Pontifícia Universidade Católica
do Rio de Janeiro

Hudson Lima Mendonça

The Role of Open Innovation in the Energy Transition

Tese de Doutorado

Thesis presented to the Programa de Pós-Graduação em Administração de Empresas of PUC-Rio in partial fulfillment of requirements for the degree of Doutor em Administração de Empresas.

Advisor: Prof. Jorge Ferreira da Silva

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Abstract

Mendonça, Hudson Lima; da Silva, Jorge Ferreira (Advisor). **The Role of Open Innovation in the Energy Transition**. Rio de Janeiro, 2019. 124pp. Tese de Doutorado - Departamento de Administração, Pontifícia Universidade Católica do Rio de Janeiro.

The energy transition is one of the most significant challenges of our time. By 2050, more than US$ 13 trillion of investments are expected in the electricity sector, with 77% from renewable sources. In this context, the open innovation paradigm should play a key role in reducing the costs of current technologies, creating new markets and reshaping the existing ones through the interaction of the five main stakeholders in this process: universities, corporations, governments, entrepreneurs and venture capitalists. In the first article, we show the importance of the interaction of the first three actors around mission-oriented public policies. We build a framework that can address the best practices of this type of policy when applied to the energy transition context. In the second, we seek to identify the patterns that have led energy startups to success or failure over the past 20 years. We find that business models, invested values, and investor profiles play a key role in these trajectories. Finally, considering the relevance of the relationship between startups and corporations during the energy transition, we analyzed in the third article the role of corporate venture capital (CVC) over the last 25 years and we recognize the fifth wave of CVC, which has many particularities and drives the CVC units to the innovation's strategic center of modern corporations. Overall, we conclude that all these main five stakeholders have a distinct but fundamental role in the energy transition.

Keywords

Open Innovation; Energy Transition; Startups; Corporate Venture; Entrepreneurship; Energy.

Resumo

Mendonça, Hudson Lima; da Silva, Jorge Ferreira (Orientador). **O Papel da Inovação Aberta na Transição Energética**. Rio de Janeiro, 2019. 124pp. Tese de Doutorado - Departamento de Administração, Pontifícia Universidade Católica do Rio de Janeiro.

A transição energética se põe como um dos grandes desafios de nosso tempo. Até 2050 são previstos mais de US$ 13 trilhões de investimentos só em energia elétrica, sendo 77% em fontes renováveis. Nesse contexto o paradigma das inovações abertas deve exercer um papel fundamental, reduzindo os custos das tecnologias atuais, criando novos mercados e remodelando os existentes através da interação dos cinco principais atores desse processo: universidades, corporações, governos, empreendedores e capitalistas de risco. No nosso primeiro artigo, mostramos a importância da interação desses três primeiros atores ao redor de políticas públicas orientadas às missões. Construímos um framework capaz de endereçar as melhores práticas desse tipo de política quando estas são aplicadas à transição energética. No segundo, buscamos identificar os padrões que levaram startups de energia ao sucesso ou ao fracasso o longo dos últimos 20 anos. Descobrimos que os modelos de negócio, os valores investidos e o perfil dos investidores exerceram um papel fundamental nestas trajetórias. Por fim, dada a relevância da relação entre startups e corporações na transição energética, analisamos no terceiro artigo o papel do *corporate venture capital* (CVC) ao longo dos últimos 25 anos e identificamos a existência de uma quinta onda de CVC, que possui notáveis particularidades e que leva as unidades de CVC ao centro estratégico de inovação das corporações modernas. De modo geral concluímos que todos os cinco principais atores possuem papeis distintos, mas fundamentais, na transição energética.

Keywords

Inovação Aberta; Transição Energética; Startups; Corporate Venture; Empreendedorismo; Energia.

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Throughout the centuries there were men who took first steps, down new roads, armed with nothing but their own vision.

Ayn Rand.

1 INTRODUCTION

The energy transition can be defined as a long-term structural change in energy systems (WORLD ENERGY COUNCIL, 2019). From various theoretical and empirical aspects, we can say that we are living one of these most structuring changes in the energy sector (GREENPEACE, 2015; IEA, 2019a; SMIL, 2010). According to the U.S. Energy Information Administration (EIA), 86% of the world's primary energy is still from fossil origin (HARTLEY; MEDLOCK, 2017). However, investments in renewable energy and energy efficiency are growing at a substantially faster rate and are already the most significant investments. In 2018, US$ 1.8 trillion was invested in the energy sector, but US$ 1.03 trillion (or 57%) was invested in renewables and energy efficiency (IEA, 2019b).

The forecast is that this speed will be even higher going forward. Bloomberg New Energy Finance predicts investments of US$ 13.3 trillion by 2050 in the electricity sector, with 77% of this volume just in renewable energy (BLOOMBERGNEF, 2019). There is some consensus on the general direction of the energy transition (renewables and energy efficiency). Although, the same cannot be said about the speed or exact shape/change that will occur.

On speed specifically, sustainability-related institutions claim that change will occur much faster than expected by fossil fuel related institutions. Although, both agree on the rapid growth of renewables over the coming decades. Considering the percentage of energy generated from renewable sources in 2035 as an indicator, forecasts made in similar periods range from only 6% (BP, 2014) to 57% (WWF; ECOFYS; OMA, 2011). At this point, it is interesting to note that BP has been systematically “adjusting” its forecasts in recent years to 9% in 2016 and 13% in 2018 (BP, 2016, 2018).

Regarding the way/configuration of this energy transition, the complexity tends to be even higher. The three “Ds” of this energy transition (Decarbonization, Decentralization, and Digitization) can take many forms. Many possible paths could completely change the sector where variables outside the energy area itself have a considerable impact on the sector.

These examples include new technologies and business models that are already impacting the automotive industry. Electromobility (electric and hybrid vehicles), connectivity, autonomous vehicles, and fuel cells are among the key trends for this industry in the future. The Global Automotive Survey conducted by KPMG annually (Figure 1) shows that, since 2016, bets on cars with internal combustion engines (ICEs like gasoline, diesel, ethanol, etc.) are no longer a priority for industry executives (KPMG, 2018). The number of electric vehicles has grown exponentially from 400,000 in 2013 to 5.1 million in 2018, a compounded average growth of 155% per year over the last five years (IEA, 2019c). However, 94% of the world's transportation sector's energy consumption is still based on oil, and most of the world's oil consumption is carried by the transportation sector (BP, 2018). Thus, we can conclude that changes in the automotive sector could be a significant catalyst for the energy transition in the coming years. Along the same lines, business models that advocate automobiles as a service could rapidly expand the impact of electromobility also to current power and oil distribution models.

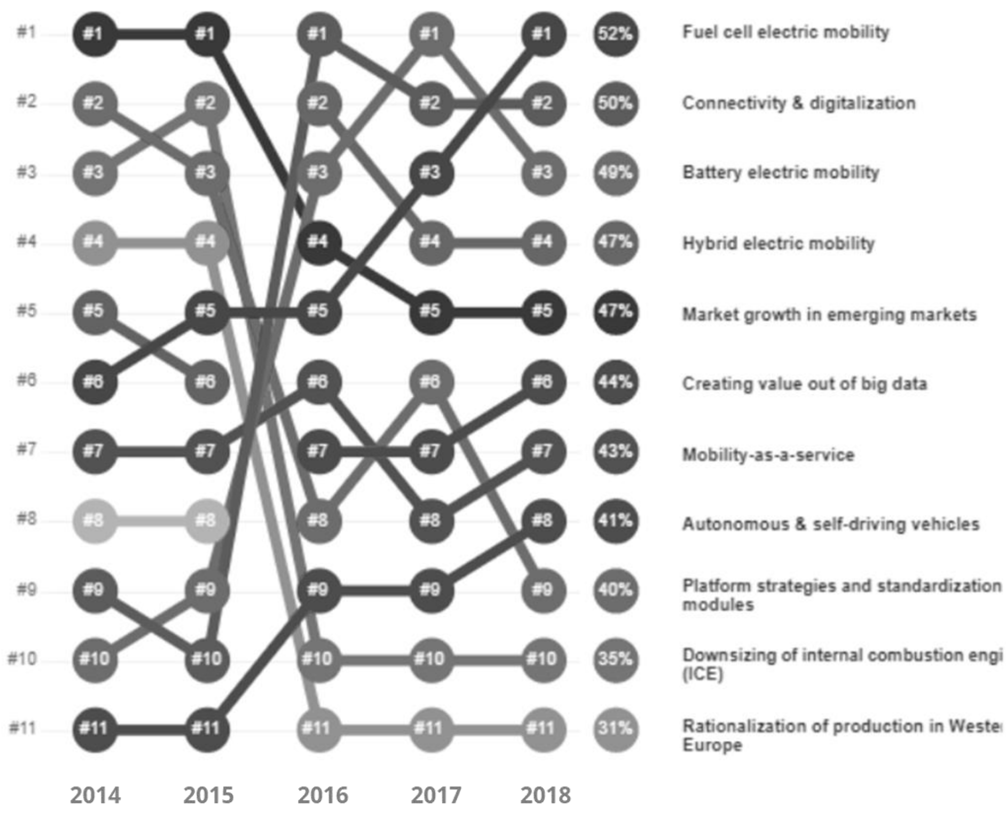

Figure 1: Top Global Automotive Trends to 2025
Source: (KPMG, 2018)

Concerning the digitization and decentralization of the energy sector, distributed generation, smart grids, and smart contracts (utilizing blockchain technology) are also trends with disruptive potential. They can change the sector, but also bring new actors to the energy fields. The exponential fall in the price of photovoltaic solar panels and energy efficiency solutions is already a reality (IEA, 2019b) and has stimulated the emergence of several startups in a sector. Until recently, it was considered unfeasible for them due to the need for high investments since the earliest moments.

The role of biomass in power generation (or even liquid biofuels) is still unknown, has significant potential, but also great uncertainties in its use within the expected changes in the sector. Together, these technological and business model innovations (among many others) could substantially affect every energy production and distribution chain in the world.

What we can see in general is that this "certainty" about the direction of a major change coupled with a considerable "uncertainty" about how and in what step this will occur, closely resembles the period well known as the dot-com boom that occurred in the late 1990s and early 2000s (MENDONÇA, 2017). At that time, there was some consensus that the internet and its applications had a promising future, but there was little certainty about the speed and way/configuration that some trends would materialize. One of the big bets of the period, content portals (Yahoo, AOL etc), today play a much less relevant role than experimental concepts from that time such as search engines without manual indexing (Google, founded in 1998), social networks (Facebook, founded in 2003), and e-commerce platforms (Amazon, founded in 1994). These three firms (Google, Facebook, and Amazon), which took the lead in their segments during the disruption, are now among the top ten most valuable companies in the world by market capitalization (Table 1). Meanwhile, four of the top five energy companies are no longer on the list (FINANCIAL TIMES, 2011; PWC, 2019).

In this way, we can draw some interesting exploratory parallels between the Internet revolution and the energy transition from two different perspectives: technological and capital markets.

Table 1: Top 10 Global Companies by Market Capitalization (US$ Billion)

#	2011		2019	
	Company	**Mkt Cap**	**Company**	**Mkt Cap**
1	**Exxon Mobil**	**417**	Microsoft	905
2	**PetroChina**	**326**	Apple	896
3	Apple	321	Amazon	875
4	ICBC	251	Google	817
5	**Petrobras**	**248**	Berkshire Hathaway	494
6	BHP Billiton	247	Facebook	476
7	China Construction Bank	232	Alibaba	472
8	**Royal Dutch Shell**	**228**	Tencent Holdings	438
9	**Chevron**	**215**	Johnson & Johnson	372
10	Microsoft	213	**Exxon Mobil**	**342**

Tech Companies
Energy Companies

Sources (FINANCIAL TIMES, 2011; PWC, 2019)

From a technological point of view, we can consider that the internet revolution has started its basis in the 1960s through the advances in microelectronics, which made possible a dramatic fall in costs and an exponential increase in the capacity of microprocessors. The so-called Moore Law, created in 1965, provided that the computing power of processors would double every 18 months and remained valid for over 40 years (ATKINSON; MCKAY, 2013). The substantial cost savings and the expansion of hardware capacity enabled the fast development of the software industry a few years later. Companies such as Microsoft (1975), Apple (1976), and Oracle (1977) emerged in this wake. The union of hardware and software developments enabled the emergence of telecommunications and the Internet as we know it today (CB INSIGHTS, 2017). Moreover, it was under the Internet infrastructure (hardware and software) that the opportunities for the development of startups and new business models were built during the internet revolution.

In the energy sector, we had a similar technological trajectory. The hardware needed for a low-carbon energy matrix (which includes solar panels, batteries, LEDs, wind turbines, and others) has shown exponential decreasing costs and significant increases in efficiency and power in recent years (IEA, 2019b). These developments have enabled the current industry scenario. Beyond the decarbonization we have the increasing importance of the other two "Ds" of the energy transition: the digitalization (internet of things or IoT, artificial intelligence, big data analytics, etc.) and decentralization (distributed generation, smart contracts, blockchain etc.) (CHRISTIDIS; DEVETSIKIOTIS, 2016; WORLD ENERGY COUNCIL, 2019). With some time lapse, this trajectory has a similar pattern to that observed throughout the internet revolution, which does not guarantee that the future trajectory will continue to follow the same model, but allows some interesting exploratory inferences for the context of this research. We can observe the stage of some of these technologies through the hype cycle and maturity analysis of these technologies (BELLIDO et al., 2019).

Another way of looking at possible trajectories is through the capital market point of view. Overall, we can consider that the market value of companies is mostly given by its future growth prospects and profitability. This thinking is especially relevant for startups that have few assets, but considerable growth prospects, especially in their early stages (KÖHN, 2017). From the late 1990s until the late 2000s, the energy sector was significant and relatively stable growth, which provided high valuation prospects for their companies. By the end of this period, energy companies were among the most valuable in the stock markets. Information technology (IT) companies, in turn, still sought their spaces in an environment full of uncertainties, which drove their market values down (FINANCIAL TIMES, 2011)

From 2010s, new business models and the leading internet companies started to stand out and consolidate their leadership becoming the most valuable companies. In the energy sector, the opposite has happened. The uncertainties about the future have grown along with the diffusion of new technologies linked to low cost solar and wind energy, smart grids, electromobility/autonomous vehicles, biofuels, internet of things, etc. This set of uncertainties has led to a relative undervaluation of energy companies compared with internet companies (PWC, 2019), but the energy sector remains quite large, and, regardless of the form, energy remains one of the main drivers of human development (SMIL, 2010).

