and balance the individual and collective interests, leaders also assume activities involving the establishment of roles, positions of members, key coalitions, and even the flow of value through the linkages (Cennamo & Santaló, 2019; Leten, Vanhaverbeke, Roijakkers, Clerix, & Van Helleputte, 2013; Valkokari et al., 2017). This coordination of functions, positions, membership, and partnerships is commonly defined as orchestration (Cennamo & Santaló, 2019). Hence, it is expected that a healthy interactions between leaders and follower organizations enables the shared investments toward a common future and, consequently, the emergence and development of the ecosystem (Moore, 1993).

Although compelling, the complexity of the concept raised by Moore, which requested a holistic view of multiple relationships, did not yield a stream of related academic researches until Iansiti and Levien (2002) further explored roles, strategies, and measurements related to the topic, defining how these elements impact the ecosystem health (Järvi & Kortelainen, 2017). The authors see the ecosystem as composed by suppliers, distributors, outsourcing firms, makers of related products or services, technology providers, and a host of other organizations. The main objective of ecosystem participants is extending the radius of influence in resources and markets beyond direct control. They also posited that the dynamics of the participants in this loosely interconnected network dictates prosperity of the whole system and provides a stable core around which new capabilities can be built. Such stability is developed around central actors or hubs, defined as keystones (Iansiti & Levien, 2004). Members of the ecosystem interconnect among each other expanding the network, although more commonly, they couple to keystones, who define the dynamics of the relationships (Iansiti & Levien, 2004).

Just like leaders (Moore, 1993), keystone species make use of their resources or advantageous positions to develop connections and exert influence over other members (Iansiti & Levien, 2002). They also assume responsibilities and take actions that propagate through the entire system, being beneficial to at least part of the other participants. Keystones can increase the overall health of the ecosystem by creating meaningful diversity of functions and products, promoting stability, providing foundations on which other species rely, and limiting or removing species that otherwise would reduce productivity. Although being central figures, not necessarily they will be the largest nodes in the network. If instead, an overly expansionist strategy is adopted with an increasing number of nodes being occupied by the same actors, they risk becoming dominators, who eventually start to jeopardize its own ecosystem (Iansiti & Levien, 2002). Complementing the roles identified by Iansiti and Levien (2002), niche players form the biggest part of an ecosystem, but with less connections than the other roles previously presented.

Since early works related to the topic there were always efforts on identifying central figures as keystones and leaders as their actions help to understand the creation and evolution of ecosystems, besides clarifying its boundaries and providing a rational for its applicability (Iansiti & Levien, 2002; Moore, 1993). Accordingly, Adner (2017) labelled this approach as ecosystem-as-affiliation, emphasizing how other studies following this line focused on assessing network density, centrality, and interdependencies from the standpoint of specific central actors. He also offered a complementary approach, delimitating the boundaries of ecosystems through the joint value proposition that aligns the interactions of a diverse multilateral set of members. By changing the unit of analysis, the conceptualization of ecosystems was divided into one ruled by affiliation to a focal actor or platform and another defined by the structure that must exist for value to be generated and captured. In this last case scenario, the integration is forged through complementarities of solutions, which allows members to coordinate without a full hierarchical structure (Jacobides et al., 2018). Still, living in the same environment, the organisms within an ecosystem share some degree of interdependency, requiring alignment among them for value to be generated (Adner, 2017). Consequently, they tend to increasingly commit to a collective effort, building complementarities that bound them together to a non-transferable arrangement and drives the pace of their coevolution and co-specialization (Jacobides et al., 2018).

Another aspect that makes the identification of roles important in this matter can be related to the fact that the ecosystem construct usually encompasses while also transcends other traditional categorizations in strategy studies as networks, value chains, alliances, and regional industrial clustering (Adner, 2017). This poses a challenge to define the locus and scope of analysis (Shipilov & Gawer, 2019) and it is reflected in many studies which place efforts to disentangle the ecosystem's factors from the ones of correlated areas, aiming to justify the usefulness of summoning this view (Adner, 2017; Kapoor, 2018; Shipilov & Gawer, 2019).

As the applications of the theory encompassed other contexts and areas, other central roles were also delineated. Orchestrators of open collaboration platforms take responsibility to balance tensions by adopting governance systems to sustain generativity and avoid value erosion (Cennamo & Santaló, 2019). Anchor tenants act in the knowledge generation process, collaborating and eventually transferring technological research results to business ecosystems (Clarysse et al., 2014). Some of these roles inherently possess overlapping characteristics and with previously presented ones, as leaders and keystones, being more applicable depending on the context that is focus of assessment. However, an excessive focus on the interdependencies involving only leader companies and followers, usually characterized by the relationship between a focal company and suppliers and complementors, may be seen as narrowing down the analysis and risking providing little further insights than other approaches (Oh, Phillips, Park, & Lee, 2016).

Moreover, the challenges and number of activities needed in the different stages of a business ecosystem seem to be plentiful to be divided between two types of roles. Focusing on initial stage, Dedehayir et al. (2018) undertook a systematic literature review, distinguishing four main group of roles during an ecosystem genesis and expanding the knowledge: leadership, direct value creation, value support, and entrepreneurial, which are presented in **Table *1***. Ecosystem RolesFrom this study, it is important to note as well that not all the roles are directly connected to value creation, as the champion role that supports ecosystem construction by building connections and alliances between actors and providing access to local and nonlocal markets. Even activities linked to leadership role may be seen as more supportive than directly connected to value creation, as designing roles of ecosystem actors. As these roles are identified, the understanding of how an ecosystem emerge can be better fulfilled and it is possible "to determine how it will be shaped and adapted later to deliver value embedded in its products and services" (Dedehayir et al., 2018, p. 26). Breaking down activities also leads to the understanding that some actors can play different tasks of multiple roles at the same time.

Table 1. *Ecosystem Roles*

Group	Role	Activity
Leadership roles	Ecosystem leader	Ecosystem governance - Initiates, maintains, and develops ecosystem functionality by: (i) designing roles of ecosystem actors (ii) coordinating internal and external interactions (iii) orchestrating resource flows between partners

Group	Role	Activity
		Forging partnerships - Creates a network by: (i) attracting and gathering relevant partners together (ii) forming links and alliances with firms owning various resources from different industries (iii) creating collaboration between parties in alliances (iv) stimulating complementary investments and providing opportunities for niche creation
		Platform management - Provides technical basis for market to function by: (i) designing and building a platform (ii) opening platform, data, and infrastructure to build user-community and enhance value from producers (iii) orchestrating complementor innovations to align with platform
		Value management - Creates and captures value by: (i) bundling offerings and supplied components (ii) stimulating value appropriation for all producers and the end-user
	Dominator	Conducts mergers and acquisitions in related fields
Direct value creation roles	Supplier	Delivers key component offering by supplying materials, technologies, and services, to be used by others in the ecosystem
	Assembler	Provides products and services by: (i) assembling components, materials, and services (ii) processing information, supplied by others in the ecosystem
	Complementor	Delivers key complementary offering by: (i) attaining compatibility with the platform (ii) utilizing the design of the ecosystem's other offerings (iii) meeting customer specifications
	User	Contributes to value creation by: (i) defining a problem or need (ii) developing ideas based on product data provided by ecosystem leader (iii) engaging in transaction and purchasing of offering (iv) integrating key complementarities and using the product or service
Value creation support roles	Expert	Supports primary value creators by: (i) generating knowledge from basic and applied research (ii) providing consultation, expertise, and advice (iii) encouraging technology transfer and commercialization
	Champion	Supports ecosystem construction by: (i) building connections and alliances between actors (ii) interacting between partners and sub-groups (iii) providing access to local and nonlocal markets
Entrepreneurial ecosystem roles	Entrepreneur	Starts new venture around a vision by: (i) co-locating in a region with others (agglomeration economies) (ii) setting up focused network of staff, suppliers, customers, and complementors (iii) coordinating collaboration between research and commercialization partners
	Sponsor	Supports new venture creation by: (i) giving resources to entrepreneurs (ii) financing low-income markets (iii) purchasing and co-developing offerings of firms (iv) linking entrepreneurs to other ecosystem actors

Group	Role	Activity
	Regulator	Supports entrepreneurial activity and opening avenues for ecosystem emergence by: (i) providing economic and political reform (ii) loosening regulatory restrictions

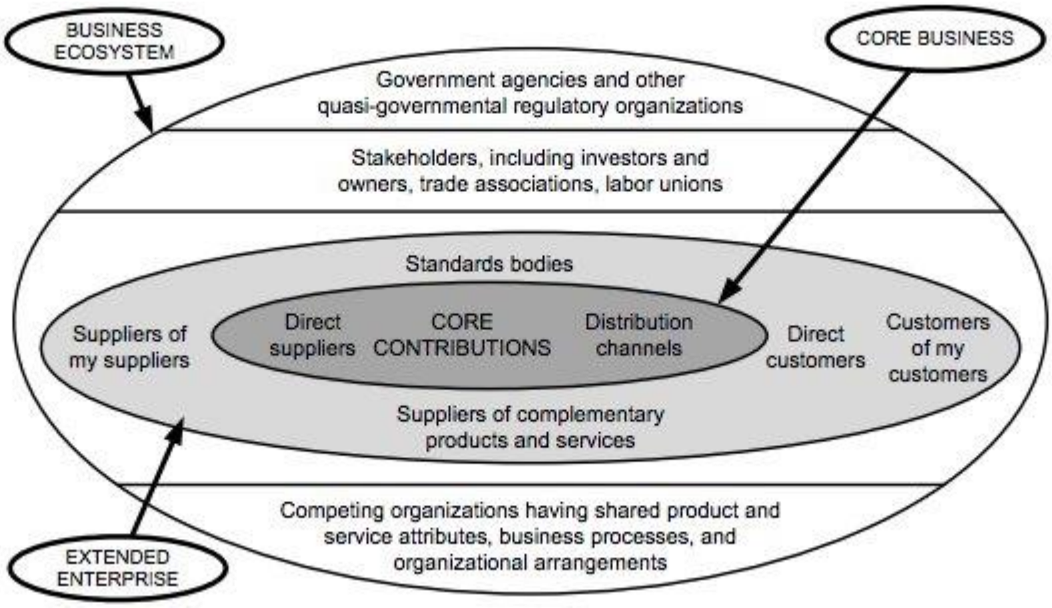
Note. Adapted from Dedehayir et al. (2018).

2.2.4. Structure and Relevance

Discussions were raised on whether the business ecosystem construct could provide a new lens through which the relationships between organizations could be assessed (Anggraeni, Hartigh, & Zegveld, 2007; Kapoor, 2018). Ritala, Agouridas, Assimakopoulos, and Gies (2013) use the ecosystem construct as an exchangeable term for a network of inter-firm collaboration structure. Anggraeni et al. (2007) saw it as a still weak metaphor that could be used as a perspective to study relationships between companies and their business networks. In contrast, according to L. Thomas and Autio (2014) an ecosystem concept is similar to value networks, but broader, as it covers the community of organizations, institutions, and individuals that impact the fate of the focal firm and its customers and supplies, including complementors, suppliers, regulatory authorities, standard-setting bodies, the judiciary, and educational and research institutions. They also see it as an extension of value chain as it includes participants from outside the traditional set of suppliers and distributors, such as outsourcing companies, financial institutions, technology providers, competitors, customers, and regulatory and coordinating bodies. This view is aligned to Moore (1996), who accounts for the influence of actors from distinct areas in the structure of a business ecosystem (Figure 1). In complement, Adner (2017), who also efforts to disentangle the factors related to the ecosystem logic from other traditional approaches as networks and alliances, supply chains and value chains, or systems of technology, concludes that there is value invoking an ecosystem logic when a multilateral alignment among a diverse set of organizations is needed for a value proposition to materialize. Therefore, an ecosystem pervades a variety of industries while is inserted in a business environment, offering greater systematic assistance to assess cooperative networks and more details to understand the strategic logic of change (Adner, 2017; Moore, 1993, 1996).

Furthermore, the consideration of peripheric actors in the construction of the value proposition provides a different way to assess the strategic challenges involving competition and cooperation. This study benefits from this view by taking the actions of a government agency, more specifically a state investment bank, into account as an active member that can impact this dynamic. In general, these entities are placed in a secondary plan or not even considered in frameworks, which tend to overly focus on the relation between a focal company and its suppliers and eventual complementors, not uncommonly using the same sectors and companies in the empirical studies.

Figure 1. *Business Ecosystem*



Note. From Moore (1996).

The relevance of interactions that cross traditional views of industry boundaries presents another aspect that help to differentiate this approach from other similar paradigms (Moore, 1996). The need of cross-industry coordination, places a company as part of a broader system and not only inside the boundaries of a single industry (Moore, 1993, 1996). It is implicated that companies that focus on verticalization of activities and internalization of capabilities are being outcompeting by others that can manage such features in a community level, leveraging over the relationships between contributors and partners (Moore, 1993). Thus, it is important to point that not necessarily these companies are themselves inserted in different industries, but the joint set of activities and actors that compose the customer value proposition transpose organizational boundaries and categorizations.

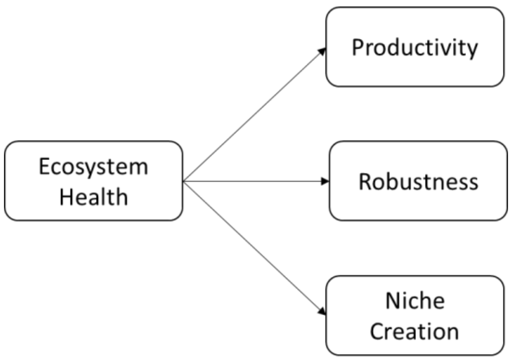
By encapsuling elements from value networks and regional clusters, business ecosystem seems a suitable lens of analysis to investigate how global societal challenges (e.g., climate change, energy security, water access, sanitation) faced by capitalist economies are being treated and how actors and mechanisms within such economies can contribute to overcome them. Particularly, the complex network of actors and specific regional challenges related to energy transition initiatives can benefit from summoning this approach. As "the ecosystem is defined by the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize" (Adner, 2017, p. 42) and many actors must alignment their efforts in this context, there is value to invoke an ecosystem logic (Adner, 2017).