These comparative perceptions between the internet revolution and the energy transition over the past two decades have allowed us to move to the central framework of this research's investigation, where we use multi-stakeholder models in the context of open innovation. This approach was critical to building the current dominance scenario of Internet companies, but it has not been analyzed in enough depth in the context of the energy transition.

1.1 The Role of Open Innovation Stakeholders on the Energy Transition.

The construction logic of this Thesis follows a timeline that considers three aspects: the writing of the articles themselves, theoretical development on stakeholder engagement in the open innovation process, and my career as a professional and researcher.

From the conceptual point of view, we must highlight some points before we begin with the timeline perspective. The first key concept, the energy transition, has already been broadly addressed before, and we only reinforce that it is a large-scale movement with a global reach, where significant uncertainties remain over the trillions of dollars invested. The direction of this energy transition is from fossil and centralized sources to digital and decentralized arrangements with a focus on decarbonization.

It is also essential to conceptualize what is open innovation, that can be understood as "*the antithesis of the traditional vertical integration model where internal R&D activities lead to internally developed products that are then distributed by the firm*" (CHESBROUGH, 2006). The most relevant underlying perception behind this definition is that in the new paradigm, innovations are no longer only generated within the company boundaries, but in cooperative processes with other stakeholders outside them. Open innovation is also related with strategic alliances concept when it is linked with the corporation's efforts to leverage and absorb external innovation (MACEDO-SOARES; PAULA; MENDONÇA, 2017)

The union of these two core concepts – energy transition and open innovation – leads us to the main objective of this Thesis, which is to investigate the role that open innovation may (or should) have during the energy transition.

In this sense, the first article "WORKING TOWARDS A FRAMEWORK BASED ON MISSION-ORIENTED PRACTICES FOR ASSESSING RENEWABLE ENERGY INNOVATION POLICIES" sought to report the classic interactions of triple helix stakeholders (universities, government, and corporations) through mission-oriented public policy concept (MENDONÇA; VAN ADUARD DE MACEDO-SOARES; FONSECA, 2018). Although the concept of the triple helix (ETZKOWITZ; LEYDESDORFF, 2000) predates the concept of open innovation (CHESBROUGH, 2003a), in this article, we have found that cooperation between institutions, outside corporate boundaries and driven by government programs, were crucial in the development of radical and high-impact innovations, such as those required in mission-oriented energy sector programs.

Greco, Locatelli & Lisi (2017) highlight the role of open innovation efforts and cooperation between university, corporations, and government in the energy sector. Due to its strategic nature, the energy sector is often heavily regulated and subsidized, and the role of the government tends to be critical in the energy transition process. The mission-oriented approach has been an essential driver for the public policy toolkit in the efforts to reduce the environmental impact of the energy sector (decarbonization). The needs for clear objectives and goals are highly relevant in the broader context of sustainable development challenges demanded by the current energy transition.

A systematic literature review is one of the most relevant findings of the first article. However, its application test with three real Brazilian programs (PAISS, Inova Energia, and PAISS 2) is also quite relevant in the context of this Thesis, going beyond the article itself. We also must highlight my involvement with the program's design and execution as Finep's Manager and Superintendent. This condition also leads to another adjacent perception that is one of the primary motivations for the second article: the notable absence of startups and venture capital funds in a more structured way within the scope of the programs.

The second article, “ENERGY STARTUPS: IDENTIFYING WINNING STANDARDS DURING THE ENERGY TRANSITION”, focuses precisely on startups and venture capital investors, two other stakeholders not directly addressed by the triple helix model, but which had a pivotal role during the internet revolution. Investigating their role also during the energy transition is a key-point for the comparative understanding of the two phenomena. More specifically, in this article, we have tried to observe and analyze the standards that defined the success (IPO) or failure (Closing) of energy startups in the last 20 years (MENDONÇA; FERREIRA; VINICIUS, 2018). We have considered, among many other variables, the importance of investments and the profile of investors in their trajectories.

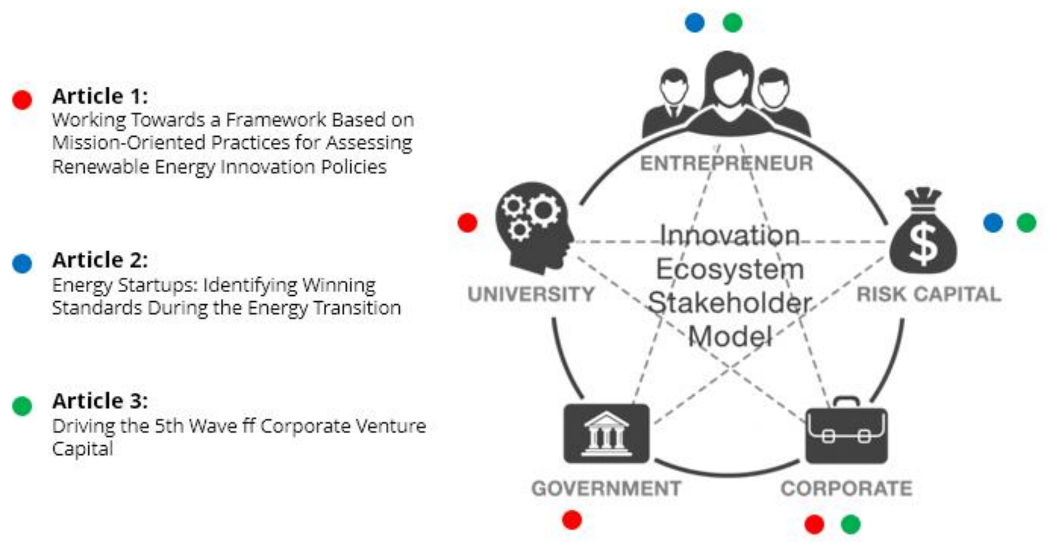

Figure 2: Innovation Stakeholder Model and Thesis Articles
Source: (BUDDEN; MURRAY, 2017)

It is noteworthy that the addition of startups and venture capitalists among triple helix’s original stakeholders (university, corporation and government) is in line with the Massachusetts Institute of Technology (MIT) Innovation Ecosystem Stakeholder Model (BUDDEN; MURRAY, 2017) represented by Figure 2 that presents the link of the five stakeholders with the articles of this Thesis. Although MIT's approach is predominantly focused on specific geographic boundaries (innovation ecosystems, or iEcossistems), the concepts behind the importance of each of the five stakeholders remain valid even for broader concepts linked to open innovation.

Once again, the theoretical and writing course of the article meets the personal aspect. Throughout this Thesis writing process, I had the opportunity to study the model personally with the professors who created this approach at MIT: Prof. Fiona Murray and Prof. Phil Budden, and empirically check the challenges experienced by energy startups as Cleantech Director at the Brazilian Startups Association.

Finally, in the last article, we face the latest theme from the literature's point of view: The relationship between startups and corporations. While the triple-helix concept began to spread widely in the early 1990s (ETZKOWITZ; LEYDESDORFF, 2000) and the boom in startups and venture capital funds occurs in the early 2000s (CB INSIGHTS, 2017; RIES, 2011) the use of cooperation between corporations and startups as an innovation tool is more recent.

In the third article, "UNRAVELING THE 5TH WAVE OF CORPORATE VENTURE CAPITAL", we have investigated one of the latest trends within the field of open innovation: The Corporate Venture Capital (CVC) activity. In this manuscript, we discovered the existence of a fifth wave that has characteristics quite peculiar when compared to the previous ones. While the first three waves had mainly financial motivations, and the fourth wave would be considered as a learning period, the fifth wave of CVC is a real candidate for the new mainstream of innovation management, increasingly being linked to the strategic core of corporations. We realize that on the fifth wave, large corporations are starting to use their CVC units as value capture platforms within their innovation ecosystems (COVIN; MILES, 2007).

We were able to highlight the existence of a new cycle analyzing the general characteristics of the waves (13,012 CVC unit investment operations) and taking a closer look at the 101 most active CVC units in the world over the last 25 years. It is a novelty to CVC industry and not yet reported by the academic business literature.

The union of the three articles using the MIT approach as the base model can be pointed in Figure 2 and shows the clear connection between the stakeholders and articles. Altogether, the research shows that in the energy transition would be expected a more significant balance between the five stakeholders compared to the internet revolution.

2
WORKING TOWARDS A FRAMEWORK BASED ON MISSION-ORIENTED PRACTICES FOR ASSESSING RENEWABLE ENERGY INNOVATION POLICIES

Abstract

Mission-oriented programs have regularly been used as innovation policies when governments (or societies) are faced with complex challenges that demand radical innovations and multiplayer coordination. Nowadays, the global climate-change question, including the energy source issue, is an example of a mission-oriented challenge. Several countries have adopted energy programs with mission-oriented characteristics. Brazil, for example, launched three programs (PAISS, PAISS 2 and Inova Energia) to foster innovations in renewable energy sources such as biofuels, solar and wind power. These programs dealt with radical innovations, big challenges and multiplayer coordination, but did not use some important mission-oriented best practices. Based on an extensive literature review, this article's aim is to present a framework developed to verify whether renewable energy innovation programs meet the requirements for being classified as mission-oriented programs. It is assumed that mission-oriented programs can contribute to the effectiveness of renewable energy innovation policies. The case of Brazil and its Inova programs is used as an example of how to apply this framework, although the latter was designed for application to any renewable energy mission-oriented program.

2.1. Introduction

The landscape of global integration and the threat posed by climate change has been pushing leaders in many countries to pay closer heed to sustainable development. In this context, the discussion of the energy sector and the necessary energy transition is particularly important since 77% of the world's installed energy capacity is based on non-renewable sources such as coal, oil and gas (WORLD ECONOMIC FORUM, 2016). It is estimated, that 53% of the efforts needed to contain global warming should come from the energy sector (IEA, 2016).

This trend has gradually been transformed into concrete global investments in renewable energy, which have been growing in recent years, reaching US$ 285.9 billion in 2015, equivalent to an addition of 147 gigawatts (GW) to global energy supply. This is the first time since the industrial revolution that investments in renewable sources of energy exceeded investments in fossil sources (REN21, 2016).

Important specialized energy sector institutions predict continuous growth of renewable sources in the world energy mix. The International Energy Agency (IEA) and even some oil companies like British Petroleum (BP) forecast that renewable sources will continue to rise in the next decades, becoming responsible, in relative terms, for the greater part of additional energy generation in the world. (BP, 2016; IEA, 2015).

Reaffirming this trend, 195 countries, including the most important economies of the world such as China, Japan, Russia, India, Germany, France, UK and Brazil, signed a cooperation agreement in Paris during the 21st Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC) in 2015. Note that the United States originally signed the climate change agreement in 2015, but the new president, Donald Trump, decided to withdraw the country from the agreement in June 2017, in accordance with one of his campaign promises (THE NEW YORK TIMES, 2017). In this agreement these countries committed to use their best efforts to keep global warming below 1.5 ºC (UNFCCC, 2016). Researchers from the UNFCCC, other institutions and specialists agree that this goal will only be reached with the improvement and diffusion of renewable energy sources and new low-carbon technologies (BP, 2016; IEA, 2015; REN21, 2016; UNFCCC, 2016).

Long-term and large-scale global change necessarily involves a concerted effort by various sectors of society, with large volumes of investment and sound and well-structured public policies. The energy transition to a low carbon economy is a global challenge that demands local action to be carried out effectively.

In this scenario, and using some of its competitive advantages, Brazil has been seeking to position itself as a global leader in this transformation process. Host to two major climate conferences (Rio 92 and Rio +20), Brazil already produces 43.5% of its primary energy from renewable sources (EPE, 2015), and still has huge expansion potential in biomass (Ferreira-Leitao et al., 2010; EPE, 2015), solar (UFPE, CEPEL, & CHESF, 2000), wind (CRESESB, CEPEL, Camargo Schubert, & True Wind, 2001) and other sources. However, the country only ranked in 69th place (1998) in the Global Innovation Index (Cornell University, INSEAD, & WIPO, 2015).

With the objective of harnessing the country's potential strategic position and also overcoming part of its deficiencies regarding the innovation environment, the Brazilian government has included the energy sector, especially renewable energy, at the center of its main innovation policy in recent years: the plan called "Inova Empresa" ("Company Innovation"). Launched in March 2013 by the Brazilian government, this plan was the largest innovation financing initiative in Brazil's recent history. From the beginning, the plan had an unprecedented budget (by Brazilian standards) of US$ 16.5 billion, just to support technological innovation in a wide range of initiatives. The core of the policy, called "Inova Programs" or "Inova Family", was composed of 11 sectorial and thematic initiatives, and corresponded to 65% (US$ 10.6 billion) of the whole budget (BRAZIL, 2013).

These "Inova Family" initiatives had a unique set of characteristics, which were unprecedented in Brazil. The most important aspect of these programs was each initiative's attempt to integrate all federal efforts around a specific theme, aiming to improve the efficiency of investments in innovation. To reach this goal, these initiatives were structured as mission-oriented programs (MAZZUCATO; PENNA, 2015).

Three of the Inova programs (and 17% of the entire budget) were concerned with renewable energy: PAISS (2011), Inova Energia (2013), and PAISS 2 (2014). The PAISS and PAISS 2 aimed to bring Brazil "back into the game" of ethanol productivity and other advanced sugarcane bio-products. The second one, Inova Energia, targeted a wider scope, with three different lines designed to rethink the Brazilian electrical sector, calling for new technologies in smart grids, solar and wind generation, in addition to electric cars and their components (motors, batteries etc.).