Concluding, business organizations are relying less in individual and more in collective capabilities to deploy their strategies, as part of an increasingly interconnected network of entities that depend upon a joint array of actions and interactions to achieve goals and thrive (Lang, Szczepanski, & Wurzer, 2019; Panetta, 2016; Reeves, Lotan, Legrand, & Jacobides, 2019). This way they form a business ecosystem that coevolve over time when the results of the dynamic relationships within provide a healthy environment for participants to continue committing their efforts, resources, and developing innovations.

2.2.5. Ecosystem Health

Building upon the metaphor, Iansiti and Levien (2002) also define the importance of a healthy ecosystem and present some measures for it (**Figure *2***). The first, robustness, relates to the capacity of the participants to buffer against disruptions and perturbations that otherwise would pose a treat for the survival of the whole structure. Productivity shows the effectiveness of an ecosystem in converting raw materials and other inputs into reduced costs and new products. The last one, niche creation, aims to capture the increase in meaningful diversity that leads to the creation of new capabilities. Taken together these measures of ecosystem health represent the importance of stability and continuity as conditions for members to coevolve. Differently from dominators, keystones strive to positively impact these measures maintaining a healthy ecosystem and their removal may lead to catastrophic consequences as the collapse of the entire ecosystem (Iansiti & Levien, 2002).

Figure 2. *Measures of Ecosystem Health*



Note. Adapted from Iansiti and Levien (2004).

The general health of the ecosystem was introduced by Iansiti and Levien (2002) as the capacity of generating “durably growing opportunities for its members and for those who depend on it” (p. 32). A challenge to assess this aspect is related to the fact that using a comprehensive approach as the ecosystem requests a holistic view of health measures not only in the individual level. Nevertheless, the idea of evaluating the health of the whole system seems compelling as other important aspects of the ecosystem may be deeply impacted by this. For example, it seems unlikely that coevolution processes will take place in an ecosystem where participants are suffering. In this case, competition would leave few space to cooperation and the main players would aim to physically dominate the system, absorbing other participants and their activities (Iansiti & Levien, 2002).

For what it was presented about business ecosystems it seems clear that companies striving to coordinate efforts towards a shared view of the future seek advantages provided by the integration with the other members of the ecosystem. However, it may be hard to capture the extent to which such advantages come from the collective joint of activities. Iansiti and Levien (2002) proposed to measure it through three factors: robustness, productivity, and niche creation. These measures will be further presented on the basis of what was introduced by the authors.

2.2.5.1. Robustness

This measure seeks to evaluate the capacity of the ecosystem to buffer itself against environmental change. Discontinuous waves of technological innovations place a challenge not only for individual species but for the network and may represent an exogenous threat that leads to catastrophic change for the ecosystem. At the same the presence of keystone organizations and a diverse community of interconnected members may provide the necessary stability for the structure to face and survive perturbations and disruptions. The proposed metrics for this factor are:

- Survival rates: Participants of one ecosystem will have high survival rates in comparison to other similar ecosystems or throughout time.
- Persistence of ecosystem structure: Relationships and connections are maintained, and the general structure is not affected by external shocks.
- Predictability: Changes are predictably localized, and the core will generally remain unaffected.
- Limited obsolescence: After a dramatic change in the ecosystem there is no radical termination of technologies or components used.
- Continuity of use experience and use cases: The user experience will follow a gradual process of evolution rather than being radically transformed.

2.2.5.2. Productivity

An ecosystem is also expected to be effective in converting the raw materials of innovation into lowered costs and new products and functions. The metrics for this factor are:

- Total factor productivity: The capacity and effectiveness of participants in converting factors of production into useful work, at lower costs, or with higher performance.

- Productivity improvement over time: Basically, the same evaluation as the first measure, but evaluated over time.
- Delivery of innovations: It evaluates how the innovations propagate through the participants and the advantages of developing and employing them in the ecosystem context.

2.2.5.3. Niche Creation

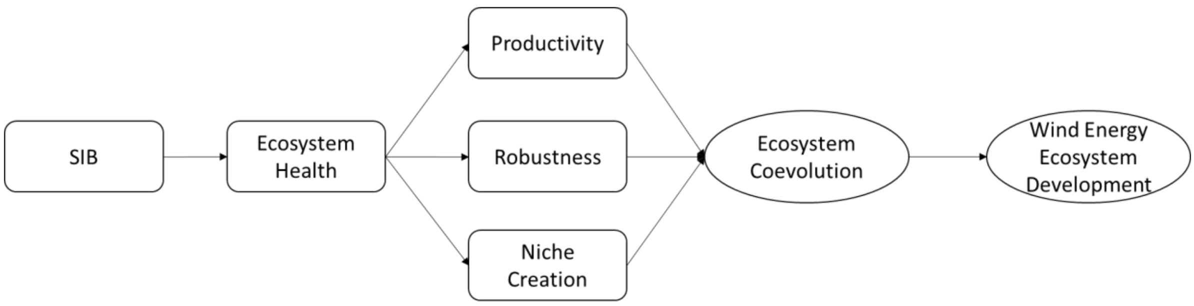
For last, niche creation concerns to levels of variety or diversity. However, a simple evaluation of the amount of it, considering that the higher the better, would hide the nuances related to this aspect. As stated by Iansiti and Levien (2002) “what matters in these systems is more the capacity to increase meaningful diversity over time through the creation of new valuable functions. In terms of the ecosystem metaphor: the capacity to create new valuable niches” (p. 37). The presented metrics are:

- Variety: The number of new options, technological building blocks, categories, products, and/or businesses created within the ecosystem in a given period of time.
- Value creation: The overall value of new options created.

2.3. Conceptual Framework

Considering what was discussed in the literature review in section 2.2, a conceptual framework is developed to visualize the important concepts and the proposed relationships. The conceptual framework elaborates how SIB contributes to ecosystem health through productivity, robustness, and niche creation.

Figure 3. *Conceptual Framework*



In the conceptual framework, SIBs are considered as having central roles in the development of wind energy ecosystems and, as such, positively impact or strive to positively impact the ecosystem health, which is measured by productivity, robustness, and niche creation. For what was presented in the literature review, it seems clear that the participants in the ecosystem will coevolve when their coexistence and interactions are healthy. In the opposite case, an unhealthy ecosystem, will lead participants to suffer and, logically, they will not have incentives to coevolve. Coevolution, in turn, is the mechanism that leads the ecosystem to next stages, ergo it develops from initial phases to more mature ones.

3. Methodology

In this section the methodology used to plan and operationalize the research will be presented. First, the research design is described, explaining the approach and justification for the methods used in the study. In sequence, the data collection process presenting the plan for it and also how it was operationalized. After, data analysis, reflections on research quality, ethical considerations, and, finally, a brief description of the case and reasoning for its selection.

3.1. Research Design

According to Hennink, Hutter, and Bailey (2011) qualitative research can be used for exploring complex social issues and, therefore, is most suitable for addressing ‘how’ questions which describe processes or behavior. Business ecosystems are commonly approached as complex adaptive systems (Peltoniemi & Vuori, 2008) and complex networks (Basole et al., 2015) which justifies the use of qualitative methods and suits the research questions proposed.

Qualitative methods, in general, are also more connected to inductive approaches which aim to condense raw textual data into a brief format, establish clear links between the evaluation or research objectives and the summary findings derived from the raw data, and develop a framework of the underlying structure of experiences or processes that are evident in the raw data (D. Thomas, 2006). As the aim of the study is to contribute to the literature of business ecosystems and state investment banks, new knowledge is expected to be generated, therefore inductive reasoning is used through the process. However, in order to narrow down the main concepts from relevant theories and refine research questions in light of the literature used, deductive reasoning is also applied, especially, in the design cycle, with inductive reasoning being more prominent in the data collection and analysis cycles (Hennink et al., 2011). This interplay of approaches follows an iterative process throughout the research.

Within the umbrella of qualitative methods, different strategies and techniques can be employed. In this study, single case study is also being applied as the objective is to gain in depth knowledge about a topic that is still being theoretically constructed, as is the case of business ecosystems. Case study is a research strategy that focuses on understanding the dynamics present within single settings (Eisenhardt, 1989). Although providing fruitful terrain to generate rich and detailed knowledge, this approach calls for extra caution in relation to generalizability of the results, as the settings of the case might be too idiosyncratic.

Finally, the methods used to gather data about the case are semi-structured interviews and documental analysis, which will be further presented in sequence.

3.2. Data Collection

In qualitative research, different methods can be employed to gather data. This study made use of two different techniques, namely document analysis and interviews. These two methods were chosen in order to provide multiple sources of evidence, which ensures the credibility of the research and helps to prevent the presence of biases (Bowen, 2009). In order to obtain rich and detailed information about the topic presented, semi-structured interviews. The interviewees will be experts in BNDES and wind energy. They will most likely not be employees working for BNDES, but rather experts working with BNDES on several projects. Considering the fact that the chosen interviewees are experts on the topic, the flexible approach of semi-structured interviews is most suitable (Frances, Coughlan, & Cronin, 2009). By using this method, the interviewer allows the occurrence of spontaneous issues to be raised by the interviewee, which may lead to a richer collection of data for the research and more in-depth information (Frances et al., 2009).

Secondary data was also collected for this research. Document analysis is especially relevant in providing a rich description of a specific case such as the mechanisms adopted by BNDES in the context of energy transitions in Brazil, and for this reason it will be used as a research technique during this study (Bowen, 2009). Since the bank is a public organization there is plenty of information to be found, which will be used to provide context within the study and to provide background information of the case discussed in the research. The data for the document analysis can be found in the online database of BNDES, which provides annual reports, sectorial analysis, and market statistics. For this study, the researcher will focus on the three types of documents mentioned above regarding the topic energy transitions. The main points that emerged in the interviews will be used to look up specific information in the online database.

To allow participants to be more comfortable and fully express themselves about views and experiences, the interviews were held in their mother language, in case Portuguese. In total, 8 interviews with 9 participants were held (two participants were interviewed in the same session), ranging from roughly thirty minutes to one hour. **Table 2** provides an overview of the participants in this research. The interviews were performed via online meetings using specific software which allowed them to be recorded whenever the interviewee agreed. For these cases the interviews were transcribed and coded still in the original language. After that the parts used in quotes were carefully translated. It is important to note that this research focuses on textual content of the discourses of the participants to understand the meaning of the communications performed, the manifest and latent content, as well as the meanings in the speech (Oliver, Serovich, & Mason, 2005). Thus, when the researcher judges that there is no gain for the goal of the research in transcribing literal sentences, adding slangs, syllabic repetitions, pauses, these will be omitted or adapted favoring clarity, coherence, fluidity, and comprehension. The researcher adopts a reflexive position in order to balance these aspects and the avoidance of losing or changing meaningful data (Oliver et al., 2005).

In case of respondent 8, recording was not allowed, then notes were made during the interview and immediately at the end enriched with details of the conversation. Data was collected following the principles of saturation point and availability sampling (Hennink et al., 2011). Thus, in some cases the level of new information seems not to be increased by sourcing extra participants, as in case of the specialists in BNDES. However, it is recognized that for other cases the data collection did not continue due to lack of willing participants – who did not answer or answered negatively to participate – or unavailability during period when the research was done.

Table 2. *Respondents*

Code	Area	Field of the Company	Activity
Respondent 1	Wind Energy Operations	Wind Park Constructor and Owner	Operation Director
Respondent 2	BNDES Specialist	Consultancy	Advisory to projects financed by BNDES including wind power plants
Respondent 3	BNDES Specialist	Consultancy	Advisory to projects financed by BNDES including wind power plants
Respondent 4	BNDES Specialist	Commercial Bank	Advisory to projects financed by BNDES including wind power plants
Respondent 5	Wind Energy Supply Chain	Wind Turbine Manufacturer	Supply Chain Manager
Respondent 6	Wind Energy Specialist	Wind Energy Class Association	Technical knowledge generation, coordination of the wind energy sector
Respondent 7	Wind Energy Specialist	Wind Energy Class Association	Technical knowledge generation, coordination of the wind energy sector
Respondent 8	Wind Energy and BNDES Specialist	BNDES	Ex employer from the area of energy of BNDES
Respondent 9	Wind Energy Specialist	International Financial Institution	Advisory to projects financed by BNDES including wind power plants

Table 3. *Documents*

Code	Document Name	Source

Document 1	BNDES - Critical reflections on the Brazilian experience in the wind sector	https://web.bndes.gov.br/bib/jspui/handle/1408/15360
Document 2	NT_EPE-DEE-NT-017-2020-r0	https://www.epe.gov.br/sites-en/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-206/NT_EPE-DEE-NT-017-2020-r0%20(English).pdf
Document 3	BNDES - Development of the wind sector in Brazil	https://web.bndes.gov.br/bib/jspui/bitstream/1408/16081/1/PRArt_Desenvolvimento%20do%20setor%20e%C3%B3lico%20no%20Brasil_compl.pdf
Document 4	Market study: Wind energy in Brazil	https://www.rvo.nl/sites/default/files/2014/08/Wind%20Study%20Brazil%202014.pdf
Document 5	Analysis of the regulatory framework for wind power generation in Brazil	https://gwec.net/wp-content/uploads/2021/01/GWEC_Analysis-of-the-regulatory-framework-in-Brazil_2011.pdf
Document 6	BNDES - Annual Report 2018_BD	https://web.bndes.gov.br/bib/jspui/bitstream/1408/18800/1/PRPer161100_Annual%20Report%202018_BD.pdf
Document 7	Regulation for the Accreditation of Machines, Equipment, Industrial Systems and Components in the BNDES Computerized Supplier Accreditation (CFI)	https://www.bndes.gov.br/wps/wcm/connect/site/2a2750df-1a44-46b7-92b1-17dd83e4aee4/Regulamento+para+o+credenciamento+de+m%C3%A1quinas%2C+equipamentos%2C+sistemas+industriais+e+componentes+-+Completo.pdf?MOD=AJPERES&CVID=lPMg17B
Document 8	Regulation for Accreditation of Wind Turbines in the BNDES Computerized Supplier Accreditation (CFI)	https://www.bndes.gov.br/wps/wcm/connect/site/10f19d81-33df-4c4c-95e0-d7909975c911/credenciamento_aerogeradores_anexo1.pdf?MOD=AJPERES&CVID=lmylw0v
Document 9	Update of the Mapping of the Productive Chain of Wind Industry in Brazil	http://inteligencia.abdi.com.br/wp-content/uploads/2017/08/2018-08-07_ABDI_relatorio_6-1_atualizacao-do-mapeamento-da-cadeia-produtiva-da-industria-eolica-no-brasil-WEB.pdf
Document 10	The Brazilian electric energy sector and BNDES: reflections about funding to investments and perspectives	https://web.bndes.gov.br/bib/jspui/bitstream/1408/920/1/O%20setor%20el%C3%A9trico%20brasileiro%20e%20o%20BNDES_reflex%C3%B5es_P-final.pdf
Document 11	Contour Global – Sustainability Report 2019	https://www.contourglobal.com/sites/default/files/2020-12/contourglobal_2019_corporate_sustainability_report_0.pdf
Document 12	BNDES and renewable energies: the cases of the sugarcane energy and wind sector	No weblink available. Electronic copy in possession of the researcher.
Document 13	Book 'BNDES and sectorial agendas: contributions to the government transition' - Chapter 5 – Electric Power	https://web.bndes.gov.br/bib/jspui/bitstream/1408/18041/1/PRCapLiv214785_Energia%20El%C3%A9trica_compl_P.pdf

3.3. Data Analysis

First of all, the interviews were recorded intending to make the analysis precise and clear. The data were collected through interviews, transcribed, and coded still in the original language they were held, aiming to keep the nuances of the participants discourses. After, the main points of the transcript of the interviews were identified and related to the main question and the sub-questions of the research. In this part of the research, both deductive and inductive reasoning are used, however they demand the researcher to analyze the information separately when following one or the other method. Deductive reasoning in this case has the objective to provide validation for the concepts, relations, and assumptions related to the conceptual framework and its underlying logic. Inductive reasoning aims to identify new aspects, not previously mapped and that can produce new knowledge about a phenomenon. The parts used in quotations were carefully translated.

Secondly, the data collected through document analysis has to be analyzed. To do this the researcher has to undertake several steps to analyze it. These steps involve skimming, reading and interpretation (Hennink et al., 2011). It is important that the researcher treats the collected data critically and does not simply rephrase words and passages. Rather, the researcher should define the importance and meaning of the document and should determine the added value it might bring to the research (Bowen, 2009). The documentary data collected will be analyzed together with data obtained from the interviews. For this reason, specific themes will emerge across the different sets of data.

3.4. Research Quality

Research quality can me expressed by its internal and external validity, and reliability (Hennink et al., 2011). Internal validity means that the researcher used the right measures to assess the case according to purpose of the research. Thus, it means that the study has been conducted in such a way that what has been measured is sufficient to answer the research question. In this study, the measures of ecosystem health were based on existing literature (Iansiti & Levien, 2002), which was also empirically used before, even though in different research settings (Hartigh, Visscher, Tol, & Salas, 2013). External validity is related to the extent the results are generalizable. Single case studies may recognizably be low in this measure, while on the other hand may offer a deeper understanding of a phenomenon in its social context, which might be also an important part of the research goals. This is a trade-off that must be considered by researchers following qualitative methods and its underlying interpretivism paradigm (Hennink et al., 2011). Recognizing that this research may be pointed as having low external validity, it is proposed that the detailed description of the social phenomenon in context should provide specific and general patterns, process defined as analytic generalization (Polit & Beck, 2010). For last, reliability seeks to measure whether the same results will be generated when the study is reproduced under the same conditions (Hennink et al., 2011). Once again there is a trade-off in following a complete structured process of data collection, which can increase reliability, and allow space for more flexibility, which can provide additional knowledge if the researcher is willing to explore some topics as they emerge from the process of data collection. To try to address reliability issues, the interviews followed a semi-structured script.

3.5. Ethical Considerations

There are a few things to be reflect upon. First of all, the positionality of the researcher. Such as the cultural background, in this case, Brazilian and with previous contact and knowledge about the case of study, may influence how the research is conducted, the outcomes and results (Holmes, 2020). It is important to realize that the positionality of the researcher can impact the research, such as biases that may exist about the public bank BNDES.

Secondly, there are some ethical considerations. In order to guarantee transparency confidentiality and anonymity to the participants, it is imperative that the interviewees are presented with a full explanation of the nature and intention of the research (Frances et al., 2009). Moreover, participants should be informed on the format of the interview, so they know what to expect. In order to ensure this happens correctly a written consent of the interviewees will be asked in advance. Furthermore, the interviewer will pay attention to any sensitive issues that might occur during the interview and will ask for consent once more might these issues arise (Frances et al., 2009). The interviewer will ensure that all recordings and transcripts are not identifiable and are stored properly and secured.

3.6. Case Selection

This research is a result of an initial instigation from Larissa Shnayder, original supervisor of this thesis, who proposed "through the lens of organizational ecosystems, a student can empirically explore the dynamics of actors in energy transition focused initiatives". The choice for the case to be empirically assessed was based on the previous experience of the researcher and his knowledge about the meaningful development of the wind energy sector in Brazil. To assure that the settings of the case were adherent with the general research topic, an experiment was held in one of the respondents of the research (Respondent 1) in a moment previous to the interview itself. As the idea was to validate some general view of the area and connection to the research topic the session was not recorder nor a formal method for the experiment was designed. The process can be found in Appendix A. In the sequence the context related to the case will be presented.

4. Case Analysis and Results

In this chapter, the results of the research will be demonstrated considering the data collected, the research objective and related questions, the conceptual framework, and in light of the literature presented in the theoretical background. This chapter aims to answer the last two sub-questions, but also considers both initial two sub-questions as part of the building blocks to, lastly, get insights into *how did the involvement of the Brazilian SIB influence the development of a local clean energy business ecosystem.*

4.1. Brazilian National Development Bank

In this part, the history and role of the Brazilian National Development Bank and its relevance both in relation to other SIBs in the world and in the Brazilian economy will be briefly presented. Following, its involvement with clean energy financing will be described, opening the way to clarify SQ3: *How did the role of the Brazilian SIB (BNDES) influence the local wind energy business ecosystem?*

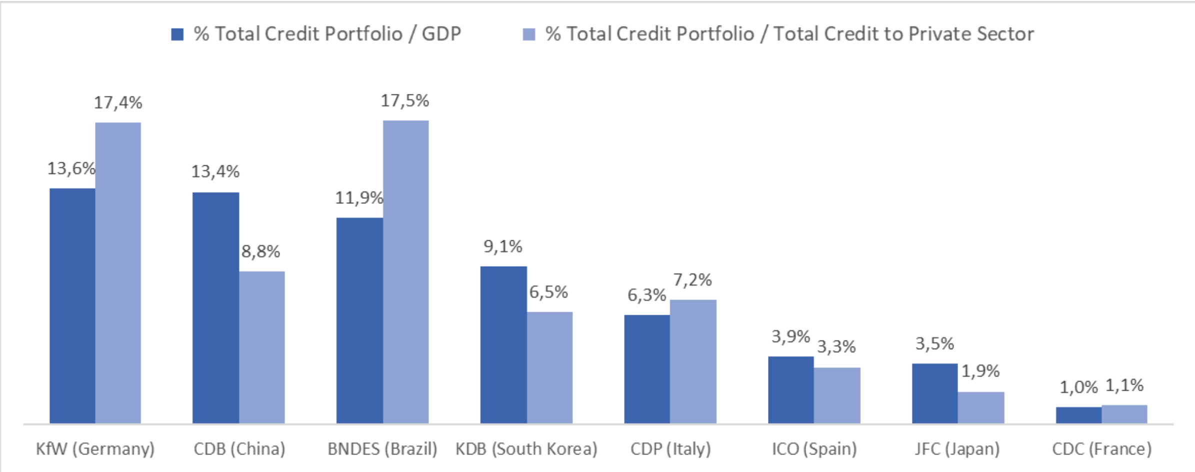
4.1.1. Role in the Brazilian Economy

The Brazilian National Development Bank (BNDES) was created in 1952 with the goal to invest in infrastructure projects. Since then, the Bank has played a key role in the Brazilian economy, especially by promoting transformational investments in all periods of Brazil's socioeconomic development. In its early years, it had the primary function of financing economic infrastructure projects in addition to supporting the growth of the steel industry, both of which were essential for industrialization-based durable consumer goods (The Brazilian Development Bank, 2018). In subsequent decades, BNDES played a crucial role in import substitution programs that bolstered various industrial input-producing sectors such as capital goods and the petrochemical industry. In addition, it contributed to the formation of new sectors in the 1970s such as the microelectronics and the information technology industries. During the 1980s, BNDES fostered an increase in energy exports, agribusiness, and social integration. In the 1990s, it played a vital role in the federal privatization initiative by facilitating the sale of significant state-owned Brazilian corporations (The Brazilian Development Bank, 2018).

Throughout time, the role of the Bank was refocused and reshaped according to the guidelines from the long-term plans formulated by the Ministry of Economy, but also considering cultural and social contexts. Currently, its mission is defined as “to facilitate financial solutions that contribute with investments for sustainable development of the Brazilian nation” (BNDES, 2020, p. 16). To achieve its goal, the Bank supports private and public companies with credit lines, equity investment, non-reimbursable grants to innovation, project structuring, and knowledge production. Moreover, it has with a very wide scope of activity, serving all sectors of the economy (infrastructure, industry, agriculture, trade, and services), all company sizes (from micro to large), and several focuses (innovation, green economy, exports, and capital markets) (Pessoa, Roitman, Ribeiro, & Barboza, 2020).

It is considered one of the largest state development banks in the world and one of the most actives (Lazzarini, Musacchio, Bandeira-de-Mello, & Marcon, 2015; Pessoa et al., 2020). To contextualize, **Figure 4** compares its relative importance to some of the main SIBs in their respective countries, showing how relevant is the support of BNDES for the local economy and credit formation. In 2015, the total credit portfolio of the three largest development banks in the series represented more than 10% of their countries' gross domest product (GDP), with BNDES in third, accounting for 11,9% of Brazilian GDP. In relation to the share of credit from SIBs to the total credit to private sector, BNDES and KfW stood out, with 17,5% and 17,4%, respectively.

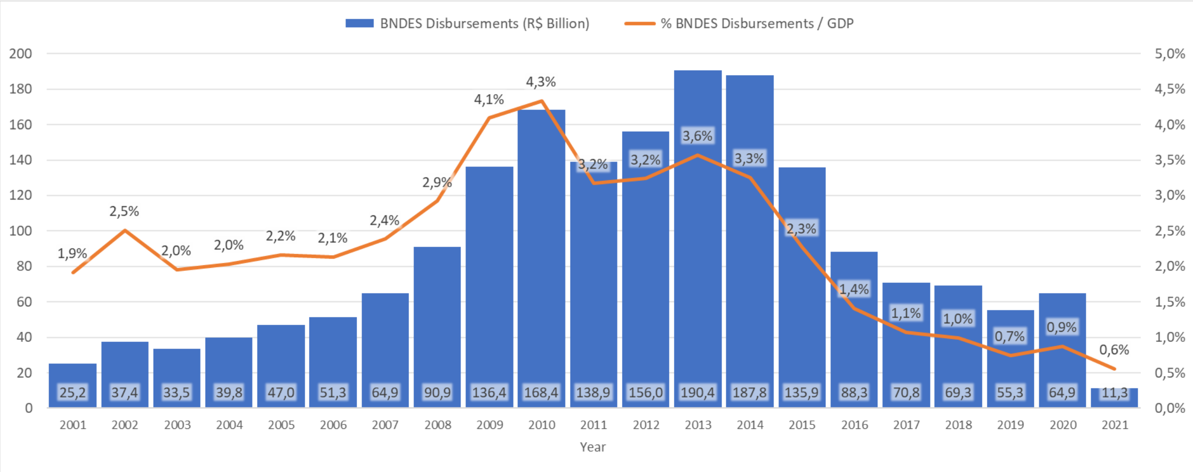
Figure 4. *Relation between credit portfolio, GDP, and credit for the private sector by SIB - 2015*



Note. Adapted from The Brazilian Development Bank (2018).

Although the bank has always had a strong presence in the Brazilian capital market, between 2007 and 2014 its total disbursements had a consideradable increment and impact in the national GDP, as it can be seen in **Figure 5**. This process was mainly fueled by resources from the Brazilian National Treasury and subsidized long term interest rate, lower than market options. The underlying motivation for such conditions was tied to a logic of countercyclical intervention to deal with economic effects of global recession (Pessoa et al., 2020). In the following years, the countercyclical stimulus in the economy started to be reduced, but the active role of the Bank still finds justification in the presence of other market failures as information asymmetries and externalities (BNDES, 2018).

Figure 5. *BNDES Disbursements and relation with Brazilian GDP*



Note. Self-prepared based on data from Central Bank of Brazil publicly available at *https://www3.bcb.gov.br/sgspub/localizarseries/localizarSeries.do?method=prepararTelaLocalizarSeries.*

Along with macro and micro economical scenarios, the conditions of specific sectors are also part of the evaluation used to design financial products and programs to operationalize the funds. Thus, credit conditions can be crafted accordingly to the needs and moments of different industries. Respondent 8 emphasized this aspect, pointing that indeed BNDES is constantly seeking to provide tailored made financial products to sectors in different stages. Still according to the Respondent, even though BNDES is a public entity and, thus, considered to be sometimes overly bureaucratic, it is, by economy sector, flexible. By contrast, private banks push “off-the-shelf” finance products that many times do not attend the specific needs. It was also indicated that BNDES makes clear the “rules of the game” to each sector through the guidelines available in its website.

Yet, as recognized by BNDES, individually it is not feasible to promote development and achieve goals related to higher order social challenges. Thus, the effective results of its strategic plans depend on a set of players, partnerships and alignments (BNDES, 2020). Among such partners, financial agents – private and public commercial banks, regional development agencies, and credit cooperatives – provide capillarity for BNDES to act in national territory, passing-along its funds. They are the main operators of credit lines to small and medium in indirect operations. At first glimpse, this situation would lead to a tension as financial agents, particularly private banks, possess their own credit lines with no limitation of conditions, but those applied to the regulation of the whole financial system. Credit lines from BNDES, on the other hand, have their own policies and even limits for spreads (interest rates of the financial agents that pass along the original resource). However, Respondent 4 pointed out that *“for BNDES, if a demand can be attended by the private bank, there is no problem, even better, the money [BNDES credit line] can be used in an area that is more important, effective”*.