Considering the energy transition scenario and based on an extensive literature review, this article's main objective is to present a framework that was developed to verify whether renewable energy innovation programs meet the requirements for being mission-oriented programs. We assume that mission-oriented programs can contribute to the effectiveness of renewable energy innovation policies. The case of Brazil and its Inova programs is used as an example of how to apply this framework. The main objective is to help assess and formulate new renewable energy policies also in other countries.

To achieve our main objective, we established the following intermediate objectives:

- Identify which characteristics a renewable energy innovation program must have to be considered a mission-oriented program;
- Develop a framework with mission-oriented constructs to verify to what extent a renewable energy innovation program/policy meets the requirements to be a mission-oriented program; and
- Apply this framework to the case of the Inova programs to illustrate how it can be used.

2.2. Research Methodology

To achieve these objectives, it was important to first find comparable parameters to analyze renewable energy programs in terms of being mission-oriented programs. We did this by an extensive systematic literature review of mission-oriented innovation programs and policies, focused on initiatives in energy as the sector and Brazil as the region. We ran four searches in the Scopus database, restricted to the last 10 years and to articles and reviews.

In the first search we looked for mission-oriented public policies to establish recent benchmarks. Then, we used "mission-oriented" AND "public policy" keywords to conduct the search. We also searched for the concept of mission-orientation associated with innovation efforts. We used "mission-oriented" AND "innovation" as keywords in this case. We refer to these two searches as “mission-oriented searches”.

To improve the scope of energy as a sector and Brazil as a region, we ran two more searches: one with “Brazil” AND “energy” AND “innovation”, to increase knowledge regarding the latest efforts in energy sector innovations in Brazil; and the other using “Brazil” AND “energy” AND “public policy" to better understand public energy policies in Brazil in recent years. We refer to these other two searches as “Brazil and energy searches”.

The combination of these searches returned 188 articles/reviews. We applied a thematic filter to exclude purely technical papers and restrict subject areas to those linked to the scope of this article: Business, Management and Accounting; Social Sciences; Economics, Econometrics and Finance; and Decision Sciences. We thus obtained 74 articles.

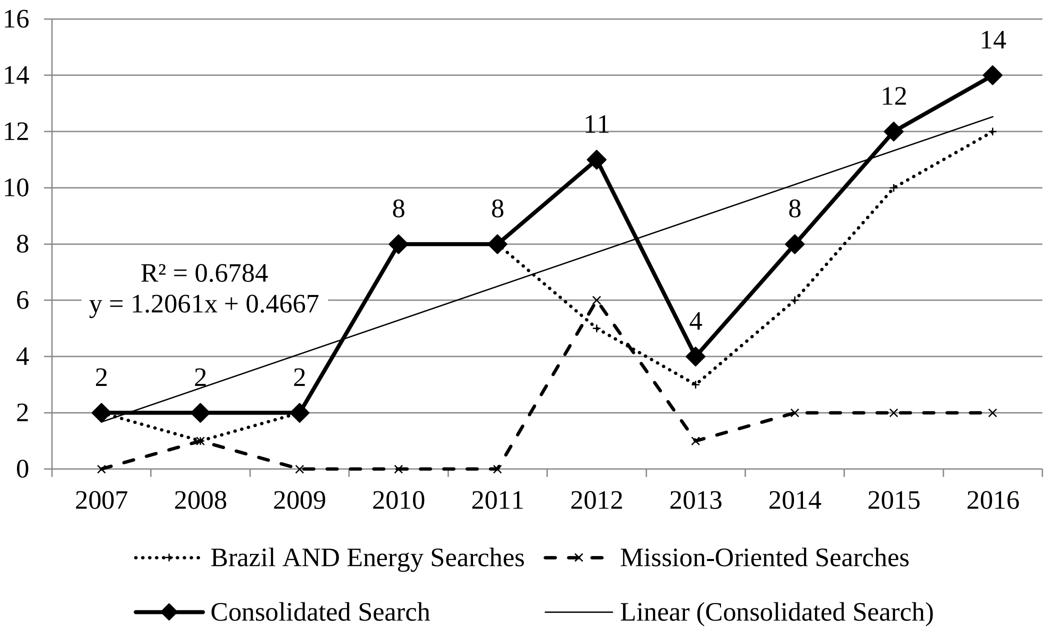

Figure 3: Publications by Years - Business, Management and Accounting; Social Sciences; Economics, Econometrics and Finance; and Decision Sciences.

The authors of these papers totaled 189, but only six had published more than one article on the themes at issue: Yokoo, Y. (Japan); Gobbo, J. A. (Brazil); Ismail, K. A. R. (Brazil); Lino, F. A. M. (Brazil); Silveira, S. (Sweden); and Johnson, F. X.

(Sweden). Even these authors had written only two articles each out of those returned by our searches. The diversity of authors on these themes, but with no single one standing out, provided us with some interesting insights, such as the prevalence of Brazilian and Swedish researches in these themes.

The timeline of the number of articles/reviews in Figure 3 shows a growth trend in publications in the areas investigated ($\beta > 0$ and $R^2 = 0.678$). There are also more publications about Brazil and energy than the mission-orientation concept. The peak of publication about mission-orientation in 2012 occurred because a special issue of *Research Policy* was published that year, entitled: “The need for a new generation of policy instruments to respond to the Grand Challenges” (volume 41, issue 10).

Regarding journals, the most important publications in the areas of interest have the highest H Index too. The average H Index of journals with two or more publications in our searches was 50.1. The special issue of *Research Policy* propelled it to the top of the ranking. The sectorial focus of the *Journal of Cleaner Production* put it in second place. This journal also has the second highest H Index among the listed ones (Table 2).

Table 2: Top Journal Rankings in Publications

Rank	Outlets of Articles/Reviews	N*	H Index
1	Research Policy	5	160
2	Journal of Cleaner Production	4	96
3	Technological Forecasting And Social Change	3	68
4	Energy Economics	2	85
5	Technovation	2	82
6	Resources Conservation and Recycling	2	75
7	Industry and Innovation	2	41
8	Innovation	2	22
9	Foresight	2	20
10	Energy Research and Social Science	2	14
11	Environmental Development	2	13
12	Journal of Technology Management and Innovation	2	13
13	Gestão e Produção	2	9
14	Espacios	2	3

*N = number of articles/reviews

As regards keywords, the most cited ones in mission-oriented searches were: “Innovation” (8), “Innovation Policy” (3) and “Public Procurement” (3); the others were cited only two or fewer times. The presence of “Innovation” or “Innovation policy” is not surprising because they were used as keywords in the searches, but “Public Procurement” appears as an important keyword, and none of the Inova Programs deals with it.

In the case of Brazil and Energy searches, the most cited keywords were: “Brazil” (30), “Innovation” (23), “Biofuel” (9), “Biofuels” (8) and “Ethanol” (8). “Brazil” and “Innovation” were keywords from the parameters of the searches, but the others were not, and all three were linked to the biofuels concept. This is important because despite the discovery of the subsalt (or pre-salt) oil and gas reserves, and Brazil’s continentally integrated power grid, most research about energy in Brazil in the last 10 years has been directed towards biofuels.

After this screening process, we performed a content analysis (Weber, 1990) of the articles’ titles and abstracts to identify those that could help us achieve our secondary objectives, namely the development and application of a framework based on the mission-oriented benchmark constructs that we had identified in the first step of our bibliographic research. The framework was basically a checklist or chart to analyze the similarities and differences between renewable energy programs and the mission-oriented benchmarks.

To collect the data for applying our framework adequately to the case of the Inova programs, aiming to illustrate how one can verify to what extent such programs have the necessary characteristics to be effective mission-oriented programs, we resorted once again to content analysis. This technique helped to evaluate the data and information collected from different sources, notably semi-structured informal interviews with staff members of Finep (a Brazilian innovation agency) and data available at the websites of Finep, BNDES (Brazil’s National Bank for Economic and Social Development) and ANEEL (National Electric Energy Agency), including program evaluation reports, public and internal presentations, official databases, public tenders and their official results, and sectorial BNDES/Finep studies (for references, see Table 5).

2.3. Literature Review

We started our literature review by looking for a definition for the central concept of our research: mission-oriented policies. For policy formulation, a correct definition of a mission-oriented policy and identification of its characteristics is critical because of economic and social implications (Amanatidou et al., 2014; Foray et al., 2012; Mazzucato and Penna, 2015). Although this central concept has been described very differently by many authors, there is a consensus that what characterizes these policies are that they are centralized and focused on contending with big national challenges (DASGUPTA; STONEMAN, 2005; EDQUIST; ZABALA-ITURRIAGAGOITIA, 2012). These policies are more focused on radical innovations needed to achieve clearly set goals of national importance (CANTNER; PYKA, 2001; ERGAS, 1987). In contrast to those developed according to the mission-orientation concept, diffusion-oriented policies focus on providing general innovation-related public goods to diffuse technological capabilities throughout industrial infrastructure and produce a large volume of incremental innovations (ERGAS, 1987).

The original mission-orientation concept was used to classify countries' policies. Researchers in the innovation policy area tried to classify countries' policies as mission- or diffusion-oriented (CANTNER; PYKA, 2001; CHIANG, 1991; ERGAS, 1987). However, even they, and many other authors, admitted that this could be complicated because countries might adopt different strategies in different sectors, regions or innovation contexts and with different time frames (ANADÓN, 2012; ERGAS, 1987; HAHN; YU, 1999). We can cite as examples of changing policy directions/strategies, the defense innovation policies between 1948 and 1989 during the Cold War (MOWERY, 2012); the increase in the number and direction of energy innovation policies after the 1970's oil and gas crises (ANADÓN, 2012); or the current discussion regarding the generation of radical innovation versus diffusion of incremental clean technologies (ELEFTHERIADIS; ANAGNOSTOPOULOU, 2015; MAZZUCATO; PENNA, 2015). A radical innovation (Leifer et al., 2000, p. 5) "*is a product, process, or service with either unprecedented performance features or familiar features that offer potential for significant improvements in performance or cost. Radical innovations create such* *a dramatic change in products, processes or services that they transform existing markets or industries, or create new ones*."

We assumed that mission-oriented programs can contribute significantly to enhance the effectiveness of innovation policies, including renewable energy innovation policies. This assumption is based on the studies of Amanatidou et al. (2014), Foray et al. (2012) and Mazzucato and Penna (2015), who highlight the importance and positive impact of mission-oriented policies in technology and innovation environments.

We adopted the institutional research approach, using public agents as sources. As unit of analysis we used specific programs (DOSI, 2016; FORAY; MOWERY; NELSON, 2012; RUMPF, 2012; SANTOS; IANDA; PADULA, 2014). This approach enables a more accurate analysis of the characteristics and results of policies in specific sectorial, regional and time contexts. Below we describe the characteristics of a mission-oriented program, based on the literature review.

The first is the alignment of the program with the country's general policies (economic, industrial, environmental etc.) (ERGAS, 1987; MAZZUCATO; PENNA, 2016). An example is the Chinese Renewable Energy Scale-up Program (CRESP), created to build a legal, regulatory, and institutional environment conducive to large-scale, renewable-based electricity generation. It was created in full alignment with the 10th Chinese Five-Year Plan, the national plan which establishes China's priorities (ABDMOULEH; ALAMMARI; GASTLI, 2015; WORLD BANK, 2016).

The second characteristic is the need for a clear objective involving a major challenge to be solved. Generally, it involves the development of a set of new technologies to achieve this major objective. Defining measurable intermediate goals is important for managing and evaluating the progress of mission-oriented programs. The Apollo Program, whose aim was to send the first human being to the Moon, is an eloquent example of a clear objective mission-oriented program (MAZZUCATO; PENNA, 2016; VEUGELERS, 2012).

The third characteristic is a focus on high impact radical innovations. It is important to be able to justify politically, economically or socially the choice of one program over another (AMANATIDOU et al., 2014; DASGUPTA; STONEMAN, 2005). By definition, in diffusion-oriented policies there is no focus on requiring the achievement of a few specific targets, so policymakers can spread funds more widely and foster more incremental innovations. An example of a mission-oriented program focused on radical innovation is the Manhattan Project to develop nuclear bomb technology during World War II (FORAY; MOWERY; NELSON, 2012; MAZZUCATO; PENNA, 2016; MOWERY, 2012).

The fourth characteristic of a mission-oriented program is the focus on generating new technologies instead of the diffusion of existing ones (ERGAS, 1987). Some authors refer to the importance of balancing the generation of new technologies with diffusion of innovations (GLENNIE; BOUND, 2016; HAHN; YU, 1999), but it is widely agreed that mission-oriented programs are generally more focused on the generation of new technologies.

The fifth characteristic is the time frame for results. A long-term view is generally necessary, but less required than in the case of diffusion-oriented policies (CHIANG, 1991). It also depends on the kind of mission being specified. The Manhattan Project delivered expected results in less than six years, but challenges like climate-change prevention demand much more time to be effectively addressed (AMANATIDOU et al., 2014; VEUGELERS, 2012). The concern about long-term missions versus political cycles is a significant risk factor in mission-oriented programs (AMANATIDOU et al., 2014).

The sixth characteristic that differentiates mission-oriented programs from other ones is the role of government. The government’s priority-setting role is always critical in the mission-oriented paradigm (ERGAS, 1987; MAKHOBA; POURIS, 2016; MAZZUCATO; PENNA, 2015; RUMPF, 2012). But the government’s role can sometimes be extended to more active participation, including the execution of part of the program in public facilities such as technological institutes, universities or companies (MAZZUCATO, 2016; MOWERY, 2012).

The seventh characteristic refers to program governance. Mission-oriented programs generally have a more centralized decision process than other technology policies, with just one (or a few) government agencies making the critical decisions

(ERGAS, 1987; MAZZUCATO, 2013; MAZZUCATO; PENNA, 2015). However, the programs' governance models can differentiate the decision process according to whether this involves setting priorities, monitoring overall progress or evaluating performance (FORAY; MOWERY; NELSON, 2012). Ergas (1987) emphasizes the need to centralize all decisions in one agency that can combine technical expertise, financial resources and decision-making autonomy.