In the last decades, more commitments to address societal challenges were clearly defined, as it can be seen in the alignment stipulated in its strategic plan with the Sustainable Development Goals (SDGs) of the United Nations (BNDES, 2019). In this context, the Bank held in 2017, the IV Seminar on Localization of SDGs in Brazil: Partnerships to Integrate, Innovate and Include, together with the United Nations Development Program (UNDP). The event mobilized key actors and promoted reflection on fostering partnerships and financing development. Efforts to coordinate interactions of different actors comes from the understanding that meeting the SDG's depends on the cooperation between governments, civil society, academia, and the private sector (The Brazilian Development Bank, 2018). This behavior seems to show that the Bank aims to assume a leading role in dealing with social challenges towards the national sustainable development. The efforts of interaction and coordination led to the approval by BNDES in July 2017 to use social sub-credit in the Chapada do Piauí I Wind Farm, owned by the British ContourGlobal. The funds were invested to strengthen policies that accelerate the implementation of the SDGs in the state of Piauí, as corroborated by Document 11, p. 69:

> *In the State of Piauí, Brazil, home to our Chapada do Piauí wind complex, we [ContourGlobal] have been working in partnership with the United Nations Development Programme (UNDP) and the Brazilian Development Bank (BNDES). This innovative four-year partnership with the State of Piauí is designed to integrate the SDGs into state and municipal policies and initiatives and, in turn, accelerate economic, social and environmental development in the state. ContourGlobal, along with other investors, funded UNDP with BRL 2.1m (BRL 417k in 2019) to launch the initiative.*

4.1.2. Involvement with Wind Energy Generation

In the energy market, BNDES follows the guidelines of the National Energy Policy, which main goals are to offer energy security, quality of service, and affordable tariffs. Also considered are regulations and standards of the Brazilian Ministry of Mines and Energy (MME) and the Brazilian Electricity Regulatory Agency (ANEEL), as well as of the Ten-Year Energy Plan (PDE) prepared by the Energy Research Office (EPE) (The Brazilian Development Bank, 2018).

BNDES supported alternative renewable sources (small hydropower plants, biomass thermal projects, wind farms, and photovoltaic power plants) since their initial stages in Brazil. Historically, investment projects related to these sources enjoyed some of the best financial conditions offered by the Bank. However, it was only after the creation of the Alternative Sources Incentive Program (Proinfa), in 2002, that these sources started to acquire greater importance in the Brazilian electricity grid. The program defined the implementation of 3,3 GW to be sourced from wind, biomass, and small hydroelectric, equally distributed between these three sources. This program was jointly developed by BNDES and the Ministry of Mines and Energy (MME) who:

> *Worked together in the structuring of the program, in the definition of the price modeling and the structure of the models of energy purchase and sale contracts, their clauses and deadlines, guarantee models, budget needs, and cost of capital, among other issues relevant to the public call of projects and for the granting of investment credit. (Document 1, p. 205)*

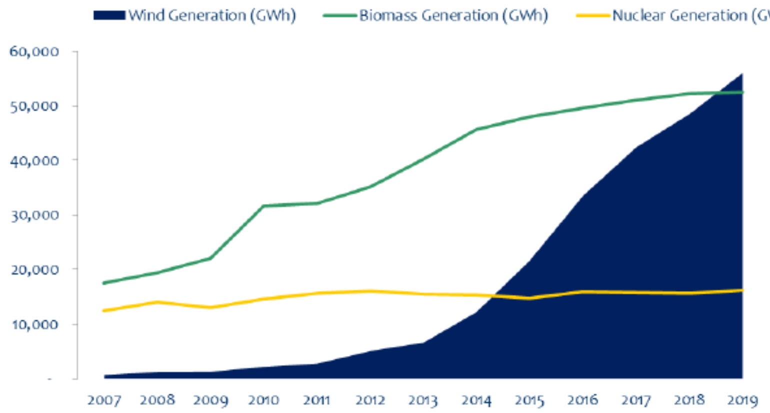
The execution of the program was the responsibility of state-owned Eletrobras, the largest power utility company in Brazil, operating in generation and distribution. The company assured the purchase of the energy generated by the wind parks, with pre-agreed conditions. BNDES assured to funding for all projects contracted by Eletrobrás. However, following the local content requirements policies that traditionally were held by BNDES, the power purchase agreements defined that the wind turbines used in the parks had to comply with a rule of a minimum of 60% of local content. With a still incipient wind turbines industry, counting with only one firm partially producing in Brazil – the German Wobben – and few qualified suppliers – an exception to wind blades with the local company Tecsis – the projects established by Proinfa suffered to attend the conditions, being heavily delayed. With this scenario, the structure of the energy market was changed, with the implementation of auctions and with the mandatory minimum of 60% of local content being applied only to projects sourcing financing from BNDES. As the conditions of the bank were still very advantageous, most cases still counted on this source of financing.

Proinfa had a limited impact on the production chain. Few new newcomers to the Brazilian market have been accredited by BNDES. Although the program has created a demand for wind turbines, sustainability of demand was not guaranteed and there was a lack of planning to distribute it in time. However, with the learnings from the implementation of the Proinfa projects, the Federal Government changed the development model of the electric sector creating a regulated environment for contracting energy through auctions. The auction model encouraged competition for lower tariffs, a relevant innovation concerning the contracting model fixed fee from Proinfa.

After, the experience with Proinfa and with the new model based on auctions, BNDES then became the biggest financier of clean energy in the world considering the period between 2009 and 2018, lending US$ 23,5 billion to related projects (Bloomberg New Energy Finance, 2019b). In this period, investment in wind energy represented a relevant part of these resources, mainly through programs of debt financing. Wind energy went from an insignificant installed generation capacity in 2005 to 18 GW in the beginning in 2021, representing around 10% of the Brazilian electricity matrix (Brazilian Wind Energy Association, 2021). BNDES funded wind farms that summed approximately 13,4 GW to the Brazilian energy installed capacity (The Brazilian Development Bank, 2020). As result, in 2019, the Brazilian total electric generation was 626.328 gigawatt-hour (GWh) with wind power representing 8,94% of this total (***Figure 7***). Calls attention to the evolution of this source, which in a space of five years surpassed nuclear and biomass (***Figure 6***).

Figure 6. *Evolution of Wind Generation (GWh)*

2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Δ 19/18
663	1,183	1,238	2,177	2,705	5,050	6,578	12,210	21,625	33,489	42,373	48,475	55,986	15.5%



Note. From EPE (2019).

The relevance of this SIB both in a global and local levels, besides its close engagement with different actors in the energy sector and recognized importance for the development of this area, made it a suitable case to be used in the investigation of the phenomenon focus of this research.

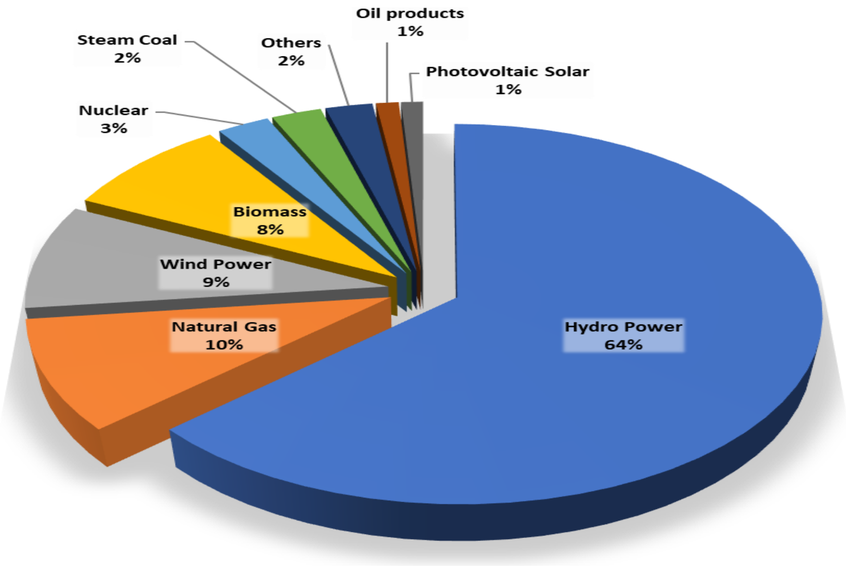
4.2. Brazilian Wind Energy Ecosystem

To help answering the main research question, it is important to understand the general structure of the energy market in Brazil, besides the development of the whole wind energy sector, which will be the focus of this section. Thus, this part aims to shed a light into *SQ4: How did BNDES influence the wind energy ecosystem's health and coevolution in Brazil?*

4.2.1. Social and Natural Aspects

The Brazilian energy mix has a high portion of renewable sources, however, most of it comes from big hydroelectric power plants (Error! Reference source not found.). The biggest part of the remaining potential of this type of energy source lies on hydric geological endowments from Midwest and North of the country. These regions are also globally important from an ecological point of view and new investments in exploration of water sources in these locations are controversial due to its impact in natural environments (Cavaliero & Da Silva, 2005).

Figure 7. *Brazilian Electrical Matrix by the end of 2019*



Note. Adapted from EPE (2019).

In parallel, in 2001, the potential of wind energy was already estimated in 143 gigawatts (GW), considering towers up to 50 meters high. With the expansion of the sector and increase in the height of the towers, this potential was re-estimated reaching 500 GW (Aroeira, Bittencourt, & Rates, 2017), making this type of energy source a relevant option. Brazil counts with an important potential for wind energy generation, especially in the Northeast region, where winds are constant, stable, directional, and regular, enabling greater efficiency in generation (Misticone, 2014). This region is also one of the poorest of the country, which brings challenges as logistics of heavy equipment's and parts to the wind parks, availability of skilled labor, and connection to the electrical transmission network (Misticone, 2014).

Notwithstanding, the effects of climate change are already pressuring energy generation in Brazil, requiring increasing investments in the sector to avoid an energy crisis in the country. Between 2001 and 2002, the country faced a serious energy crisis rooted especially in the atypical low level of rains in the area of the main reservoirs. Poor investment planning, lack of participation from private actors, and adverse business environment were also recognized as contributor factors (Jardini, Ramos, Martini, Reis, & Tahan, 2002). Considering these challenges, the Ministry of Mines and Energy (MME) and BNDES put in place an elaborate plan for alternative sources of renewable energy to mitigate future energy crises due to reduced rains (Lucena & Lucena, 2019). As presented in the next section, wind power plants were considered essential in addressing potential energy crises in the future (Filgueiras & Silva, 2003).

4.2.2. Goals and Planning

The wind energy goals are reflected in the Ten-Year Energy Expansion Plans (PDE). The PDE is updated annually and continually serves to reflect the Brazilian government's medium-term wind energy policy. Initially confined to the electrical industry, PDE's were expanded to include the wind energy sector in 2007. Developed in 2006-2007, the National Energy Plan 2030 (PNE) presents a longer-term integrated green energy strategy (Aroeira et al., 2017). A National Energy Plan 2050 is now in development. The Law 9478 of 1997 not only defined the main principles of Brazil's national energy policy, but also included the need to develop and use renewable energy sources like wind, solar, and hydro (Misticone, 2014).

While the National Council for Energy Policy (CNPE) is in charge of setting energy policy in Brazil, the MME has the overall policymaking responsibility for the electricity sector including formulating wind energy goals. By contrast, the Brazilian Electricity Regulatory Agency (ANEEL) is responsible for controlling and regulating electricity generation in wind farms, its transmission, and final distribution. In the last two decades, the Brazilian wind energy goals or targets have been embedded in its PDE. The PDE aims to ensure that wind energy accounts for between 9-12% of the national grid. As of the year 2020, wind energy represented around 9% of the energy generated in Brazil.

The latest PDE edition projects renewable energy sources including wind, solar, and large hydro to account for 86,1% of electricity generation by the year 2023. Such a capacity will be an increase from 79,3% in the year 2013 when wind power accounted for 8,1% of the power generated (Martins & Pereira, 2011). By the end of 2023, wind power is estimated to exceed 20 GW or more than 10% of the current installed generation capacity. In 2007, the PNE estimated wind generation at 3,3 GW by the end of 2023, indicating that in the last decade, there has been substantial growth in wind energy investments (Martins & Pereira, 2011).

Considering its robust wind energy plan, Brazil has become one of the fastest growing wind energy markets. Part of this success is also driven by reliable wind resources, a governmental auction (tender) system, and sound financing schemes by BNDES (Bayer, 2018). As previously elaborated, the success of the Brazilian wind energy market was initially triggered by Proinfa, especially after adjustments in the program in 2004. Under Proinfa, the focus was to create a subsidy-driven incentive that resulted in approximately 1 GW of onshore wind farms.

By the year 2009, the contract auctions had largely become part of the energy policy in Brazil, which increased competition and developed energy sector (Bayer, 2018). The establishment of auctions was motivated by price transparency, procurement efficiency, and the decrease in information asymmetry (Aroeira et al., 2017). The auction mechanism introduced transparency, a thorough screening of projects and auction competitors, and guaranteed project completion. Auctions for new capacity exclusively contemplating renewable sources (wind, small hydro, and biomass) were carried in 2009. Such a move led to an increase in the number of new wind generation projects being executed and built (Silva, Rosa, Freitas, & Pereira, 2013). After that, wind energy started to be part of regular auctions, competing with other sources of energy as hydro in calls for new energy capacity.

Today, the conditions for awarding energy contracts to wind projects at auction are getting more stringent, particularly in terms of the quality of wind measuring instruments and high data recovery rates (Rocha, Sousa, Freitas, & Silva, 2012). The purpose of these rules is to increase the creditworthiness and decrease the risk of underachievement of prospective wind farms (Rocha et al., 2012). However, when compared to international norms, the current amount of wind turbines and the size of wind farms in Brazil are modest. Even so, as the industry consolidates around established developers, both turbines and farm size are anticipated to grow (Aroeira et al., 2017).

4.2.3. Structure and Roles

The Brazilian electricity sector, primarily constituted by a state monopoly since its creation, from 1990 onwards, went through a process of institutional and regulatory reformulation (Aroeira et al., 2017). The creation of the National Privatization Program in 1990 ended the state monopoly that was in force until then and allowed the privatization of concessionaires, which operate in energy production, transmission, and distribution. Yet, still nowadays, the main power utility in the country is mostly owned by the Federal Government, Eletrobrás, which generates about 30% and transmits almost 50% of the energy in the country (Eletrobras, 2021). In the early 2000's an improved regulatory framework that clarified roles and attributions for energy production, transmission, and distribution was developed. Although the same company can operate in these three activities, the new regulations avoided mechanisms that caused distortions. As one example, the self-dealing system allowed bilateral purchase contracts and sale of energy between generators/traders and distributors from the same economic group with full immediate transfer of the energy cost directly to the end consumer (Misticone, 2014).

In general, the negotiation of electric energy is carried out in two different environments: the first is the Regulated Contracting Environment (ACR in Portuguese acronym), where the commercialization takes place between regulated generators and distributors, focused on common use of electricity. The second, the Free Contracting Environment (ACL in Portuguese acronym), is where takes place the contracts between generation agents and free consumers – in general large industrial companies – with a demand greater than 3 megawatts (MW). Thus, the first is marked by the use of public auctions for the purchase, in the "lowest tariff" modality: prices are established by the offer of interested parties, with a ceiling established by the MME, while in the second modality there are no such limitations. Auctions are the predominant form of energy contracting in Brazil, and the basis for its stipulation comes from the energy guidelines of the MME and market studies from EPE. ANEEL announces the auctions and EPE also discriminates the generating companies able to participate in them. Afterwards, the CCEE carries out the selection process and contract the project offered at the lowest price (Aroeira et al., 2017).

Most part of consumers in Brazil, whether residential, commercial, or even industrial, do not choose the exact source of energy they will use. They do not choose neither the energy company, which is responsible for the supply of electricity, as these companies operate in regional concessional areas. However, the government has been trying to stimulate consumers with high energy demand, mainly at the industrial sector, to set up new contracts through the ACL environment as more players have been establishing in the energy generation area and competition tends to drive energy prices down (Aquila et al., 2016).

The ecosystem around the Brazilian wind energy sector is defined by multiple companies and stakeholders who interact to build a strong network for the successful deployment of innovations while maintaining a competitive and cooperative approach toward wind energy goals. The complex interplay between cooperative and competitive aspects taking place in the Brazilian wind energy ecosystem may be divided into twelve segments. These segments were based on insights from Document 4.

First in the line, there is the *wind farm development and ownership*. In this part of the ecosystem, the focus is on energy generation which consists of all activities related to the design, construction, acquisition, and ownership of the actual wind farms. The main developers include ContourGlobal from the United Kingdom, and local players such as CPFL Renováveis, Casa dos Ventos, Renova Energia, and Enel.

Second, not necessarily the firm which constructs a wind park will be the one to own it, as many companies specialized in *the engineering, procurement, and construction* (EPC) segment. These companies offer services that seek to assure that wind farms are well designed and remain architecturally sufficient. Mostly, they are involved in the so-called Balance of Plant (BoP), which refers to everything needed for a wind farm excluding the wind turbines. This involves, between other processes, studies, engineering projects, civil construction, and procurement and commissioning of electric equipment's. Companies in this area include Camargo Correa, Andrade Gutierrez, Queiroz Galvão, Novonor, OAS, Mammoet, DNV-GL, and Camargo-Schubert.

Third, *wind turbine manufacturers* compose one of the main elements in the wind energy ecosystem. They are responsible for the design, production, and commercialization of the heart of a wind farm, the turbines. The large potential of the Brazilian wind energy sector continues to attract most international suppliers of wind turbines. Some of the turbine suppliers that are or passed by the Brazilian in the market include Wobben (Germany), WEG (Brazil), Suzlon (India), Vestas (Denmark), Siemens (Germany), Impsa (Argentina), GE Energy (United States), Goldwind (China), Gamesa (Spain), Alstom (France), Acciona (Spain), and Nordex (Germany). GE acquired the energy division of Alstom in 2015. Suzlon ended its activities in Brazil in 2017. Impsa filed for bankruptcy in Brazil in 2015. Acciona and Nordex merged in 2016. In the same year, Siemens and Gamesa followed the same path.

Fourth, *tower manufacturers*. Players in this segment focus on delivering the towers in line with relevant weight and size of the wind turbines, and can be made of concrete, iron, or be hybrid between these two materials. The components in this ecosystem as of low technical details, are less technologically sophisticated, and can easily be produced locally. In this segment, competition is based on costs. Some players verticalize the production altogether with the whole wind turbine elements, as Wobben and Acciona-Nordex, while others are contracted to build according to project specifications as Gestamp, Intecnial, and Engebasa.

Fifth, the *Blades designers* are also important players in the wind energy ecosystem. Brazil mostly produces its blades, with the market being dominated by Tecsis. Tecsis inherited its technological capacity from a previous insertion in the aeronautics sector, as Brazil's EMBRAER is the third-largest manufacturer of airplanes. Aeris Energy is also another important Brazilian blade manufacturer, with most of its success informed and created by former Tecsis employees.

Sixth, *technologically advanced components* present others important key players in the wind energy ecosystem. In terms of enhanced wind energy generation, the key focus on the most technologically advanced parts of the turbines focuses on five main parts: generators, electronic controls, gearboxes, blades, and rotor. Other than blades (that are mostly supplied by Tecsis and Aeris) the large international turbine manufacturers produce the majority of the remaining parts. To comply with the local content requirements, most of these international companies have established operations in Brazil, so that these parts are assembled or produced locally.

Seventh, *parts and non-technical components*. The players of parts and non-technical components focus on supplying general electronic components, internal elevators, power generators, transformers and inverters, transmitters, cables, ladders, castings, among others. These components are mostly sourced locally and, in general, do not demand specific technical requirements, although several of them are critical for the functioning of the turbines. Various Brazilian parties play a key role in supplying parts and low technology components.

Eighth, *electricity grid transmission*. This segment must be well synchronized with all others as wind farms must be connected in the National Electricity Transmission Grid to successfully trade the power they generate. The main players from Brazil include CTEEP, CEMIG, COPEL, Furnas, Electrosul, and Chesf.

Ninth, *electricity distribution* further complements the role of other players in the wind energy ecosystem. Public service distribution contracts are sourced locally via tenders and define clauses related to safety, continuity, regularity, tariffs, updating, and quality of energy generation. In Brazil, most of the wind energy distributors are state-owned and some of them include Light, CPFL, Eletropaulo, Cia Energética do Rio Grande do Norte, and Cemig.

Tenth, *financial engineering* is also part of this framework as wind energy generation is capital intensive. To increase clean energy generation in the national electrical matrix, the financial system must be integrated providing the necessary substantial funds. This role falls under public finance institutions as BNDES and Bank of Northeast (BNB), however, must be followed by the private banks and the private capital market.

Eleventh, *operation and maintenance (O&M)*. Wind farms are expected to operate for decades. Yet, to keep high performance it is necessary skilled labor, trainings, technical expertise, spare parts, process innovation mainly related to monitoring, and adaptation to new technical equipment's. Due to the ease of spare parts and knowledge of the operation of the wind turbines, wind turbine manufacturers offer these services in long-term contracts between 5 to 10 years.

Lastly, *regulators* form part of key players in the success of the wind energy generating ecosystem. In the Brazilian energy market, it is important to highlight the main agencies involved with regulations, operations, coordination, and other vital activities: the Ministry of Mines and Energy (MME), responsible for regulations and guidelines in the nationwide level; the National Electricity Agency (ANEEL), develops the policies for the use and exploitation of the electricity services by the distribution companies and its relationship with consumers; the National Electricity System Operator (ONS), responsible for the coordination and monitoring of electric power generation and transmission facilities connected to the National Interconnected Energy Grid (SIN); the Energy Research Company (EPE), makes expansion projections of the Brazilian electric sector and; the Electricity Commercialization Chamber (CCEE), responsible for managing the processes of commercialization of energy electricity, register, and manage the contracts signed between the generators, traders, distributors and consumers (Aroeira et al., 2017).

4.2.4. The Influence of BNDES in the Ecosystem

Each of the segments presented bring its own challenges to the development of the whole network. Since multiple parties are involved with different interests and views of the ecosystem itself it is important to understand the dynamics, most important players, and how they can influence the ecosystem development (Panetta, 2016). Accordingly, as the focus of this study is on SIBs, this section will assess the previously presented segments in the context of BNDES influence on them.

In relation to the w*ind farm development and ownership*, when Proinfa was launched there were few experienced project developers in the Brazilian market. In parallel, BNDES has strict regulations to provide financing to majority foreign owned firms, which restricts international investors to count on the Bank credit lines to fund their projects (Document 1). To cope with that, BNDES and the MME defined that the wind park owners should assume the legal form of Special Purpose Entities (SPE). This allowed Eletrobrás, through its energy distribution subsidiaries, and other state-owned energy distributors to be part of such SPE's. This way, they could achieve minimum national ownership and, thus, receive BNDES' support.

> *Thus, like the other state-owned companies (such as Cemig and Copel), Eletrobras started to act predominantly as a partner of private companies in SPE's. In these SPE's, control is exercised by the private partners, while the state-owned companies act as strategic partners due to two important factors: raising of own resources (shareholders' equity) and knowledge of the projects, thanks to the accumulated know-how of the sector. (Document 10, p. 221).*

In *the engineering, procurement, and construction* (EPC) segment, according to Respondent 1, initially, big construction contractors as Odebrecht, OAS, Camargo Correa, Andrade Gutierrez, and Queiroz Galvão, had important roles in the construction of wind parks, contributing with their engineering expertise. With time, their learning with the wind energy projects and strong financial capacities, led some of them to even become owners and operators of wind parks, as did Queiroz Galvão and Odebrecht. However, in 2014 operation "Lava-Jato" – a legal investigation about corruption involving the aforementioned construction contractors, political parties, and other public organizations – and this segment was heavily impacted. Some of these companies went into judicial recovery and impacted the completion rate of some wind parks. Still according to Respondent 1, such challenge required BNDES to reevaluate ongoing contracts, as implementation schedule of the parks, power purchase agreements, and payment terms of the loans were intrinsically connected. The loan contracts and power purchase agreements of such operations themselves were target of public scrutiny, internal and external auditing, and new operations where EPC's involved in "Lava-Jato" took part were received extra attention by BNDES.

Regarding *wind turbine manufacturers, blades designers*, *tower manufacturers, technologically advanced components, parts and non-technical components*, these are all connected to local content requirements present in BNDES credit condition policy. To benefit from BNDES credit lines, wind farm developers had to comply with a condition: wind turbines (including blades, towers, etc.) have to be acquired from local suppliers, regardless the origin of companies' capital. In turn, through an accreditation process, manufacturers have to comply with BNDES's rules of local content. This equipment represents, in Brazil, around 75% of the total investment, thus, to finance the implementation of the wind parks is, fundamentally, to support the purchase of these wind turbines (Document 3, p. 95).

For BNDES, this minimum local content requirement is a known industrial policy tool for stimulating specific areas of the economy and is rooted in mandates to promote local employment, industrial and technological development (Hansen et al., 2020). This model combined energy and industrial policies, and later evolved through the establishment of auctions of energy and adjustments in BNDES's accreditation rules of equipment. According to Respondent 3: *"This rule exists since I started to work with BNDES, forty years ago (…). It is to promote the national industry, but there are a lot of discussions if it indeed helps"*. The idea to use this conditional capital, seems to come from BNDES's previous experiences in the development of industrial policies and intends to impact, among other aspects, productivity.

> *This is expected to stimulate investment in productive capacity and research, promoting productivity growth, competitiveness, and the insertion of national industry into global production chains and international markets for capital goods, as well as the generation of skilled jobs and income. (Document 6, p. 21)*

In practice, according to information from Document 7, the producers of machinery and equipment present to BNDES a detailed list of costs, weight, and origin of parts, internal and external services, engineering processes, and technological components of the products they seek accreditation. Local manufacturing is proven by the inclusion of wind turbines in the Computerized Supplier Registry (CFI) from the BNDES Machinery and Equipment Financing Agency (FINAME). If the minimum threshold of 60% of local content in weight and value is reached, the product is approved, receives a code called Finame, and is listed in the online public catalog of BNDES. From this moment on, clients can purchase such equipment's using any credit line from BNDES. The accreditation focuses on production processes, origin, and weight, not certifying aspects related to quality.

Following demand incentives as Proinfa and the almost mandatory need to comply with local content policies to be able to participate in the nascent wind energy-BNDES ecosystem, some wind turbine manufacturers started to establish operations in Brazil or to develop local partners to source parts and components. Gamesa, GE, Vestas, Impsa, Alstom, Siemens, Acciona, Suzlon e Führlander signed individual contracts with BNDES committing to progressively place part of production locally, either by own operations or partnering with local companies to achieve the requirements. This way, although they may had not reach the minimum threshold (60%), their products could still receive support through the Bank's credit lines (Documents 1 and 3).

> *This policy from BNDES was very opportune for recognizing the moment of the producers and the moment of different national industries. For example, there were already two or three suppliers for the blades, Aeris, Tecsis, and the other one that I don't remember now. There was the capacity to produce the towers, which is structural cement or steel but requires*

> *technical knowledge in the field to do it right. There were companies from the electromechanical field that could produce parts of the gearbox or the nacelle. … Each manufacturer had its plan, some brought operations, and some partnered with local suppliers. (…) Some [manufacturers] that had similar basic platforms got together to develop some local suppliers. (Respondent 5)*

Thus, as a way of accrediting new wind turbine manufacturers and, with this, enabling the financing of investors in the park's wind farms, BNDES started to structure Progressive Nationalization Plans (PNP). PNPs were negotiated individually with the company interested in accreditation. The logic behind the plans was changing the measurement by the weight and value, in order to prioritize some production stages and items of greater complexity. It was defined based on a diagnosis of the sector and the industrial base already established in the country, yet still considered specific cases of each manufacturer.

A higher rate of local manufacture of wind turbines or incorporation gradual increase in the number of locally manufactured items implied greater participation in the financing of wind turbines in the wind farms generation, which encouraged greater localization of the production process. Through bilateral agreements between BNDES and the wind turbine manufacturers, milestones were formally set to gradually increase local production, leading to 11 agreements with firms in this segment. Wobben, Gamesa, GE, Vestas, Impsa, WEG, Alstom, Siemens, Acciona, Suzlon, and Führlander. With the exception of the only Brazilian company WEG, all of them had a history in the sector wind. Eventually, some of these manufacturers were excluded for not meeting the established milestones. For BNDES this represented a learning stage. It was an opportunity to understand technical and cost characteristics of products, components and production processes, get acquainted with international best practices, and evaluate the conditions of Brazilian-based value chains (Plattek et al., 2021).