The eighth characteristic refers to success factors of a mission-oriented program. The evaluation process in diffusion-oriented programs has broader indicators of success, like the number of PhDs in the private sector, percentage of GDP invested in R&D, number of innovative companies etc. (DUTTA, 2011). Mission-oriented programs usually have a "mission accomplished" target (ERGAS, 1987). However, mission-oriented programs have frequently generated spillovers. Defense-backed technologies such as GPS, Internet, microprocessors and touch screens, are spinoffs of mission-oriented initiatives (MAZZUCATO, 2013; MOWERY, 2012).

The ninth characteristic concerns program participants. While other technology programs could aim at just one part of the innovation chain (universities, SMEs, big corporations, technological institutes, government facilities, regulators etc.), mission-oriented programs need to act in the whole universe of involved players and coordinate them in the same direction (AMANATIDOU et al., 2014; CHOUNG; HWANG; SONG, 2014). This big challenge is one of the reasons that a centralized governance model is required in mission-oriented programs (CANTNER; PYKA, 2001). Regarding this point, Ergas (1987) recommends that the project leader be a big corporation in order to guarantee the financial support and technical quality and diversity needed to deal with the challenges and oscillations during the process.

The tenth and final mapped critical characteristic of a mission-oriented program refers to its public policy instruments. To solve a big and complex question, all efforts need to be analyzed and aligned. Table 3, based on Borrás and Edquist (2013), provides a guide to understand the diversity of innovation policy instruments that can be used in mission-oriented programs.

Note that public procurement (EDQUIST; ZABALA-ITURRIAGAGOITIA, 2012; LEMBER; KATTEL; KALVET, 2015; MOWERY, 2012; VEUGELERS, 2012; ZELENBABIC, 2015), as well as legal/regulatory frameworks and grants (ABDMOULEH; ALAMMARI; GASTLI, 2015; HAHN; YU, 1999; MAZZUCATO; PENNA, 2015; MOWERY, 2012; POLZIN et al., 2015; VEUGELERS, 2012) deserve special attention as critical instruments for mission-oriented programs.

Table 3: Innovation Policy Instruments

Positive incentives (encouraging and promoting):
- Cash transfers
- Cash grants
- Subsidies
- Low-interest loans and soft loans
- Loan guarantees
- Government provision of goods and services
- Private provision of goods and services under government contracts
- Vouchers
Disincentives / Regulatory (discouraging and restraining)
- Taxes
- Charges
- Fees
- Customs duties
- Public utility rates

Source: Borrás and Edquist (2013)

These ten characteristics and the resulting framework can be used to analyze any mission-oriented program, but some considerations have to be made in the case of renewable energy programs. First of all, we need to consider that effectively managing climate-change as a mission is a global challenge and that a solution necessarily involves many countries and many technologies (ABDMOULEH; ALAMMARI; GASTLI, 2015). It is very different from a mission like sending a man to the Moon or Mars (NASA, 2016), or building nuclear bombs, which can be conducted by only one or a few countries and use one or a few central technologies.

Another question concerns specific instruments for renewable energy. The most cited is the “Feed-in Tariff” (FiT), which is a long-term contract used to guarantee the attractiveness of deals involving renewable energy generation (ELEFTHERIADIS; ANAGNOSTOPOULOU, 2015; POLZIN et al., 2015).

Another important indirect mechanism is specific taxes or compensatory levies for non-renewable sources like coal, oil and gas (POLZIN et al., 2015).

Table 4: Framework for Analyzing Renewable Energy Programs According to Mission-Oriented Program Benchmarks

#	Characteristic	Classification				References
1	**Alignment with General Economic/Innovation Policy**	**High**	Medium	Low		*Ergas (1987); Mazzucato & Penna (2016); Abdmouleh, Alammari, & Gastli (2015); World Bank (2016)*
2a	**Clear Objectives**	**Yes**	No			*Mazzucato & Penna (2016); Veugelers (2012)*
2b	**Big Question to be Solved**	**Yes**	No			*Amanatidou, Cunningham, Gök, & Garefi (2014); Dasgupta & Stoneman (2005)*
2c	**Number of New Technologies Involved**	**One**	**Few**	Many		*Foray et al. (2012); Mazzucato & Penna (2016); Mowery (2012)*
3a	**Innovation Degree**	Incremental	**Radical**			*Cantner & Pyka (2001); Ergas (1987)*
3b	**Potential Impact**	**High**	Medium	Low		*Amanatidou, Cunningham, Gök, & Garefi (2014); Dasgupta & Stoneman (2005)*
4	**Program Focus**	**Innovation Generation**	Competence Diffusion			*Ergas (1987)*
5	**Time to Achieve Practical Results**	Short Term (less than 2 years)	**Medium Term (3 to 5 years)**	**Long Term (6 to 10 years)**	**Very Long Term (more than 10 years)**	*Chiang (1991);Amanatidou et al. (2014); Veugelers (2012)*
6a	**Role of Government - Setting Priorities**	**High**	Medium	Low		*Ergas (1987); Makhoba & Pouris (2016); Mazzucato & Penna (2015); Rumpf (2012); Mazzucato (2016); Mowery (2012)*
6b	**Role of Government - Monitoring Overall Progress**	**High**	Medium	Low		
6c	**Role of Government - Evaluating Performance**	**High**	**Medium**	Low		
7a	**Decision Process - Setting Priorities**	**Centralized (1 Institution)**	**Semi-Centralized (2 or 3 Institutions)**	Decentralized		*Ergas (1987); Mazzucato (2013); Mazzucato & Penna (2015); Foray et al. (2012)*
7b	**Decision Process - Monitoring Overall Progress**	**Centralized (1 Institution)**	Semi-Centralized (2 or 3 Institutions)	Decentralized		
7c	**Decision Process - Evaluating Performance**	**Centralized (1 Institution)**	**Semi-Centralized (2 or 3 Institutions)**	Decentralized		
8	**Evaluation Metrics**	**Specific goals**	Macro Indicators			*Dutta (2011); Ergas (1987)*
9a	**Projects Leadership**	Government	**Large Corporation**	Universities / Research Institutes	SMEs	*Cantner & Pyka (2001); Ergas (1987)*
9b	**Participant Type (Companies, Universities etc.)**	One	Few	**Many**	**All**	*Amanatidou et al. (2014); Choung, Hwang, & Song (2014)*
10a	**Instruments (Subsides, Grants, Taxes, Procurement etc.)**	One	Few	**Many**	**All**	*Edquist & Zabala-Iturriagagoitia (2012); Lember, Kattel, & Kalvet (2015); Mowery (2012); Veugelers (2012); Zelenbabic (2015)*
10b	**Procurement**	**Yes**	No			
10c	**Grant**	**Yes**	No			*Abdmouleh et al. (2015); Hahn & Yu (1999); Mazzucato & Penna (2015); Mowery (2012); Polzin, Migendt, Täube, & von Flotow (2015); Veugelers (2012)*
10d	**Legal/Regulatory**	**Yes**	No			
10e	**Feed-in Tariff***	**Yes**	No			*Eleftheriadis & Anagnostopoulou (2015); Polzin et al. (2015)*

Table 4 presents our framework for checking whether renewable energy programs have mission-oriented benchmark characteristics. Each characteristic can be classified as shown in column 2 “Classification”, based on “References” regarding benchmarks in column 3. The highlighted attribute in column 2 is considered the benchmark in terms of ensuring effectiveness of the mission-oriented program. Items #1 to #10c are general characteristics of any mission-oriented program, while items #10d and #10e more specifically apply to renewable energy mission-oriented programs.

Before presenting the results of our research, it is important to explain what the Inova programs are so we can show how our framework can be applied.

2.4. Inova Renewable Energy Programs

The “Inova Empresa” plan had three specific renewable energy programs: PAISS, PAISS 2 and Inova Energia. These programs had some common characteristics, and it is important to understand their range and novelty. The first common characteristic was the nature of the programs themselves. Though the specific goals of each program were completely different, all of them were directed towards dealing with a really big problem that could only be solved through innovations or diffusion of new technologies. All these programs aimed to provide total support for each step in achieving these objectives, from scientific efforts, followed by development and prototyping, until the initial phase of marketing the innovations (FINEP; BNDES, 2011, 2014; FINEP; BNDES; ANEEL, 2013).

As regards coordination, all of it was led, formulated and operated jointly by Finep and BNDES**,** The “Inova Energia” program also included ANEEL. The integration and cooperation of these key Brazilian institutions around the same goals was the first step and a big novelty of the Inova programs (BRAZIL, 2013). These institutions were the sponsors of each program. The related ministries (Science, Technology and Innovation; Development, Industry and Foreign Trade; Agriculture; and Mining and Energy) acted as a higher council and were more active in the macro-formulation and general evaluation of the progress achieved.

The three programs tried to combine all these sponsors' innovation support instruments. In Finep`s case, this was grants and loans to universities, technological institutes, startups, SMEs and large companies. Finep could also invest in the equity of program-selected companies. BNDES used similar instruments, with the exception of grants to companies, because according to Brazilian legislation, only Finep can operate this kind of resource. The conditions and amount of funding offered by BNDES was also different. In ANEEL's case, the mechanism for supporting innovation in the program was different. One of the regulatory obligations of power companies in Brazil is to invest at least 1% of their turnover in research and development (R&D). The acceptance of these expenditures is up to ANEEL. Companies that were approved in the Inova Energia program could automatically include this R&D expenditure in ANEEL's regulatory 1% provision.

The process and governance of the programs were very similar. They started with a public tender notice in which participants needed to sign a letter of interest containing basic information about the institution (firm, university or research institute), the key team and its alignment with the notice's objectives. At this stage the sponsors simply performed a single filter of the participants, then promoted match-making events and distributed material with basic information about the approved institutions. The aim of this first stage was to introduce institutions with similar interests and technological solutions to each other in an organized and secure way.

The second step involved encouraging leading companies to form consortiums with SMEs, universities, technological institutes, etc. to provide an entire solution to one or more of the problems mapped in the public tender notice. Wider scopes of collaboration guaranteed more access to grants and better loan and investment conditions. The main objective of this arrangement was to foster complete innovative solutions (basic/applied research, technological development, testing and initial marketing) on the part of the participants and financial support as counterparts of the leading companies.

In the third phase, the sponsors divided the innovation and business plans sent by consortiums into specific projects. Each project was directed to a specific combination of instruments (grant, credit etc.) and sponsors (Finep, BNDES and/or

ANEEL) already approved on merit. The guarantees, certifications, legal issues and other bureaucratic requirements were handled only by the specific sponsor of the project. Each sponsor had its own internal rules to be observed by participants.

During the whole process, the selection of instruments, projects and supported companies, universities and technological institutes was undertaken jointly by a technical committee composed of managers of the sponsors: representatives of BNDES and Finep sat on all committees, and people from BNDES, Finep and ANEEL were members of those related to the Inova Energia program. Once approved by a committee, the final arrangement was approved by each sponsor's board of directors.

Having a common general concept, process and governance can help the external public better understand the innovative points of these programs, but each one obviously has its own characteristics.

2.4.1. PAISS (2011)

The first of the Inova programs, launched even before the general Inova Empresa Plan, the PAISS (Joint BNDES-FINEP Plan to Support Technological Industrial Innovation in the Sugar-Energy and Sugar-Chemical Sectors) acted as a pilot project of BNDES-Finep institutional cooperation in the Inova Empresa Plan.

The aim of this program was to support the development, production and sale of new industrial technologies to process sugarcane biomass. The program had specific subthemes that could be aggregated into three main areas, with all of them exclusively using sugarcane biomass as raw material (FINEP; BNDES, 2011).

- 2^{nd} generation (2G) bioethanol from sugarcane;
- New biochemical products from sugarcane; and
- Gasification of sugarcane biomass.

The motivations behind this option were the huge amount of residues (bagasse, straw and leaves) produced by the first-generation bioethanol industry: 64% sugarcane biomass or 415 million metric tons a year (FERREIRA-LEITAO et al., 2010). The second-generation technology could increase Brazilian bioethanol production by 50% with no additional land use (MILANEZ et al., 2015). Biogas and other biochemicals could increase the added value of sugarcane and related industrial sectors, mainly considering the biorefinery trends (MENDONÇA; FONSECA; FRENKEL, 2017).

As usual, the PAISS program suffered from "first-mover effects", and feedback from the players involved was used to improve the others. The program's budget totaled US$ 600 million, with US$ 300 million from Finep and US$ 300 million from BNDES (FINEP; BNDES, 2011).

2.4.2. Inova Energia (2013)

Following the changes that were occurring in the world electricity sector, Inova Energia included ANEEL, the Brazilian electricity regulator, along with Finep and BNDES to support innovation. This inclusion was critical because most of Brazil's electricity sector operates through a centralized system and this market is highly regulated. ANEEL is also important in Brazilian R&D efforts because power distribution companies have a legal obligation to invest in innovations.

Inova Energia had three macro objectives:

- To support the development and diffusion of technological solutions for implementing smart grids in Brazil;
- To support the development and technological mastery of Brazilian companies in the solar and wind energy value chain; and
- To support industrial development and integration in the hybrid/electrical vehicle segment and foster greater energy efficiency in Brazil's auto industry.

These three goals were encapsulated into three specific lines, with a total of 10 subthemes. Here, we do not discuss each subtheme, merely the overall features.

The budget of the program was R$ 3 billion, with R$ 1.2 billion from Finep, R$ 1.2 billion from BNDES and R$600 million from ANEEL (FINEP; BNDES; ANEEL, 2013).

2.4.3. PAISS 2 - Agro (2014)

PAISS 2, also known as PAISS Agro, had objectives that complemented those of the first PAISS. While PAISS focused on industrial solutions aimed at adding value to, and increasing the productivity of, sugarcane bioproducts, PAISS 2 focused on improving performance “outside and inside the gate”. PAISS 2 addressed the following five lines (FINEP; BNDES, 2014):

- New varieties of sugarcane with more biomass and/or total recoverable sugars (TRS);
- Equipment to improve sugarcane planting or harvesting;
- Systems for planning, managing and controlling sugar production;
- Biotechnology applied to sugarcane;
- Development of agro-industrial solutions and complementary varieties of sugarcane.