However, good part of the national production was concentrated in towers and blades which account for great part of weight in this type of equipment. They were already being produced nationally and did not require much technological advances. Thus, in 2012, BNDES launched a new sectoral accreditation procedure, replacing bilateral agreements. This was the first time the Bank had developed specific policies for a whole sector. It moved from the cost and weight ratio to focus on national production of more technological devices in the wind turbines, besides it also considered areas where the national industry would require more time to be developed.

In the new methodology, it was defined for the whole sector, instead of individually by manufacturer, the production steps to be carried out locally and the minimum localization level for some of the critic wind turbine components. These steps were distributed over time in order to enable the densification of the supply chain. It was based on the evaluation by the BNDES' technical team in conjunction with components suppliers, manufacturers, and various class associations.

> *BNDES was really active in consulting with us [Wind Energy Class Association], in making calls to clarify doubts. [They have] A really good team that held several meetings with important players to align everything. … They listened to the market, they listened the wind turbine manufacturers, put deadlines that were reasonable, also gave more time when they saw it would not happen. But, at the same time, they pushed it. (Respondent 7)*

In the case, Respondent 7 was referring to the agreements BNDES made with the wind turbine producers and other component suppliers to define deadlines for each of the steps defined in the new methodology. Six steps were defined, originally with a space of six months between each (Document 8, p. 2-9). Respondent 6 confirmed saying "if it was not for the BNDES, it would be much different today. *… [BNDES] was who orchestrated it"*.

For the steps and elements that had an industrial base already established, a faster ramp-up was defined, as in the case of the towers and its main components. For more complex components that, however, could start to be manufactured locally in short period, first local manufacturing was required and, later, the acquisition of inputs. That was the case with the blades. In the group of items of great complexity and without an existing industrial base, lower levels of local production were established. These requirements rose gradually over time, allowing for the local production of items with greater added value and technological content, as done for some of the components of the electromechanical energy conversion package. Plattek et al. (2021) summarized well the aspects covered by the new accreditation method:

> *For technology, simple components with well-established facilities, such as steel-based towers, were set up, but existing technical levels were ramped up; For turbine manufacturers the focus was on the localization of metal mechanical parts for which local suppliers were already available; For middle-range components, the focus was to increase assembly capabilities and, gradually, to expand the acquisition of locally produced components with higher levels of sophistication. The chemical components for the fiberglass for blades are an example; For high-technology devices without a standing industrial base but with potential local competencies, lower levels of localization were accepted against gradual increases in local content, as was the case of electromechanical energy conversion package components; For segments with extremely high technological density and without potential local capacity (or minimum efficient scale), imports were allowed. This was the case for digital-based controls.* (p. 18)

Electricity grid transmission also presented an important characteristic to be considered by the whole ecosystem in the implementation of new wind farms. First wind farms implemented during Proinfa faced long delays to be completed due to delays in the connection to the national electricity grid transmission. However, this was not a contractual clause to be fulfilled by the *wind farms developers*. ANEEL was responsible for the coordination and expansion of the transmission network to the wind farms and the construction of the substations. Since 2013, *wind developers* have to coordinate the grid connection. As a result, they assume the risks of grid expansion to the wind farms and of any delays from that grid connection. Respondent 8 mentioned that BNDES participated in conversations with other stakeholders this point in future contracts, however, he could not say how relevant was the participation of the Bank, nor other respondents and documents provided further insights.

For the segments *electricity distribution* and *operation and maintenance (O&M)*, it was not identified any specific mention in the interviews or documents that could be clearly related to the influence of BNDES in the boundaries and scope of this research.

In the case of *financial engineering*, first it must be highlighted the uncertainty regarding the generated volume of energy, and, consequently, regarding the future revenue of the projects, raised the perception of risk in granting credit. The availability of credit via public banks was a key aspect of the program's success. In this sense, financial modeling via project finance using energy generation revenues as collateral and for the project leverage calculation was an important mechanism. Moreover, as previously mentioned, BNDES participated in the definitions of power purchase agreements between wind farms and Eletrobrás. These conditions were settled in order to meet the Bank’s collateral securitization guidelines in the loan’s contracts.

> *The idea to use project finance came from BNDES that knew really well the details of the contracts between the wind parks and Eletrobras. They participated in the definitions of these contract terms. … As they [the wind parks] had contracts valid for 20 years, 30 years, on fixed terms, and on the other side you had Eletrobras guaranteeing the purchase, it was possible to perform it. … it showed the way for the rest of the market. (Respondent 9).*

> *Uncertainty about the volume of energy generated, and, consequently, as for the future revenue of the projects, raised the perception of risk in granting credit. The provision of credit via public banks was a key aspect of the program's success. … Financial modeling via project finance used energy generation revenues as collateral and for the calculation of project leverage. This modeling was not trivial. There was no history of wind generation levels in the country, only international references. (Document 1, p. 205).*

Loans were indexed to an interest rate named TJLP, plus the risk rate of the project, and a premium rate. The last two are due to the evaluation of each bank and, in general, the premium from BNDES is lower than commercial banks. The operations could happen directly, which means that the investors of wind energy parks get the loan directly from the bank, or indirectly, when commercial private banks pass along the funds from BNDES, acting as an intermediary. In the latter case, the commercial banks add their spreads over the rates calculated by the development bank. This means that especially in the first case, companies could have access to more advantageous conditions. For this reason, BNDES defined that the initial projects would be done without the intermediation of another financial agent. This is reflected in the quote:

> *Not all projects can receive direct support from BNDES. The internal team is not that big, they have to decide which areas, or what kind of projects they will do directly because it is more work. … For the first wind energy parks, BNDES favored direct operations because it could provide better conditions. (Respondent 2)*

This effect was potentialized when the bank used subsidized interest rates. Using funds from the National Treasury, the basic interest used for the projects was even lower, way below the market rates practiced by the other financial institutions. However, the maintenance of these rates, in the long term, could bring distortion to the market, as bids in the auctions for sources of energy that count on this support would be heavily impacted in the absence of the subsidies. In BNDES, changed the indexation, using a new interest rate named TLP which is increasing progressively until 2023. This way, it is expected that the Bank’s financial costs to get closer to what is offered in the private market (Griffith-Jones & Ocampo, 2018).

The learning gathered throughout years of experience with wind farms projects, as best practices, contractual modes, risk management, and other legal and regulatory aspects, were shared through indirect and co-financed operations. Regarding this factor, it was possible to observe an educational behavior from BNDES, by first working closely with main actors from the energy and wind energy area, developing internal technical expertise, for then bridging this knowledge to the financial industry. It resulted in the creation of innovative contractual structures and procedures adapted to specific needs and characteristics of the area, helping not only individual projects but the whole nascent sector to become more “bankable”.

> *BNDES has sectorial teams, and they are really engaged with the areas they target. … they become specialists. This way they can understand better the needs of the area, and they can adapt some things. … the total term of the operation, guarantees, the amortization plan, they put all this together and make a product or a program.*

Products or programs as mentioned refer to a specific set of financial conditions established with specific goals or targeting specific sectors of the economy. Respondent 8, who asked not to be recorded, confirmed that in some cases this process of organizational learning takes place considering both the needs of an emerging sector, while at the same time the structure of the financial industry which is expected to take over the investments from a certain moment on.

To bridge the knowledge internally accrued and the private banks, BNDES actively uses mechanisms such as indirect operations and co-financing. In co-financing, both BNDES and private banks share the loans provided to a project and the risks. According to respondent 8, it is common for BNDES to signal to the market the interest in partners to co-finance certain projects, especially, the bigger ones. But, in the case of the wind energy sector, as it was a new sector lacking performance history, other banks did not show interest to join, until the first projects were successfully being deployed. Indirect operations are those where a private bank operationalizes credit lines originally from BNDES. As such, private banks pass along the credit lines to investment projects following the guidelines and policies of BNDES. This relationship is not mandatory. Thus, the private institutions may choose to participate, but due to the relevance of the public bank and pressures from clients, who can actively seek BNDES funds, the main banks in Brazil are part of this system. For the private banks it represents another source of funding, expanding their portfolio, and for BNDES it is a way to expand their operating range.

> *For the bank [private bank] you can say that it generates knowledge. Because you have contact with some projects that the bank would not want to take in an initial moment, it creates relationships, and with time the bank feels more comfortable to invest in that area as well. (Respondent 4)*

In 2011 became the second cheapest one in Brazil, only behind hydro (Document 3, p. 86 and Document 12, p. 17). In the following years the low prices offered by wind energy generation started to call attention of consumers in the Free Contracting Environment (ACL). Until then this market was small compared to the Regulated Contracting Environment (ACR). In 2016 and 2017 the planned auctions for wind energy were cancelled due to impacts of severe economic crisis in Brazil (Plattek et al., 2021). Thus, projects prepared to be in these auctions turned to ACL consumers which were already interested in the wind energy low prices. Nevertheless, the contracts in this environment are in general of shorter duration than in ACR, around five years, thus, great part of the operational lifespan of a wind farm negotiating in ACL is not covered by any foreseeing sales. To cope with that BNDES adopted an innovation for financing conditions for energy market in Brazil, establishing a support price for non-negotiated energy serving as basis for financing engineering of energy generators.

To address the issue of long-term financing in the ACL, BNDES estimated and communicated to the market a long-term price reference level, designated as PLD Support, defined for credit analysis in 2018 at BRL 90/MWh. The PLD Support started to be applied to any amount of energy not contracted during the entire operational horizon of the generators (up to thirty years of grant), enabling, therefore, long-term cash flow assessment and credit sizing with compatible payment term. (Document 13, p. 67)

Finally, in relation to *regulators*, the influence of BNDES and the influence their interaction with the ecosystem, is embedded in the previous presented segments. It was also explored in the section about the Bank and its involvement with the wind energy sector. The main aspect in this case seemed to be the development of Proinfa, where several public actors, including BNDES, participated in the policies, guidelines, and operationalization of the program. Respondent 9 indicated that *"they are all public organizations, they are always talking, exchanging information"*, but, also according to this respondent, it does not seem that they interfere in each other's responsibilities.

4.2.5. Ecosystem Health

In this section the main findings will be analyzed in the light of the impact in the Brazilian wind ecosystem health. Insights from participants helped in exploring and understanding the role played by BNDES in the business ecosystem development in Brazil as relates to wind energy generation. The performance and development of the business ecosystem are largely impacted by productivity, robustness, and niche creation as further discussed below.

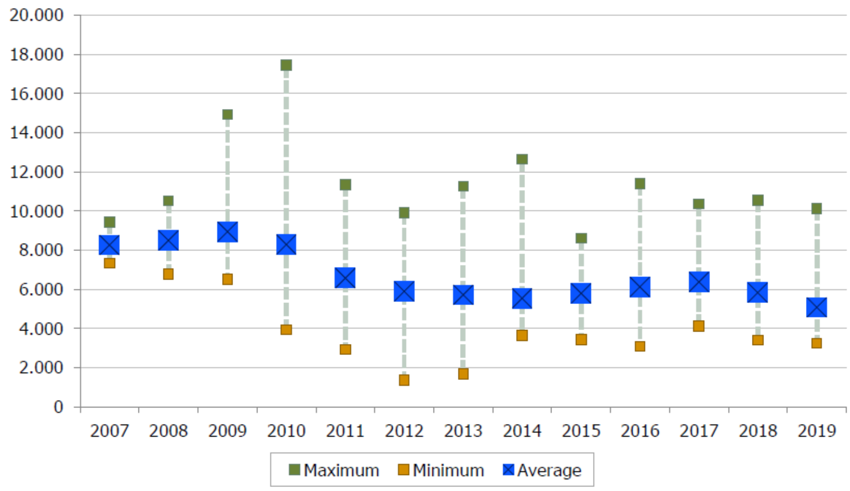
4.2.5.1. Productivity

Productivity measures the capacity of the ecosystem of transforming raw inputs into valuable outputs, or as presented by Iansiti and Levien (2002) converting factors of production into lowered costs or new products and functions. In this sense, the reduced cost of capital from BNDES, supporting wind farm developers with lower rates than the ones that could be found in the private market, reduced the costs of implementation. This was then incorporated in the downstream part of the ecosystem by electricity distributors. Thus, for the *wind farm developers and electricity distributors*, the last ones who ultimately acquire the energy in the auctions and then charge the end consumers, this meant extra productivity as the total costs of the investments were reduced, and, consequently, the prices of the energy produced went down. Such effect was mentioned by Respondents 1, and 5 and corroborated by Figure 8.

More competition, between the projects with the auctions, between the wind turbine producers, and between the suppliers, what happens? The costs go down, at least in the first *moment they go down. After, considering a globalized world, with specialization, then might be different. (Respondent 1)*

The presence of BNDES provided subsidized interest rates, many investors were attracted to the area. With these rates many projects were possible because, in the beginning, the technology was more expensive, developing the projects was more expensive, and everything was imported. It needed someone to sponsor. With more companies investing in the area, more demand, the costs started to go down. (Respondent 5)

Figure 8. *Estimated CAPEX of qualified projects per year in R$/kW*



Note. From EPE (2020).

In this aspect, the local content policy also had an impact. The initial phases of the local content policy from BNDES, when bilateral agreements were set, facilitated the process for international wind turbines producers to install their production in Brazil. Allied with demand induction incentives, many of these companies decided to enter the Brazilian market, which favored competition, and influenced the reduction of prices as shown in Figure 8. Moreover, Document 9 contributes with other factors that influenced in the increase of productivity by reduction of costs or process/products improvements:

- More specialized components' producers capable to attend higher demands from turbine manufacturers and wind farm developers,
- Concentration of suppliers nearer the areas with higher number prospects of wind farms, reducing time and costs of implantation,
- The same prementioned point applies for time and costs of maintenance, and
- Local technical and engineering teams better prepared, reducing costs with the need of foreign labor to coordinate projects.

Therefore, BNDES seems to be fulfilling its developmental role as it provides subsidized credit based on the incapacity of the market to fully internalize the positive externalities of the wind infrastructure (Mazzucato & Penna, 2015a). Moreover, fulfilling its mission-oriented, the Bank goes beyond providing financial resources role (Mazzucato & Penna, 2015b). It makes use of industrial policies in its credit conditions to guide other actors towards its view of a more productive market, with the development of a national industry.

4.2.5.2. Robustness

Robustness measures the capacity of an ecosystem to provide a stable structure that helps its members to respond to internal and external perturbations. This factor considers that in response to threats, firms can influence changes, offer solutions to multiple ecosystem participants, or buffer themselves through connections with their business partners and even competitors.