Both PAISS and PAISS 2 brought Brazil “back into the game” in the advanced biofuels world stage (NYKO et al., 2013). The PAISS 2 budget (Agro) totaled R$ 1.48 billion, with R$740 million from Finep and another R$ 740 million from BNDES.

2.5. Results and Discussion

Below we describe some of the most significant results of the application of our framework to the case of the Inova programs, as summarized in Table 5 (note that the results in gray refer to those that fully satisfy the requirements of a mission-oriented program; those in yellow only partially meet the requirements, and those in red do not satisfy any of them).

With respect to the first characteristic of an effective mission-oriented program, ‘alignment’ (see item 1 Table 4), we found that the Inova programs had considerable alignment with the country´s macro policies (see Table 5). During the Inova program period, Brazil had two major guidelines for economic/innovation policies: the Greater Brazil Plan 2011-2014 (PBM), which acted as an industrial policy (ABDI, 2014), and the National Science, Technology and Innovation

Strategy 2012-2015 (ENCTI) (BRAZIL, 2012). Both established renewable energy as a national priority.

As regards the second necessary characteristic 'having clear objectives' (see item 2a, Table 4), according to the documents investigated, PAISS and PAISS 2 had more specific goals and involved fewer technologies than Inova Energia. While PAISS and PAISS 2 had closer thematic points, like "Optimization of pre-treatment processes of sugarcane biomass for hydrolysis" (FINEP, 2011) and "New sugarcane varieties with higher amounts of biomass and/or total recoverable sugars, with emphasis on the use of transgenic enhancement" (FINEP, 2014), Inova Energia had a broader approach, with thematic issues like "Support the development and diffusion of electronic devices, microelectronics, systems, integrated solutions and standards for the implementation of smart grids in Brazil" (FINEP, 2013). Despite this, both objectives were very clear and their aim was to solve big questions (item 2b), such as changing the energy mix to be more sustainable (EPE, 2015; NYKO et al., 2013; PARENTE, 2016; UFPE; CEPEL; CHESF, 2000). The large number of new technologies (item 2c), and challenges established in Inova Energia was noteworthy when compared with the literature's recommendations.

The three programs were mainly focused on radical innovations (item 3a), but Inova Energia had some incremental innovation challenges too, such as new equipment to measure bidirectional electricity flows (FINEP; BNDES; ANEEL, 2013). In addition, the three were more focused on generating new products (item 4), processes and technologies instead of just improving or diffusing existing solutions (FINEP, 2011, 2013, 2014).

The innovations demanded by PAISS, PAISS 2 and Inova Energia required a long time frame (item 5 in Table 4 and results for this item in Table 5) to reach practical results, but for different reasons. The two biggest players in biofuels market, the U.S. and Brazil, have been investing in this technology since the 1970s (ALLAIRE; BROWN, 2015; MILANEZ et al., 2015). The challenges of biotechnology and advanced chemicals usually require a long time to overcome. For different reasons, systemic changes in the energy mix, as expected in Inova Energia outputs, also demand a longer-term view (BP, 2017; WWF; ECOFYS; OMA, 2011).

The role of government (item 6a) was critical throughout the process – setting priorities, monitoring progress, and evaluating performance – of the three programs. All the discussions and application of subsidies were carried out by national agencies (Finep, BNDES or ANEEL) or ministries. The General Committee was composed of representatives from five ministries important to the economy (Office of the President, Finance, Science & Technology, Industry & Commerce, and Small Business), and this committee was responsible for setting priorities, monitoring overall progress and evaluating performance (BNDES, 2011; IEA/USP, 2013).

But regarding this point, we found an important difference when we compared the Inova programs based on the documents investigated using our framework (Table 4) and other literature review findings. The literature strongly recommends that this process be conducted in a centralized manner. The top governance of Inova programs was conducted by five ministries and two agencies: Finep and BNDES (Brazil, 2013). Operational issues, such as selecting and monitoring projects, were dealt with by Finep and BNDES in PAISS and PAISS 2, and included ANEEL in the case of Inova Energia. Each agency had its own internal approval process, budget and other rules, which resulted in an increase in the programs' management complexity, as observed in the public tender notice in both cases.

> *"The support indicated in the Joint Support Plan will depend on compliance with the usual processes of each sponsor institution, including technical, finance, legal and guarantee analysis, as well as the approval, contracting and follow-up processes."*
>
> Finep, BNDES & ANEEL (2013, p. 3)

All their evaluation metrics (item 8) are in line with the literature, targeting specific goals such as 2G ethanol enzymes or high-performance pretreatments in PAISS (FINEP; BNDES, 2011), biotechnological seedling manipulation or new sugarcane varieties with more biomass in PAISS 2 (FINEP; BNDES, 2014), and new supercapacitor/battery technologies or thin film solar panels in the case of Inova Energia (FINEP; BNDES; ANEEL, 2013).

Table 5: Results of Application of Framework: Case of Renewable Energy Inova Programs

Characteristic	PAISS		PAISS 2		Inova Energia	
	Classification	**References**	**Classification**	**References**	**Classification**	**References**
Alignment with general Economic/Innovation Policy	**High**	*ABDI (2014); Brazil (2012)*	**High**	*ABDI (2014); Brazil (2012)*	**High**	*ABDI (2014); Brazil (2012)*
Clear Objectives	**Yes**	*Finep & BNDES (2011)*	**Yes**	*Finep & BNDES (2014)*	**Yes**	*Finep, BNDES & ANEEL. (2013)*
Big Question to be Solved	**Yes**	*Nyko, D. et al. (2013); Parente, P. (2016)*	**Yes**	*Nyko, D. et al. (2013); Parente, P. (2016),*	**Yes**	*CRESESB, CEPEL, Camargo Schubert, & TrueWind. (2001); EPE (2015); UFPE, CEPEL, & CHESF. (2000).*
Number of New Technologies Involved	**Few**	*Finep & BNDES (2011)*	**Few**	*Finep & BNDES (2014)*	**Many**	*Finep, BNDES & ANEEL. (2013)*
Innovation Degree	**Radical**	*Finep & BNDES (2011); Nyko, D. et al. (2013)*	**Radical**	*Finep & BNDES (2014); Nyko, D. et al. (2013)*	**Radical / Incremental**	*Finep, BNDES & ANEEL. (2013); IEA (2015); REN21 (2016)*
Potential Impact	**High**	*Nyko, D. et al. (2013); Parente, P. (2016),*	**High**	*Nyko, D. et al. (2013); Parente, P. (2016),*	**High**	*IEA (2015); REN21 (2016)*
Program Focus	**Innovation Generation**	*Finep & BNDES (2011)*	**Innovation Generation**	*Finep & BNDES (2014)*	**Innovation Generation**	*Finep, BNDES & ANEEL. (2013)*
Time to Practical Results	**Long Term (6 to 10 years)**	*Allaire & Brown (2015); Milanez et al. (2015)*	**Long Term (6 to 10 years)**	*Allaire & Brown (2015); Milanez et al. (2015)*	**Long Term (6 to 10 years)**	*British Petroleum (2017); WWF, Ecofys, & OMA (2011)*
Role of Government - Setting Priorities	**High**	*BNDES (2011); IEA/USP (2013)*	**High**	*BNDES (2011); IEA/USP (2013)*	**High**	*BNDES (2011); IEA/USP (2013)*
Role of Government - Monitoring Overall Progress	**High**	*BNDES (2011); IEA/USP (2013)*	**High**	*BNDES (2011); IEA/USP (2013)*	**High**	*BNDES (2011); IEA/USP (2013)*
Role of Government - Evaluating Performance	**High**	*BNDES (2011); IEA/USP (2013)*	**High**	*BNDES (2011); IEA/USP (2013)*	**High**	*BNDES (2011); IEA/USP (2013)*
Decision Process - Setting Priorities	**Decentralized**	*Finep & BNDES (2011)*	**Decentralized**	*Finep & BNDES (2014)*	**Decentralized**	*Finep, BNDES & ANEEL. (2013)*
Decision Process - Monitoring Overall Progress	**Semi-Centralized (2 Institutions)**	*Finep & BNDES (2011)*	**Semi-Centralized (2 Institutions)**	*Finep & BNDES (2014)*	**Semi-Centralized (3 Institutions)**	*Finep, BNDES & ANEEL. (2013)*
Decision Process - Evaluating Performance	**Decentralized**	*Finep & BNDES (2011)*	**Decentralized**	*Finep & BNDES (2014)*	**Decentralized**	*Finep, BNDES & ANEEL. (2013)*
Evaluation Metrics	**Specific goals**		**Specific goals**		**Specific goals**	
Projects Leadership	**Private companies**	*Finep & BNDES (2011)*	**Private companies**	*Finep & BNDES (2014)*	**Large Corporation**	*Finep, BNDES & ANEEL. (2013)*
Participants Type (Companies, Universities etc.)	**All**		**All**		**All**	
Instruments (Subsides, Grants, Taxes, Procurement etc.)	**Few/Many**		**Few/Many**		**Few/Many**	
Grant	**Yes**		**Yes**		**Yes**	
Procurement	**No**	*Finep & BNDES (2011)*	**No**	*Finep & BNDES (2014)*	**No**	*Finep, BNDES & ANEEL. (2013)*
Legal/Regulatory	**No**		**No**		**Yes**	
Feed-in Tariff*	**No**		**No**		**No**	

The three programs considered that all kinds of institutions (item 9b) (universities, technology institutes, SMEs etc.) were eligible to send proposals, but each project needed to be led by a private company. Inova Energia advanced in this issue and proposals had to be led by a corporation with a minimum of resources to support the project as an integrated solution, as is evident in the literature (CANTNER; PYKA, 2001; ERGAS, 1987), and as is stated clearly in the official website of the program**.**

> *"6.2. Lead Companies –Independent companies or those belonging to business groups whose gross operating revenues are equal to or greater than US$ 16 million, or total equity is greater than US$ 4 million in the last fiscal year are eligible to submit Business Plan proposals. They can do so individually or in partnership with companies of any size or with science and technological institutions."*
>
> Finep, BNDES & ANEEL (2013, p. 10)

This format is completely aligned with what is recommended in the literature, and helped to increase the breadth and robustness of proposed solutions.

Lastly, these Inova programs had a good set of financial instruments, such as grants, subsidized loans and equity options, but they were restricted to merely financial instruments (FINEP, 2011, 2014). Inova Energia had the R&D expenditure obligation specified by ANEEL, but in practical terms this was very similar to a financial instrument (FINEP, 2013). According to the literature, the most important instruments for mission-oriented programs are grants, procurement and legal/regulatory incentives (items 10a, 10b, 10c)**.** The Inova programs were not able to incorporate procurement or substantial legal/regulatory incentives and provided smaller grants than the other financial instruments – 73.4% of the available funds were subsidized loans (BRAZIL, 2013).

Table 5 reveals that most mission-oriented constructs were used by the Inova programs to reach their goals, including the main ones: alignment with major policies, clear targets, and radical innovation generation. However, the decentralized governance of the programs and their lack of integration with legal/regulatory and procurement instruments deserve some attention. Together, they constitute two important operational points that could have caused the programs to deviate from their planned route.

It is important to emphasize, however, that the Inova renewable energy programs are still ongoing. In particular, the Inova Energia and PAISS 2 are too recent to analyze any of their results. Indeed, the selection and contracting process takes up to two years to complete. The projects themselves take up to five years, depending on the extent of the challenge and the solution's level of radicalness. The first results of PAISS are only materializing now and can be divided into expectations and reality. As regards expectations, the program put Brazil back on the map of advanced biofuels producers, as shown in Figure 4.

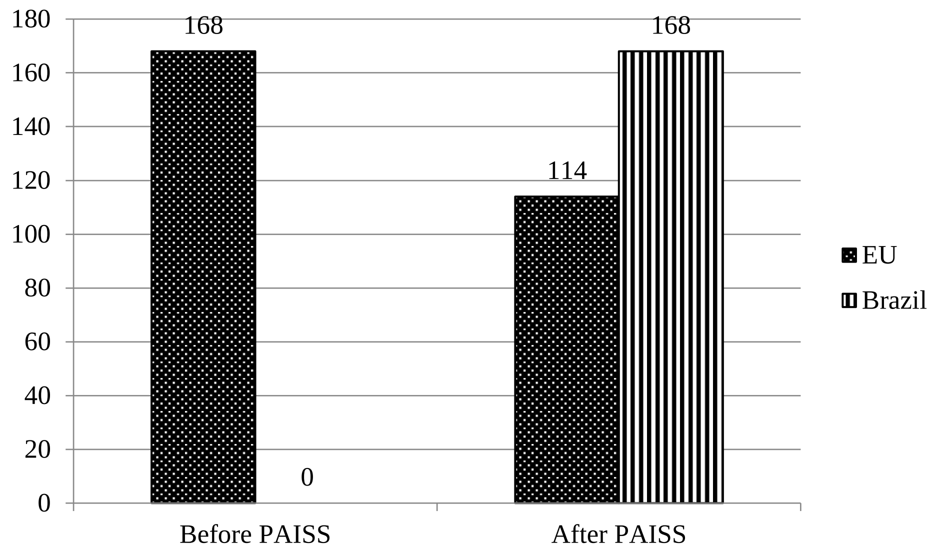

Figure 4: 2G Ethanol production estimated for 2015 (in millions of liters)

Source: Nyko et al.(2013)

The previous reality was different. When the PAISS was launched in 2011, the price of crude oil stood at over US$ 110.00/barrel. In the middle of 2014 the price fell dramatically and since then has fluctuated between US$ 30.00 and US$ 60.00 (PARENTE, 2016). During this same period, the sugar price almost doubled (NASDAQ, 2016). This large change in relative prices led to the postponement of all investments in sugarcane ethanol precisely at the end of the development cycle of 2G ethanol technologies. Other factors, like infrastructure, logistics, interest rates, exchange rates and political (in)stability in Brazil, as well as the policy changes in the US and EU, also influenced this situation, but this is not the focus of our research. Inova Energia and PAISS 2 are much too recent to analyze any of their results.

As a country, Brazil has the potential to be a big global player in terms of renewable energy. Its continental dimensions, high incidence of solar radiation, the unexplored wind and hydro power potential, and the urban and agricultural biomass surplus, all place it in a privileged position in the renewable energy market.