Many types of potential disruptions may pose a threat to an ecosystem's health. One of them comes from the erratic economical trajectories and policies quite often assumed by developing countries (Pessoa et al., 2020). It was recurrent in the comments of the interview as *"the interest rates in Brazil are historically high, but the problem is the volatility"* (Respondent 3), or *"one government comes, another gets out, everything changes"* (Respondent 4). Another participant complemented:

> *The environment in Brazil is challenging for the project developers. The Selic [basic interest rate in Brazil] goes up and down very fast, so it affects the planning. In energy generation, the planning is long-term. (…) To support one, or two projects is one thing. To support the development of a whole industry is completely different. It takes time for companies to make plans, to trust. It requests a big financial capacity and patience. (Respondent 1)*

As previously mentioned, BNDES used TJLP and more recently TLP to most loan contracts to wind farms. These interest rates are used to provide more stability and predictability to credit directed to long-term capital investment.

Another source of perturbation in the ecosystem could be the cambial variations that could impact the prices of wind turbines. These items represent around 75% of the costs of a wind farm. Thus, one of the goals of local content policies from BNDES is to reduce risks related to this problem, as indicated in Document 1, p. 188, when exploring the goals of these policies: *"To minimize exposure to exchange rate risk derived from imported equipment and maintain a healthy trade balance in manufactured goods are additional reasons that support the industrial consolidation clustering in the wind sector".*

Next, it can be also considered a situation that heavily impacted the demand in the local market. In 2016 and 2017, the Federal Government postponed or canceled some of the auctions in ACR (regulated market) planned to happen in these years due to effects of economic crisis and, consequential, reduction of energy demand. Although the whole ecosystem felt the impact, it was capable to keep its general structure and find ways to keep expanding, as it was the case with more opportunities being explored in ACL (free market). According to the survey carried out by ABDI (Brazilian Association of Industrial Development), in 2014, the wind energy production chain in Brazil was formed by 79 firms directly related to the sector. They were involved in the assembly of wind turbines, in the manufacture of components and subcomponents, and totaled 55 different items. In 2017, these numbers increased, with 116 new firms supplying 85 different items. Thus, not only the number of organizations in the sector grew, but also the variety of items used in the wind turbine (Document 9). Several of these items were direct focus of the local content policies from BNDES, especially the ones present in the nacelle and rotor, which require more technological capabilities (Document 8).

The turbine manufacturers also showed resilience and all fabricators that entered the Brazilian market stayed. Impsa, Suzlon, and Furhländer faced general administrative problems and filed for bankruptcy not only in Brazil, with factors that extrapolate the influence of the ecosystem in this analysis. Some others passed by mergers as Enercon and Wobben. WEG, a Brazilian company that had knowledge, longtime connection with the energy sector, and already provided components for turbine manufacturers, started to develop its turbine (Fabris, 2020).

The long-term commitments to develop an ecosystem related to wind energy in Brazil were challenging because the technology itself was still relatively new. In response, as noted by respondent 8, BNDES reunited wind park investors, wind turbine manufacturers, and other interest parties, assuming the commitment to assure credit to all projects with power purchase agreements with Eletrobras. For the interested investors, this was a strong indicator of the commitment to provide a persistent structure where they could join and also deploy efforts. For wind turbine manufacturers this meant a consistent environment where durable relationships could be built despite external turbulence. This behavior evidences the de-risking role assumed by BNDES and leads the participants to feel comfortable developing a stable core of relations, supporting the whole system (Geddes et al., 2018). Stability is an attribute connected to the development of business ecosystems and a strong indicator of ecosystem robustness (Iansiti & Levien, 2002).

4.2.5.3. Niche Creation

Niche creation concerns the creation of new valuable functions over time, i.e., the increase in meaningful diversity, which can be captured by the number of new options, technological building blocks, categories, products, and businesses being created within the ecosystem in a given period or the overall value of new options created.

In this aspect, it is relevant to mention the educational role assumed by the institution (Geddes et al., 2018). First by using indirect mode of financing in certain cases, where a private bank pass along the funds from BNDES. And second through co-financed operations, in which case, more responsibilities and risks are shared among the lenders. These modes, though, were only used after BNDES had accrued experience with wind farm funding. As mentioned by Respondent 4 "*BNDES defines the conditions, if it works, the [private] bank follows"*. The same could be observed in the case of innovations in contracts in ACL: "*After the BNDES' announcement, commercial and development regional banks have set price benchmarks for the ACL." (Document 13, p. 67)*.

Therefore, the educational role of BNDES supports the creation of new functions by influencing private banks to participate in the wind energy ecosystem and by sharing with them the accumulated expertise. In turn, it is expected that these actors, at least to a certain extent, take over the role of BNDES in the future, providing funding in the terms and amount needed to maintain investment levels in the sector.

5. Discussion

Guiding this research, the main question proposed was h*ow did the involvement of the Brazilian SIB influence the development of a local clean energy business ecosystem?* To drive the research towards a deeper understanding, three sub-questions complement the main research question:

SQ1: *What are SIBs and how is their involvement with clean energy sectors?*

SQ2: *How does a business ecosystem develop?*

SQ3: *How did the role of the Brazilian SIB (BNDES) influence the local wind energy business ecosystem?*

SQ4: *How did BNDES influence the wind energy ecosystem's health and coevolution in Brazil?*

Through the theoretical background, the first two sub-questions were answered in the light of what is already researched and known on the topic of SIB and business ecosystems. First, SIBs can differ according to the context they operate, as country, characteristics of supported industries, and maturity of the financial sector (Lazzarini et al., 2017). However, in general, it seems they are instrumental for the development of such contexts, particularly, when the scenario is presented with market failures that constraint the efforts of other actors (Mazzucato & Penna, 2015a). Hence, it can be expected that they will assume central and seminal roles to support the development of different players, in diverse parts of an ecosystem. This can be linked to some of the role's activities mapped in the ecosystem literature. For example, the role of expert in value creation support, which one of the activities is related to encouraging technology transfer and commercialization (Dedehayir et al., 2018). BNDES has performed this activity using its local content policy. Another example is the champion role, with activities as providing access to local and nonlocal markets (Dedehayir et al., 2018). Undoubtfully, BNDES acted as a gatekeeper for wind turbine manufacturers, which had to comply to its rules to participate in the market. Moreover, for having relevant impact in measures of ecosystem health, to a certain extent its agency resembles keystone actors (Iansiti & Levien, 2004). Document 12, p. 8, reinforces this view: *It is worth remembering that the bank has been the keystone that, in recent years, has supported the significant expansion of hydroelectricity generation, production of ethanol, electricity from sugarcane bagasse and, mostly, wind energy".*

Business ecosystems emerge from the interactions between different interest parts to the value proposition to materialize (Adner, 2017). These actors align their cooperative and competitive strategies around central contributors, developing the whole ecosystem through coevolution. Such a process is dependent on ecosystem health, which is measured through its productivity, robustness, and niche creation. Keystone species are important regulators of ecosystem health assuming strategies that impact such measures. Besides the more traditional leadership roles, as keystones, as direct value creators, entrepreneurial and supportive roles to value creation also contribute to eh ecosystem emergence and development.

Regarding the development of the wind energy ecosystem in Brazil, it took place from the search for alternatives for the expansion of generation after the energy crisis of 2001. The diversification of the Brazilian energy matrix found in wind power is a flexible and scalable alternative to the expansion of power generation capacity. The advances in wind energy in the country were notable, moving from an insignificant installed capacity in 2005 to 18 GW at the beginning of 2021, which represents slightly more than 10% of the Brazilian electricity matrix. Generation costs have been falling consistently, as well as investment costs in wind farms and the manufacture of wind turbines.

Such a scenario was attained by the conjunction of factors, among which the influence of BNDES was vital. Through its capital provision role, not only the important sizeable funds with advantageous conditions to the wind park investors were provided, but it was done by aligning the same investor and the wind turbine manufacturer to stimulate the local production chain. It also impacted the robustness of the ecosystem by reducing the perceived risk and developing innovative financial solutions adapted to the wind sector's needs. Finally, BNDES nurtured relationships with the private financial market to share and diffuse its knowledge and expertise in the sector, giving rise to new meaningful functions.

Through the BNDES credit, wind energy parties and stakeholders had to adhere to local content restrictions. As a result, good part of components in turbines were sourced locally resulting in local job creation and accelerated growth and investment in wind energy. Nonetheless, this process did not happen without mishaps. For example, BNDES credit conditions emphasized gearboxes, generators, and DFIG panels that are used in turbine models with a gearbox to be made domestically at the start of January 2014. At least three of the four primary wind turbine elements (hubs, nacelles, blades, and towers) were primarily manufactured or built-in Brazil for versions without a gearbox. Although BNDES devised credit conditions that focused on a gradual move to local production up to 2016, they ceased supplying funding in June 2013 to developers who acquired turbines from five companies that did not match the initial requirements. Some of the players in the wind energy ecosystem that did not follow the BNDES credit guidelines included Acciona, Fuhrlander, Siemens, Suzlon, and Vestas. Most of these companies were able to get back their accreditation in BNDES system.

Through its credit facility, BNDES boosted its assistance to projects, mainly, from 2002 to 2015. At the time, its lending level increased rapidly thereby facilitating growth of wind energy investment in a sector previously ‘choked’ by a lack of financing from private and commercial banks due to credit uncertainty. BNDES’s experience and knowledge generated interest among private banks and even international lenders to become key partners in financing wind energy projects in Brazil. On May 9, 2017, BNDES was the first Brazilian bank to issue green bonds in the international market. The US$ 1 billion bond had a seven-year term and was listed on Bolsa Verde from Luxembourg (The Brazilian Development Bank, 2018). The funds were intended to finance investments related to new and existing wind and solar energy projects. The success in fundraising in international markets, in part, can be attributed to the recognized efforts of the Bank to maintain a close relationship and to develop the Brazilian wind ecosystem.

In summary, BNDES influenced the design of the market and environment where diverse interest parts could align their efforts and deploy their resources. It participated in the development of the general value proposition, altogether with other important actors. Furthermore, the increase of the wind energy in the Brazilian electric mix happened alongside the development of a business ecosystem with relevant participation of the national industry (Plattek et al., 2021; Rennkamp & Westin, 2013).

This process influenced the ecosystem health favoring the development of the whole network. In the ecosystem literature this dynamic is marked by the coevolution of participants., which will be discussed in a specific topic.

5.1. Coevolution

In the wind energy sector, a business ecosystem develops through coevolution, role stipulation, structure formation, and establishment of ecosystem health (Iansiti & Levien, 2004). A key concern in the wind energy sector relates to the complexity of the system due to its multiple players and several parties required to collaborate seamlessly to create a successful supply chain for the wind farms development (Aroeira et al., 2017; Williamson & De Meyer, 2012). Due to a lack of credit and risk assessment profile, commercial banks largely remain less supportive of the sector's development. With the presence of SIBs such as BNDES, substantial financing is availed through an elaborate credit system. Access to financing from SIBs forms the foundational phase for an elaborate ecosystem development incorporating different stakeholders and key players such as wind farm development, parts, and non-technical component producers, tower manufacturers, blade manufacturers, wind turbine manufacturers, and production of technologically advanced wind generation components.

In coevolution, the process results in the creation of essential species that collaborate and coordinate within the supply chain thereby creating a system of productive wind power generation (Chen et al., 2014). In the context of wind power generation, coevolution is not a consequence of completely random variations since it is motivated by key players being motivated by advantages, which means that changes and relationships between species are intended to meet needs such as greater performance, lower prices, or specified criteria (Peltoniemi, 2005). According to Moore (1993), coevolution may be understood as a process where an ecosystem develops through birth, expansion, leadership, and self-renewal or death. In the energy sector, the birth emerged with the implementation of the Proinfa program in 2004 with a key mandate for purchasing and marketing green energy such as wind power generation. The expansion was achieved through BNDES financing in subsequent decades for wind power players and investors.

As the wind energy matures in terms of its business ecosystem, financing terms may shift to resemble more closely those supplied by the private capital market or commercial banks thereby signaling to potential investors that the wind energy sector has made substantial progress (Geddes et al., 2018; Plattek et al., 2021). SIBs also enforce industrial policies, tying lending to minimum local content standards, and requiring investors to source a portion of power plants from companies based in the SIBs' operating regions (Hansen et al., 2020). Such policies evolve throughout time to encourage the growth of specific segments within the wind energy sector such as engineering, procurement, and construction, in addition to transmission and distribution. In the ecosystem, SIBs like BNDES make substantial contributions to the development of a significant regional industrial base, which helps to sustain investments and stimulate technical innovation (Mazzucato, 2018). Thus, financial support by SIBs in a previously neglected business ecosystem such as the wind energy sector creates favorable credit conditions that drive the coevolution of an entire business ecosystem comprising multiple key players. Also, wind energy development results in the lowering of the market's perceived risks thereby encouraging the development of the entire supply chain that supports its existence where the ecosystem comprises locally and internationally sourced materials, products, and services from multiple countries (Plattek et al., 2021).

6. Limitations, Contributions, and Future Research

Regarding the limitations of this research, as a case study, first it is important to acknowledge that specific context and settings, may lead to a constraint in extrapolating findings and assessing the framework used. For example, the lack of experience of the private capital market in Brazil with infrastructure projects impose a challenge for the development of a whole ecosystem, and requires BNDES to take some actions coherent with such scenario, as developing innovations in financing policies (Plattek et al., 2021). In other settings, as in economies with more mature capital markets, such behavior might not be necessary. Thus, it will not be expected to be found a SIB assuming an educational role, accumulating knowledge and passing forward to other financial agents, creating a niche of financiers. Therefore, future research could complement the framework by bringing insights from cases of other SIBs that operate in similar contexts.

From a practical standpoint, this research helps to clarify the impact SIBs might have in the initiation and development of a business ecosystem, as well as some of the pathways these institutions may follow to do so. For managers, this means to consider SIBs in strategic plans when assessing regions and markets where one of these institutions operate. For policymakers, the case study may propitiate an amplified view of financing for clean energy as part of a larger framework that encompasses many other actors and challenges from a variety of industries.

Characterizing the structure of complex networks is critical because the structure always impacts the function and behavior of a dynamical system. Particularly a complex one, as the wind energy, which can only be comprehended by looking at the interactions among various individual pieces. In addition, the inclusion of peripheric actors in the assessment of the value proposition of the ecosystem offers an alternative view for evaluating strategic difficulties involving competition and collaboration. Insights from this study help understand the role of SIBs as active participants who can influence this dynamic through project financing and credit conditioning. In general, these entities are placed in the periphery of the ecosystem analysis, which tends to place an excessive amount of emphasis on the relationship between a focal company, its suppliers and, potential complementors. Hence, this research contributes to theory by acknowledging SIBs as key components of an ecosystem structure in markets where they are present, assuming roles that impact the ecosystem health and coevolution.

7. Conclusion

The primary research question was formulated to understand *how the involvement of the Brazilian SIB influenced the development of a clean energy business ecosystem.* Findings from the case analysis show that BNDES substantially created credit conditions that spurred growth in the wind energy sector. Five notable influences generated by BNDES included:

- Stimulating the participation of commercial private banks to start funding operations for wind energy investment,
- Creating conditions that facilitated close collaboration and cooperation with international wind turbine producers,
- Creating a competitive local market in terms of sourcing components and resources from local component manufacturers,
- Collaborating with other energy institutions to create parameters for suitable contracts and credit, and
- Facilitating a positive business environment that reduced the negative perception of wind farms among investors and private capital markets.

Therefore, under the BNDES credit conditions, there has been a substantial development of the wind energy business ecosystem in Brazil among multiple players. The integration of these players serves to enhance collaboration and coordination in multiple processes needed to successfully deploy and expand wind energy generation. As such, BNDES credit conditions served to promote the diversification of the Brazilian electric mix and influenced the development of the local wind energy ecosystem, through the increase of the ecosystem health, while coevolving with other actors.

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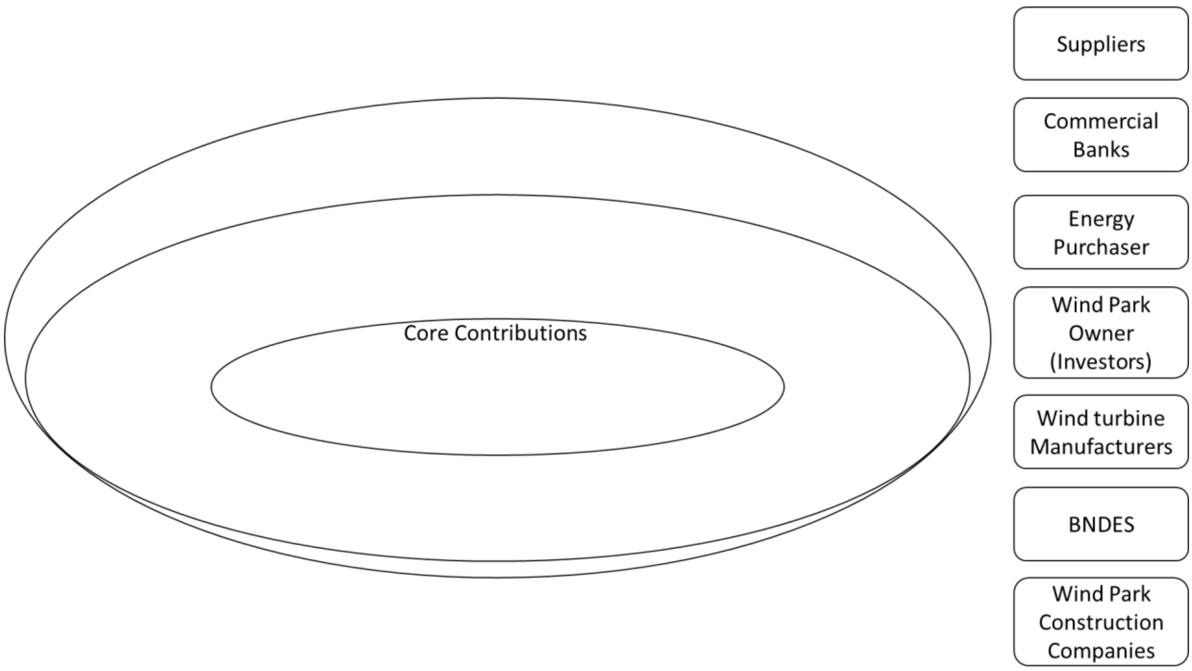
Appendix A. Confirmatory Experiment

The choice for the case to be empirically assessed was based on the previous experience of the researcher and his knowledge about the meaningful development of the wind energy sector in Brazil. To assure that the settings of the case were adherent with the general research topic, an experiment was held in one of the respondents of the research (Respondent 1) in a previous moment to the interview itself. As the idea was to validate some general view of the area and connection to the research topic the session was not recorder nor a formal method for the experiment was designed.

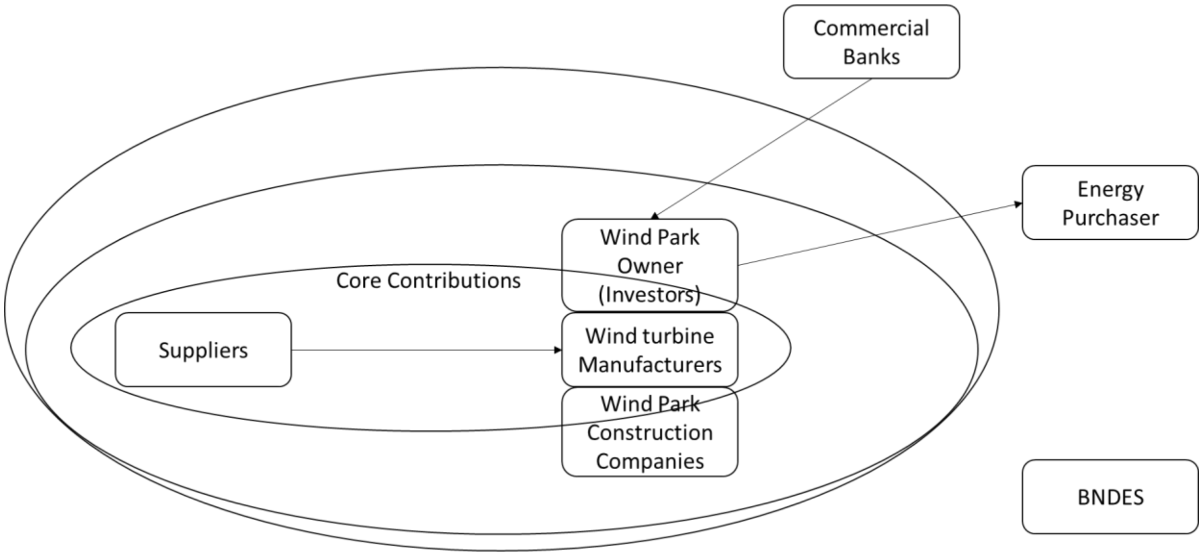
The first step was to present the general depiction of a business ecosystem (**Figure 1**), according to Moore (1993), and explain the concepts in general lines. Then, an empty conceptualization of a business ecosystem was designed by the researcher in a web application where both, researcher, and participant, shared the screen and the control of the canvas. The participant was stimulated to place the actors in the empty depiction of a business ecosystem and define relations between them. The researcher stimulated the participant to describe the wind energy sector in Brazil through time and to try to depict the ecosystem in the canvas. Some general actors related to the wind energy in Brazil in the initial moments of the sector were defined by the participant and depicted on the right.

Figure A1. *Experiment Step 1*



Initially only the 'wind turbine manufacturers' and 'supplier' were used, placed in 'core contributions'. Until the beginning of the 2000's, only one wind turbine manufacturer had operations in Brazil, with most part of the parts used in the manufacture of the turbines being imported. This was the German company Wobben, which in some projects was also the responsible for the construction of the wind park and its operation afterwards, thus, its owner. Some local Brazilian suppliers of wind blades had also already initiated, focusing mainly in exportations. Eventually, some connections with 'commercial banks' were held as providers of credit for the projects, but no specific alignment inside a business ecosystem was necessary, regular commercial credit lines were provided. The same was considered for 'energy purchaser', as this actor requested no specific alignment between any of the other members and the investments in the are were mainly pilot projects.

Figure A2. *Experiment Step 2*

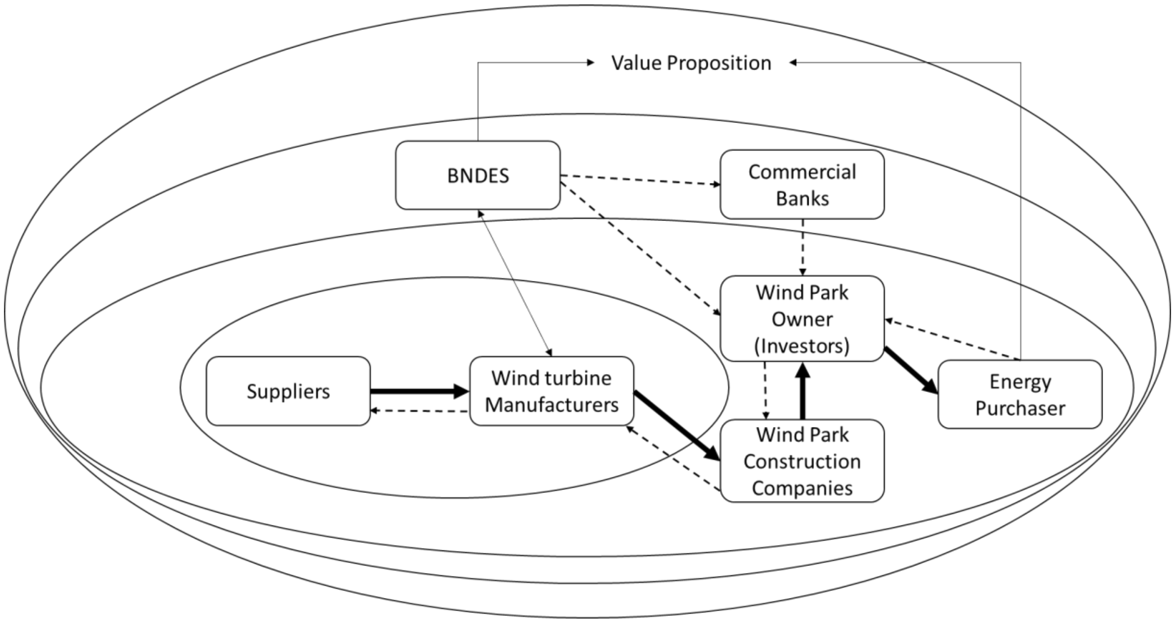


Finally, stimulated by governmental incentives, among which BNDES credit lines, the ecosystem became more complex and different relationships were developed (**Figure A*3***). The participant proposed to create different lines to explicit different flows within the ecosystem. The dashed lines represent financial flow, thick lines represent the flow of physical assets as equipment or generated energy, and the normal lines information and influence flows.

The 'energy purchaser' was embodied, in a first moment, by the main energy generator and distributor in the country by the time, Eletrobras, a state-owned company. Together with BNDES and other institutions – left out for the sake of clarity – they had great impact in the value proposition for the ecosystem, which was to accelerate the increase in the participation of wind energy in the Brazilian energy mix, with parallel development of the local market and industry. This is seen as encapsuling the ecosystem itself, consistently with what is proposed by the literature. To receive loans from BNDES, wind park investors had to comply to the Bank policies, as the rule that the wind turbines had to be acquired from accredited manufacturers, which in turn, had to submit detailed information about their products to receive such accreditation. The basic threshold was that 60% in weight and value of the turbines had to be produced in Brazil.

This experiment helped to understand the wind energy ecosystem in Brazil, its dynamics, roles, actors, relations, and to confirm the relevance of the case as an insightful source of reference for the topic in this study.

Figure A3*. Experiment Step 3*



Appendix B. Interview Guide

Semi-Structured Interview Guide

Procedure

The participants will also be briefly briefed in advance upon the subject of the interview. The interviews will be performed using the videoconference software Zoom. Whenever allowed by the interviewee the session will be recorded and after transcribed. The possibility to anonymize the names of participants and organizations they work for – or the ones they worked for when they had contact with the subject of the study – will be offered. The recordings will be deleted after the transcription assuring compliance to data protection. Finally, the interviews will be taken in local language (Portuguese) aiming to stimulate the interviewees to fully express their ideas.

Questions

Introduction – Background Questions

1. What is your name?
2. What is your position at the moment? Is this the same position that led you to have contact to BNDES and/or the wind energy business ecosystem? If not, what was your last role in the previous mentioned settings?
3. What is the name of the company you work for or worked for when in contact to BNDES and/or the wind energy business ecosystem?

General Questions (relevant to BNDES specialists)

4. How does BNDES organize itself internally to sense and assess the needs of specific sectors? (Sectorial teams, market studies)
5. How does BNDES engage with other actors to define policies for specific areas? (Other government institutions, class associations, groups of firms)

SB3: How did the roles of BNDES influenced the development of the wind energy ecosystem in Brazil?

6. What is your knowledge about how the energy market in Brazil works?
7. Do you have any knowledge about how the development of the sector of wind energy in Brazil?
8. How can BNDES be important for the participants of the wind energy market in Brazil?
    a. Does BNDES do more than just provide financial resources? (Knowledge, connections, support)

9. How BNDES adapted its financial products to attend the wind energy in Brazil? (Project finance, specific credit lines)
10. How BNDES stimulated other financial institutions to participate in the investments in wind energy in Brazil? (Co-financing, indirect operations)
    a. How BNDES managed the tensions related to attracting other financial institutions that could eventually compete for the projects in the area?
    b. How is value generated for the other financial institutions?
    c. To which extent BNDES defines how value is divided with other financial institutions?
11. How the local content requirements for machines and equipment from BNDES impacted the wind turbines producers that aimed to do business in Brazil?
    a. Why BNDES tries to implement local content requirements?
    b. To what extent this policy impacted the development of a business ecosystem?
12. How BNDES adapted its policies related to local content for wind turbines?
    a. To what extent different actors in the energy sector had to be aligned for these policies to be effective?
    b. To what extent wind turbines producers followed BNDES' directions?
    c. How the policies evolved over time?
13. How did BNDES' policies of local content for wind turbines impacted the projects in relation to:
    a. Implementation time
    b. Quality of the projects
    c. Development of new important players
    d. Costs of implementation or return of investment
14. What would be the effect of BNDES withdrawing support to the wind energy business ecosystem?
15. Summarizing, how important was the role of BNDES for the nascent business ecosystems related to wind energy in Brazil?
16. Is there something else you would like to add?