The aim of PAISS, PAISS 2 and Inova Energia was not only to bring to Brazil the application of renewable energy generation, but also to boost these industries' innovations and production chains. They were a great advance in terms of innovation policies in Brazil, and the integration of financing instruments and federal institutions in the same direction was unprecedented and desirable. But despite this great alignment of objectives, some issues limited the programs' reach, notably the design of their governance and lack of critical instruments.

As regards the instruments, most funds were composed of subsidized loans (73.4%), a policy instrument that is not fully appropriate for radical and high-risk innovations. The low level of grants available put a cap on the programs' ambitions. In 2011 alone, the US Department of Defense (DoE) provided 68 times more grants than the sum of PAISS, PAISS 2 and Inova Energia grants during the whole process (ANADÓN, 2012; BRAZIL, 2013).

The lack of formal integration with regulatory, procurement and fiscal efforts is a point that should be observed in future efforts. During the period, some of the government's actions were even at odds with incentives for biofuel and renewable electricity sources: coal/gas thermoelectricity auctions (to provide emergency energy security) or gasoline prices artificially kept at low levels (to control inflation) are two examples.

The governance of the programs could be improved according to the identified benchmarks. The number of institutions setting priorities, monitoring the process and evaluating performance delayed the process and made priority investments and project integration less effective than they could have been. In the Inova Energia case, the scope became wider than it should have been to foster a real transformation in the sector. The lack of integration of the operational systems and processes of Finep, BNDES and ANEEL also hampered integration efforts.

One of the programs’ strong points was the collaborative design of phases. In each selection step the participant could build new relationships. Official events, workshops and technology supply books helped the participants to establish cooperation agreements and improved their projects during the process. This suggests alignment between mission-orientation and open innovation (CHESBROUGH, 2003a) concepts.

As mentioned in the literature review, it is important to address specifically the case of biofuels. Brazil had success in this respect starting in the 1970s, when the mission-oriented Proálcool program created complete infrastructure for sugarcane ethanol consumption (from sugarcane planting to ethanol sale at the pump). In this respect, the flex-fuel powertrains developed at the beginning of the 2000s also deserve attention (MAZZUCATO; PENNA, 2016). It is relevant here that PAISS and PAISS 2 helped to provide the sector with a new direction, aimed at increasing productivity and international competitiveness.

In the electricity sector, Inova Energia contributed with some important technology inputs, although in the nationally integrated electricity grid, the critical issue is regulation. The role of energy auctions and smart grid rules were much more critical to accomplishing the program’s mission than the technologies themselves. In the case of the electric/hybrid vehicle powertrains and batteries line, the main question was the difficulty of setting national priorities. The pre-salt hydrocarbon discoveries, incentives for biofuels (including PAISS and PAISS 2) and the strategy of multinational automobile companies in Brazil (they preferred to keep their electric vehicle R&D efforts at home) sent contradictory signals to investors in this sector.

2.6. Suggestions for Future Research and Limitations

The main contribution of this study is to be a starting point to formulate, classify, assess and evaluate concluded, operating or future mission-oriented renewable energy programs. Therefore, suggestions for future research are particularly relevant.

One point that should be emphasized is the fact that out of the 189 authors found, only six had more than one article published on the subject in question. This may have to do with a lack of specialists, of consensus or of interest in this field, reasons that could be investigated in future studies, such as longitudinal investigations into the results of not only Inova programs, but also renewable energy mission-oriented programs in other countries.

Another suggestion is the application of the proposed framework (Table 4) to help evaluate the impact and results of the Inova programs, or compare the biofuels mission-oriented programs in Brazil, United States, Europe, China and other countries. Correlating the results of such assessments and comparisons with innovation or climate-change mitigation results from a longitudinal perspective would be particularly interesting.

We also recommend that when applying the framework in other countries to gain insights for policymakers, comparisons between countries should consider different institutional contexts.

The advances in knowledge, even if the mission goals are not reached, and the adequate time to reach each goal, are other important issues to be discussed in a much deeper analysis of renewable energy programs from a mission-oriented perspective.

Evaluating not only the program, but also agencies' internal processes, including management, competencies and technical expertise, could provide new insights into the coordination, monitoring and instrumental operation design. This would enable better identification of the strengths and weaknesses of these programs.

A survey to transform the qualitative analysis of mission-oriented constructs into a quantitative one could contribute to a better understanding of the factors involved and produce more finely tuned suggestions.

Last, but not least, the combination of mission-orientation and open innovation concepts could help find new relevant constructs for mission-oriented programs in the energy transition scenario.

Our study had some limitations. The parameters of some mission-oriented constructs could be better defined through a structured survey using a Likert scale. Another limitation has to do with the evaluation of the programs' results, a particularly important issue, although this was not the focus of our article. The evaluation process is not formalized or described in the literature, or in official documents or reports. Obviously, the task of establishing a cutoff point for mission accomplishment and of evaluating the externalities of these programs has become harder. In the Inova programs, for example, two significant exogenous factors also create some noise in program evaluation: the dramatic drop in oil prices since 2014 and the current economic and institutional crisis in Brazil, which began at the end of 2015.

2.7. Conclusions

Our main objective was to propose a framework developed to verify to what extent renewable energy programs have the characteristics of mission-oriented programs, and thus to contribute to the effectiveness of renewable energy innovation policies. The case of Brazil and its Inova programs was used as an example of how to apply this framework. The wider objective was to help with the formulation, comparison and evaluation of renewable energy mission-oriented programs also in other countries and contexts.

We started our research with an extensive literature review to find the general and renewable energy specific characteristics of mission-oriented programs with a view to developing the framework (Table 4). Next, we used the data from reports, studies, official documents, official websites, public notices etc. regarding the three most recent renewable energy mission-oriented policies in Brazil – the Inova programs - to illustrate how the framework can be applied.

More than an analysis of the three programs addressed in the research, our study sought to consolidate knowledge on the characteristics of mission-oriented programs. This type of public policy has great appeal for applications that involve major challenges, which are complex and require extensive multi-institutional coordination. The framework (Table 4) was developed for application to any energy mission-oriented program. In fact, it was developed as an analytical tool to be used by public policymakers who are dealing with challenges of this nature in the energy sector without being restricted to a specific country. We believe this is the main contribution of this research.

However, depending on the country, some adjustments may have to be made to our framework. In this respect, where the energy sector is concerned the discussion of the support instruments (item 10 of Table 4) is fundamental. Indeed, the presence of specific regulations and the commodity characteristic of the sector can enable, or restrict, a specific group of new instruments such as tariff incentives, restrictions on the use of polluting energy sources or government purchases. It is necessary to identify the set of instruments that is appropriate for the energy policy of each country, considering its demographic, geographic, political and economic characteristics. Mission-oriented programs for countries with large biomass production such as Brazil, India and the United States are likely to be quite different from those in countries with a larger presence of nuclear energy such as France, coal like China and South Africa, or oil and natural gas like Russia. From the portfolio of public policy instruments, choices appropriate to national contexts can make the difference between a successful or unsuccessful program in the context of the transition to a low carbon economy.

3
ENERGY STARTUPS: IDENTIFYING WINNING STANDARDS DURING THE ENERGY TRANSITION

Abstract

Similarly to what happened to the communications sector during the internet revolution, startups may have a pivotal role in the energy sector during the current energy transition to a low-carbon economy. The particularities of energy startups, however, mean that the growth model based on venture capital investments, which leveraged digital startups of the beginning of the 21st century, may not work equally well for clean energy startups. Thus, this article aims to identify the patterns associated with the success of energy startups in the last 20 years and develop a predictive model utilizing logistic regression. Results show that there are, in fact, some identifiable standards among the winners, such as the volume of resources previously received and their foundation date. However, being linked to sustainability or having received corporate or angel investments were not found to be determining factors for the success of energy startups in the period.

3.1. Introduction

The challenge of climate change is posed as one of the greatest concerns of the present time. Environmental, economic and social impacts of climate change have mobilized governments and other stakeholders, with 170 countries ratifying the Paris Climate Agreement (UNFCC, 2017).

Several sectors of the economy will undergo structural changes due to the worldwide striving to contain the temperature increase, and the energy sector is pivotal in this matter. The International Energy Agency (IEA, 2016) predicts that 53% of the efforts to reduce CO_2 emissions after the signature of the Paris Agreement will involve, directly or indirectly, the energy sector. In this scenario, technological changes will be especially relevant for the elaboration of new climate policies (RAO; KEPPO; RIAHI, 2006). The generation of energy from renewable sources (e.g., solar, wind, etc.), new arrangements and business models resulting from the utilization smart grids, the use of distributed energy, and new industrial paradigms, such as electric automotive motorization and advanced manufacturing, may have a substantial impact on the conformation to a new worldwide energy matrix. (GREENPEACE, 2015; UNEP; BLOOMBERG; FRANKFURT SCHOOL, 2016).

The process of change in the energy sector toward a model of low carbon emissions has been called “energy transition” (LIVIERATOS; LEPENIOTIS, 2017; POLZIN et al., 2015). However, while there is some agreement regarding a new energy matrix that is less dependent on fossil fuels, there is no consensus about the velocity of this transition, or in which ways it can be carried out. The lack of consensus concerning the velocity of this transition can be exposed by the gap between different predictions on the level of participation of renewable energy in the total global generation. While British Petroleum (2017) predicts a 16% share of participation of renewable energy in the global generation by 2035, Ecofys (WWF; ECOFYS; OMA, 2011) predicts a scenario where 57% of the world’s demand for energy will be supplied by renewable sources by the same year.

In this scenario, independently of the rate of change, the energy transition will involve investments of trillions of dollars in the next years. Investments on the energy sector reached US$ 1.7 trillion in 2016, in which US$ 724 billion were destined in renewable energy, electric grids and energetic efficiency (IEA, 2017). At the same time, the share of investments on fossil fuels fell from 68.9% in 2014 to 57.1% in 2016, a 17.1% decline in only two years (IEA, 2017).

In this light, the problem of efficient investment allocation becomes increasingly relevant, not only from the social-environmental aspect but also from an economical perspective. Thus, the role of startups, by developing new technologies and novel business models, is a prominent one. The optimization of resources that will be invested in them is, then, a important issue and it should be better understood. Thereby, the objective of this article is to develop a predictive statistical model that is able to identify the factors the influence the success or failure of energy startups.

3.2. The Role of Startups on the Energy Transition

It is possible to draw some analogies of the current period of energy transition with the changes underwent by the communication sector around 20 years ago. At that time—the end of the 1990's and the beginning of the 2000's—there was some consensus among the stakeholders of the communication sector that their business could change substantially, from a "few to many" paradigm (newspapers, radio and TV stations) to "many to many" paradigm, with the diffusion of the internet. However, it was difficult to predict how, and in which proportion and speed, the changes propelled by the internet would affect the current models of television, radio and newspapers at the time.

History has shown that, in the communication sector transition, startups had a fundamental role, bringing new technologies and novel business models that altered the paradigms of the sector. At the same time that startups were leading these big changes, the established firms could not adapt to the new and dynamic landscape, falling in the incumbent's trap and being disrupted by innovations that they could not foresee (CHRISTENSEN; RAYNOR, 2003). Today, out of the ten most valuable companies in the world (in market capitalization), four — Amazon (1994), Google/Alphabet (1998), Tencent (1998) e Facebook (2003) — were startups created in that period.

Eric Ries (2011, 37) defines startup as "a human institution designed to create a new product or service under conditions of extreme uncertainty". When the concept is applied to the energy sector, it is possible to imagine that some startups will be able to reach a prominent position, taking advantage of the period of uncertainty and the context of change that involves the energy transition.

Some researchers and recent sectorial studies indicate a fairly high probability of startup companies achieving prominent roles in the energy sector (DONADA; LEPOUTRE, 2016; GLOBAL CORPORATE VENTURING, 2016; KPMG, 2015; LIVIERATOS; LEPENIOTIS, 2017). Other studies point out that incumbent firms could learn some of the attributes that are characteristic of startups (BIERWERTH et al., 2015; DUSHNITSKY; LENOX, 2005; LEE; KANG, 2015), thus being able to conduct the energy transition themselves. A third opinion highlights that the cooperation of established firms and startups, usually called corporate venturing, can also be an interesting strategy (LIVIERATOS; LEPENIOTIS, 2017; NARAYANAN; YANG; ZAHRA, 2009).

In each case: (1) the accelerated growth of startups; (2) the learning by the incumbents, and (3) the cooperation between startups and stablished firms, it is important to understand the elements that differ a successful startup from a failed one. This issue is particularly relevant in the renewable energy sector (and to other clean technologies) since the investments of venture capital, the leading model to finance startup growth, are often questioned regarding the results obtained in the energy sector (GADDY et al., 2017; MARCUS; MALEN; ELLIS, 2013).

3.3. Characteristics of Energy Startups

An energy startup is defined in this article as a startup that operates in some link in the chain of generation, transmission, distribution or commercialization of energy. In addition, we consider as energy startups those which operate in an adjacent chain, whose innovations may substantially affect the supply or demand of future energy, such as energy efficiency initiatives, electric/hybrids automobiles, or advanced stationary batteries.

In general, energy startups possess characteristics that differentiate them from typical software and internet startups (digital startups), which are usually covered in the literature. Understanding these differences is fundamental for the elaboration in our predictive model (GADDY et al., 2017; MARCUS; MALEN; ELLIS, 2013).

Although there are exceptions, the first differentiating feature of energy startups is the high need for capital from its early stages. A digital startup, in general, can start with a smaller volume of resources and increasingly capture the additional resources necessary for its growth through several rounds of investments (DAVILA; FOSTER; GUPTA, 2003; KIM; WAGMAN, 2014; LAHR; MINA, 2016; RIES, 2011). Energy startups, on the other hand, typically require a greater amount of resources, even at the beginning of their operations, as they are usually associated with physical assets, which are more complex and costly to scale than businesses that rely only on data (MARCUS; MALEN; ELLIS, 2013; VOLANS, 2014).

A second important feature refers to the maturation period. Because of the high scalability potential of internet-based businesses, they tend to have shorter business cycles when compared to energy startups (LIVIERATOS; LEPENIOTIS, 2017; VOLANS, 2014). Thus, the need for patient capital (WEST, 2014) is another key element for the success of energy startups (MARCUS; MALEN; ELLIS, 2013; MOORE; WUSTENHAGEN, 2004).

As a contrast to the increased capital needs and longer investment cycles, energy startups have better access to a rare and precious resource type for innovative and high-risk initiatives: grants. Because the new technologies associated with the energy transition are likely to produce positive externalities, energy startups have the possibility of being supported by governments and philanthropic institutions through various forms of subsidies (ABDMOULEH; ALAMMARI; GASTLI, 2015; FORAY; MOWERY; NELSON, 2012; GLENNIE; BOUND, 2016; GRECO; LOCATELLI; LISI, 2017; VEUGELERS, 2012; WORLD ECONOMIC FORUM, 2016).

The demands of larger investments along with the long payback rates create barriers to both entry and exit of new actors. While both markets are large and global, the number of active energy startups is 12 times lower than that of software startups (CRUNCHBASE, 2019). The greater technological intensity present in the energy startups also acts as a barrier to entry, since this kind of business is based on more complex technical knowledge (GRECO; LOCATELLI; LISI, 2017; LIVIERATOS; LEPENIOTIS, 2017).

The profile of energy startups entrepreneurs is also different from the typical profile of digital entrepreneurs. Digital startups, because they are more intensive in hours of work / dedication and less in initial capital volume and advanced technical knowledge, are very attractive options for young entrepreneurs (MORONI; ARRUDA; ARAUJO, 2015; RIES, 2011; SPENDER et al., 2017; TIDD; BESSANT; PAVITT, 2005). For the opposite reasons, entrepreneurs of energy startups tend to be former executives of companies in the sector or researchers with expertise in the area (TEPPO; WÜSTENHAGEN, 2009; UNEP; BLOOMBERG; FRANKFURT SCHOOL, 2016).

Another point to be highlighted regarding the differences between energy startups and digital ones is that the former usually act in regulated environments. The energy market is regulated, with different degrees of intensity, in virtually all countries. That partially limits the speed of diffusion of technologies and increases the costs of market entry. Some researchers pose that the regulatory framework is among the most important issues in the debate on the introduction and diffusion of new technologies in the energy sector (ALMEIDA et al., 2017; ANADÓN, 2012; MARCUS; MALEN; ELLIS, 2013; OLMOS; RUESTER; LIONG, 2012; UNEP; BLOOMBERG; FRANKFURT SCHOOL, 2016).

Understanding the particular characteristics of energy startups is vital for the identification of the factors that affect the performance of these startups. Also, it becomes a prerequisite for a more accurate understanding of how to properly evaluate the performance of startups and their possible value appreciation on the long-term.

3.4. Determining Factors for the Performance of Energy Startups During the Energy Transition

An energy transition is defined as a structural and long-term change in energy systems, which, in a historical perspective, may have happened in other occasions and in different manners (SMIL, 2010). This article refers only to the current transition, resulting from global efforts, from the late twentieth and early twenty-first century, to achieve a low carbon economy (HUISINGH et al., 2015; IEA, 2017; OLMOS; RUESTER; LIONG, 2012).

Having defined the general context, it is necessary, for the construction of the predictive model, to determine the main general and specific factors that can determine success and failure. In this article, we organize these factors into one general hypothesis and four specific hypotheses, whose validation depends on the first one. The general hypothesis can be defined as:

H1: There was a specific group of startups in the energy sector that had greater chance of being more successful in the energy transition scenario.

The first hypothesis is the very condition of existence of the model. In other words, we will identify, based on literature and data, if there is a group of common characteristics among energy startups that have been most successful in the last 20 years. To clearly delineate the concept of success and failure, we will assume that a startup was successful if it reached the IPO phase and that it failed if it went bankrupt, that is, if it ended its activities. The option for a metric associated with the perspective of future capital appreciation, such as the IPO, rather than metrics associated with past performance, such as revenues, profits, EBTIDA, etc., is justified because startups tend to be valued based on their future prospect (DAVILA; FOSTER; GUPTA, 2003; KÖHN, 2017; KOLLMANN; KUCKERTZ, 2010).

Meyer & Mathonet (2005) describe and explain this particularity through their "J-curve" (Figure 5) where it demonstrates that startups are loss-making and cash-burners at first, having profits and cash generation only after a few years of existence.

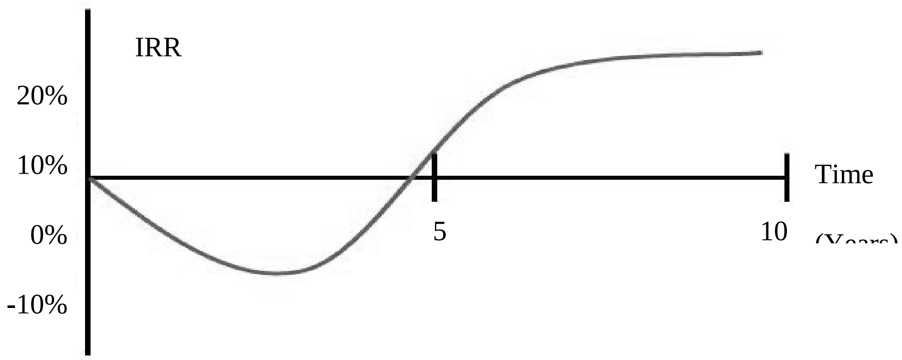

Figure 5: The Startup Investment "J" Curve
Source: Adapted from Meyer and Mathonet (2005)

Despite the standard curve, it is reasonable to assume that there are differences between the individual performances of the energy startups in this context.

However, it is necessary to test whether performance differences obey an observable standard or are in fact random, which would validate the hypothesis that there is at least one group with the best observable performance, and that this group has common identifiable characteristics.

> *H2: Startups linked to renewable energy and sustainability, or to new business models, tend to perform better in the energy transition scenario.*

The literature on the current energy transition has strongly associated this process with the underlying concepts of sustainability (GREENPEACE, 2015; LIEDTKE et al., 2015), clean energy (ALMEIDA et al., 2017; FARFAN; BREYER, 2017) and energy efficiency (ALEXANDER et al., 2012; WWF; ECOFYS; OMA, 2011). The IEA predicts that by 2035 the energy sector will account for 39% of direct efforts to reduce CO2 emissions (power generation) plus 14% through indirect efforts in the transportation, manufacturing and civil construction sectors (IEA, 2014, 2016), being responsible for more than half of the world's efforts in the transition to a low-carbon economy. Considering that US$ 724 billion, resulting from a bullish trend, were invested in renewable energy, electricity grids and energy efficiency in 2016, and that the relative share of fossil fuels in investments fell from 68.9% in 2014 to 57.1 % in 2016, a deceleration of 17.1% in just two years (IEA, 2017), we can consider sustainability as central and a trend of the current process of energy transition.

Another trend observed, which is closely linked to the concept of digital startups, are smart grids and distributed generation. Advancements regarding solar energy; sensors, predictive algorithms / artificial intelligence; energy storage systems; internet of things, smart homes / offices, blockchain - among others (CHESBROUGH, 2012; CHRISTIDIS; DEVETSIKIOTIS, 2016; LIVIERATOS; LEPENIOTIS, 2017) have allowed for the entry of new players and the advent of new business models for the energy sector, mainly related to residential and commercial demands. Electromobility and transport digitization are also pointed out as trends with growth prospects (ALEXANDER et al., 2012; DONADA; LEPOUTRE, 2016; GREENPEACE, 2015; IEA, 2016; KPMG, 2016) and which can indirectly influence the energy matrix, especially when considering the ongoing changes in road transport, which now account for 90% of all energy consumption with transportation at the global level (GREENPEACE, 2015).

The above factors indicate that new business models and businesses related to sustainability tend to have a greater perspective of future value appreciation, and consequently, better overall performance.

H3: Startups located in countries where the innovation environment for cleantechs is more developed have better performance.

Geographic location is crucial for a series of starting conditions for a new business such as: regulatory efficiency, potential market size and access to capital that an energy enterprise has at its disposal at the beginning of its journey (AMANATIDOU et al., 2014; FARFAN; BREYER, 2017; UNEP; BLOOMBERG; FRANKFURT SCHOOL, 2016; WORLD ECONOMIC FORUM, 2016). Such conditions, which may act as barriers or incentives to new entrants, are especially relevant for startups who, especially in the ideation phase, have low exit barriers.

Still on localization, from the point of view of knowledge, the literature highlights advantages for businesses close to poles of excellence in technologies related to products and services offered by startup (ANADÓN, 2012; MARCUS; MALEN; ELLIS, 2013; WEST, 2014). These advantages are mainly due to the intensification of knowledge generation in the local network, the associated R&D infrastructure and the availability of qualified human resources to initiate and support startup growth.

This set of local preconditions regarding the business and technology environment form the so-called "innovation and entrepreneurial ecosystems" (BUDDEN; MURRAY, 2017). Startups are embedded in such ecosystems, which are also highlighted as an important and influential factor in the performance of startups of virtually all sectors (HERMANN et al., 2015). In this sense, Teece, Pisano, & Shuen (1997) point out that local and regional forces shape the skills and capabilities of the firms, especially in the early stages.

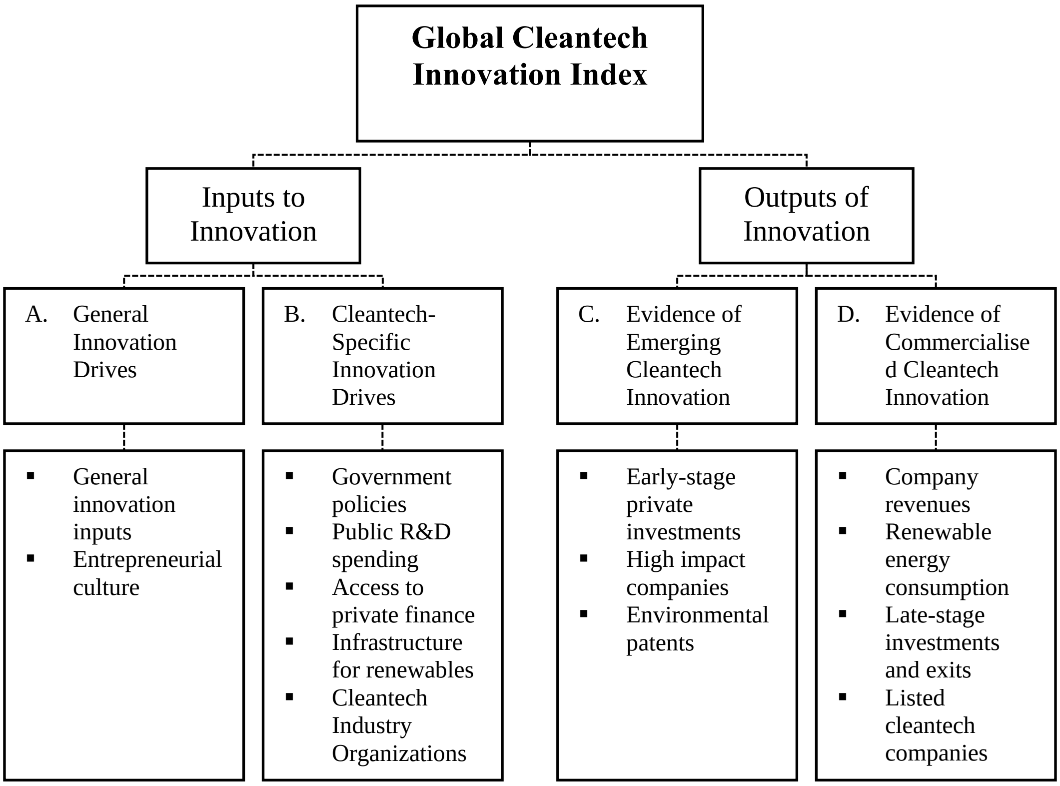

Figure 6: The Global Cleantech Innovation Index 2017 Framework
Source: Cleantech Group and WWF (2017)

The Global Cleantech Innovation Index (CLEANTECH GROUP; WWF, 2017) evaluates cleantech innovation systems in over 40 countries with inputs and outputs measured through 21 metrics, 15 indicators and two major groups (inputs and outputs), equally weighted and evaluated with scales from 0 to 5, as shown in Figure 6. Given the relevance of the geographic factor for startup performance and the fit and comprehensiveness of the Global Cleantech Innovation Index framework to the objectives of this article, it will be used as a variable to test hypothesis H3.

H4: The volume and profile of the investments received influence the likelihood of energy startups reaching the IPO

As seen, energy startups operate in a particular scenario, as they perform in regulated environments, have greater need of capital and need greater maturation time. The need for more patient capital has led us to consider that corporate investors, also known as corporate venture capital (CVC), which are more focused on sector strategy, and angel investors (less pressure for quick returns) could be more desirable by these startups than financial investors, such as banks and independent venture capital funds (IVCs), which yearn for faster returns and must justify the allocation of their resources to their shareholders (CZARNITZKI; DICK; HUSSINGER, 2010; GUO; LOU; PÉREZ-CASTRILLO, 2015; LIVIERATOS; LEPENIOTIS, 2017; VOLANS, 2014).

On the amount and volumes invested, it is expected that startups that have received more resources and more pre-IPO investment rounds will be more successful, since energy startups generally depend on a longer cycle and they need more capital to both start and maintain their operation (MARCUS; MALEN; ELLIS, 2013; WEST, 2014). Thereby, it is possible to consider that both the quantity and the possession of a patient capital profile of investments can positively influence the performance of energy startups.

H5: The date of the startup's foundation influences its performance.

As discussed earlier, the growth of an energy startup tends to be slower than that of typical digital startups (MARCUS; MALEN; ELLIS, 2013; MOORE; WUSTENHAGEN, 2004; WEST, 2014). Thus, an older energy startup is expected to have had more time to mature its investment and turn it into value.

Another factor that may be associated with the relationship between the foundation date and the performance of energy startups is the consolidation of large agreements and public policies (HAHN; YU, 1999; IPCC, 2014), mainly related to sustainable development and climate change. The energy transition has been driven in large part by major sustainability milestones such as the Kyoto Protocol and the recent Paris Agreement, as well as local government incentives / benefits. The association of the moment of foundation, traction, IPO, or the termination of energy startups may be correlated with the start and end dates of these policies and agreement.

Finally, having defined the theoretical factors that can influence energy startups in the context of energy transition, we can develop the method capable of testing the associated hypotheses and develop a predictive model capable of pointing out some observable patterns in the last 20 years, which may be used by investors, managers and policy makers in the coming years.

3.5. Method

The methodological approach for the elaboration of the predictive model of this study was based on the technique of binary logistic regression. Such a technique is appropriate for dividing samples into two distinct groups by considering a set of independent variables and their relations to a dichotomous dependent variable (HAIR JR et al., 2010).

In our specific case, the primary interest is to identify the common factors regarding the energy startups founded in the last 20 years that reached the IPO (success) that differentiate them from the startups of energy that ended their activities (failure) in the same period. For this, the study was developed with the following steps:

> Step 1: Selection of independent variables based on the literature and hypotheses formulated.
>
> Step 2: Collection and treatment of data regarding energy startups founded in the last 20 years that also made IPOs or ended their activities in the period.
>
> Step 3: Exploratory factor analysis to reduce the complexity of the model, and the treatment of eventual problems of correlation between the variables.
>
> Step 4: Execution of the logistic regression method to identify the factors that were the most influential for the success (IPO) or failure of the energy startups.
>
> Step 5: Analysis of the predictive capacity of the model as well as the variables that are individually related to the success or failure of the startups.

In Step 1, based on factors identified in the literature, we selected 10 independent variables whose coefficient estimates allow for the testing of the research hypotheses. Table 6 shows the selected variables and operational definitions that were used in the study.

Each variable or set of variables was selected with the objective of testing one or more of the established hypotheses and their respective trends observed in the literature on startups and energy transition. The values of the "Sustain" and "NBModel" variables were filled using the Crunchbase database (CRUNCHBASE,

2019) startup business descriptions – and their respective institutional sites – as references. For the "Sustain" variable, the value "1" means that the startup has its business focus linked to sustainability, the value "2" means that the startup has its business focus in an adversarial area (oil exploration, for example) and the value "3" means that the main business of the startup is neutral in relation to the sustainability theme.

Table 6: Independent Variables and Their Operationalization

Variable	Abbreviation	Operationalization
Sustainable Business	Sustain	Categorical. 1 = performance linked to sustainability; 2 = opposite action ("anti") sustainability; 3 = neutral position in relation to sustainability.
New Business Model	NBModel	Categorical. 1 = focus on new business models; 2 = focus on high technological intensity; 3 = focus not necessarily linked to new business models or high technological intensity.
Innovative Country (Environment)	InputEnv	Classification of the cleantech innovation inputs in the country according to the Global Cleantech Innovation Index 2017.
Innovative Country (Results)	OutputEnv	Classification of the innovation environment (outputs) in cleantech of the country according to the Global Cleantech Innovation Index 2017.
Investment rounds	NoRounds	Number of rounds of investments received before the IPO or termination.
Invested Capital	EquityFund	Volume of capital invested before the IPO or closing.
Total Invested	TotalFund	Total volume invested (includes debt, grants and other resources) before the IPO or closing.
Corporate Venture Capital (CVC)	Icorp	Categorical. 1 = received investment from corporate venture capital (CVC); 0 = received no CVC investment.
Angel Investor	Iangel	Categorical. 1 = received funds from angel investors; 0 = did not receive funds from angel investors.
Foundation date	FoundDate	Year of the startup’s foundation.

Sources: (CLEANTECH GROUP; WWF, 2017; CRUNCHBASE, 2019)

Similarly, for the variable "NBModel", the value "1" indicates that the startup has its business based on a new business model, the value "2" means that the startup business has high technological intensity, and the value "3" means that the startup does not necessarily have a new business model or high technological intensity.

The "InputEnv" and "OutputEnv" variables have been filled with the original values for innovation inputs and outputs of the Global Cleantech Innovation Index 2017 (CLEANTECH GROUP; WWF, 2017). Four startups were from countries that did not appear in the report; they were assigned the value relative to the lowest-ranking countries.

The variables "Icorp" and "Iangel" were transformed into binary categorical variables based on the lists of investors of each startup from the Crunchbase database, with the variable "Icorp" being indicative of corporate venture capital investments (1 = CVC, 0 = lack of CVC) and "Iangel" being indicative of angel investments (1 = received angel investments, 0 did not receive angel investments). The other variables presented in Table 1, "NoRounds", "EquityFund", "TotalFund" and "FoundDate, were obtained directly from the database (CRUNCHBASE, 2019).

In Step 2, 537 companies from the Crunchbase database were initially found that met the filters primarily established in the research design. The filters were: (i) having been founded in the last 20 years; (ii) being from the energy sector, and (iii) having either reached the IPO or having closed down its activities in the period. After this selection, cases with more than 25% of missing data and companies that did not conceptually fall into the startup category were eliminated (the original base included legal structures created by large energy companies only for the management of specific projects related to their final activity). The final result of the process was a dataset — with no missing values — of 195 startups, of which 93 closed out their activities (47.7%) and 102 did IPO (52.3%).

We do not consider energy startups with acquired status because it is not possible to know if this meant success or failure without further analysis of the valuations of the acquisition and previous rounds. In other words, if the acquisition were made considering a lower valuation than the previous rounds, it would be a proxy for startup failure. Otherwise, if the startup were acquired by higher valuations, it could mean success from a business standpoint. We have not considered energy startups still in operation too, because we do not know what will happen to them in the future (whether they will reach the IPO, will be acquired, will terminate activities or none of the previous options).

In Step 3, a factor analysis was performed using the main component extraction method with the objective of making the model simpler and solving possible correlation issues between the independent variables. In a first attempt using the eigenvalue classification criterion greater than 1.0, the result indicated four factors which were not satisfactory in terms of explained variance or in terms of clarity of interpretation. By adjusting the parameter to a fixed value of six factors, the results improved substantially, reaching 87.56% of explained variance, with better clarity for interpretation of the results, and without compromising the application of the hypotheses tests. The values for the KMO and Bartlett Sphericity tests, and of communalities, were also adequate. The result, considering a suppression of results with load below 0.6 and the application of varimax orthogonal rotation, can be observed in Table 2.

We adopted summated scales to represent the new variables extracted by the principal components method, given that components 4, 5 and 6 are formed by the original variables, and components 2 and 3 are measured on comparable scales. In this case, we transformed the original variables of component 1 into z-scores so that the sums of the values would an adequate representation.

Table 7: Principal Components for Energy Startup Characteristics

	Component					
	1	2	3	4	5	6
Sustainable Business (Sustain)				0.972		
New Business Model (NBModel)					0.985	
Innovative Country (Environment) (InputEnv)		0.950				
Innovative Country (Results) (OutputEnv)		0.957				
Investment rounds (Z-NoRounds)	0.639					
Invested Capital (Z-EquityFund)	0.956					
Total Invested (Z-Total Fund)	0.960					
Corporate Venture Capital (Icorp)			0.829			
Angel Investor (Iangel)			0.756			
Foundation date (FoundDate)						0.995

Step 4 comprises the logistic model itself, which is represented, in overview, in Figure 7. In the general diagram, we denominate the new six independent variables resulting from the previous step (1 = Previous Investments, 2 = Innovation for Cleantech: Country, 3 = Patient Capital, 4 = Sustainable Business, 5 = New Business Model, 6 = Foundation Date). Also, we associate each variable with its corresponding hypothesis. Variables 1, 2 and 6 are numerical and variables 3, 4, 5 are categorical.

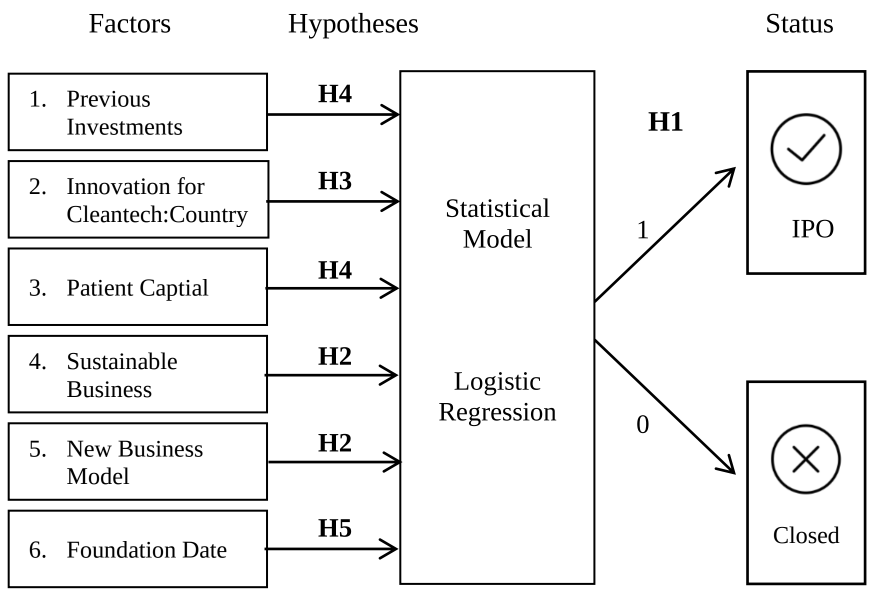

Figure 7: Methodological Diagram: Model, Hypotheses and Factors

The binary dependent variable is the variable Status, where 1 = IPO (the startup reached the IPO in the period), and 0 = Closed (the startup ended its activities in the period). We also set a 95% confidence interval for the estimates of β; a value of three standard deviations in the residuals for the consideration of outliers; and a cutoff of 0.5 for the classification of the groups, considering that the sizes of the sample groups are relatively similar (IPOs are 52.3% of cases). With the above-mentioned criteria, no cases of outliers were identified.

Having defined the model parameters, we selected a random sample of about 80% of the cases to construct the model (154 cases) and the remaining cases (41) were used as a holdout sample. The size of the sample for model construction complies with the recommendation of Hair Jr et al. (2010) to have at least 10 cases per independent variable. Finally, as a method of selecting the variables of the model, we opted for the process of backward elimination with a focus on maximizing the likelihood ratio. To analyze the results and test hypothesis H1, we used the comparisons of the base model with the hit ratio of the proposed model and the Nagelkerke's R^2. For the other hypotheses (H2 to H5), we used the estimation of the values of β and their respective p-values

3.6. Results and Discussion

In the studied period, we observed some particular characteristics of the energy startups. Most startups have sustainability-related businesses (77%) and only a small part (7.6%) have their businesses linked to segments that are antagonistic to the concept of sustainability, as observed in Figure 8.

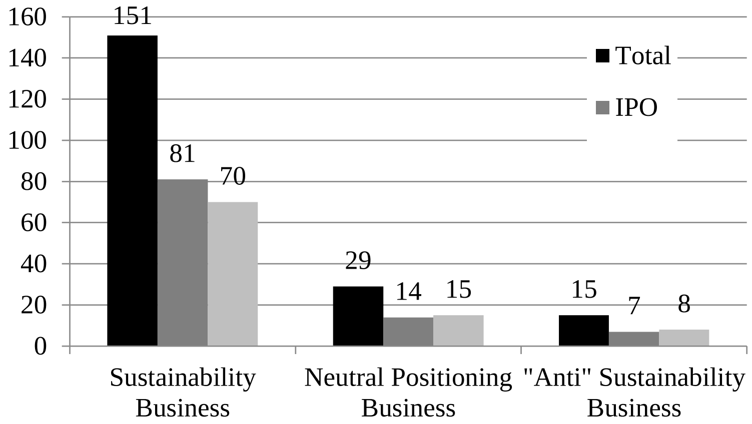

Figure 8: Energy Startups and Sustainability

With regard to new business models, most startups (51.8%) had their businesses supported by products and services of high technological intensity. 33.3% of the startups were based on new business models and 15.4% operated without necessarily having new technological models or new high-intensity technologies, as shown in Figure 9. 96.1% of IPOs were linked to new business models or startups with high technological intensity.

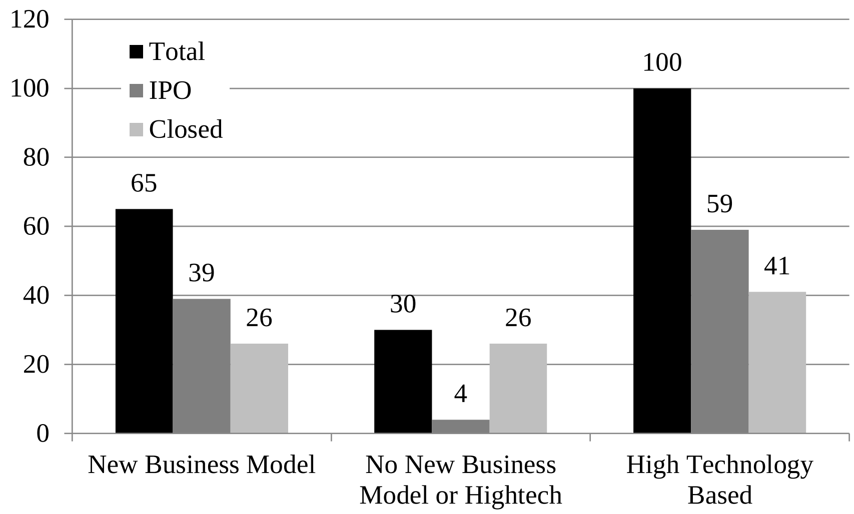

Figure 9: Energy Startups, New Business Models and Technological Intensity

Regarding the presence of patient capital among its investors, 10 startups received funds from CVC, 35 from angel investors and 17 startups received investments from angels and CVC simultaneously. However, the vast majority (68.2%) received contributions only from investors with financial profiles as shown in Figure 10. The number of IPOs, however, surpasses those of companies that closed down only in the groups of "no patient capital" investors or in the case of joint investments of angels and CVCs.

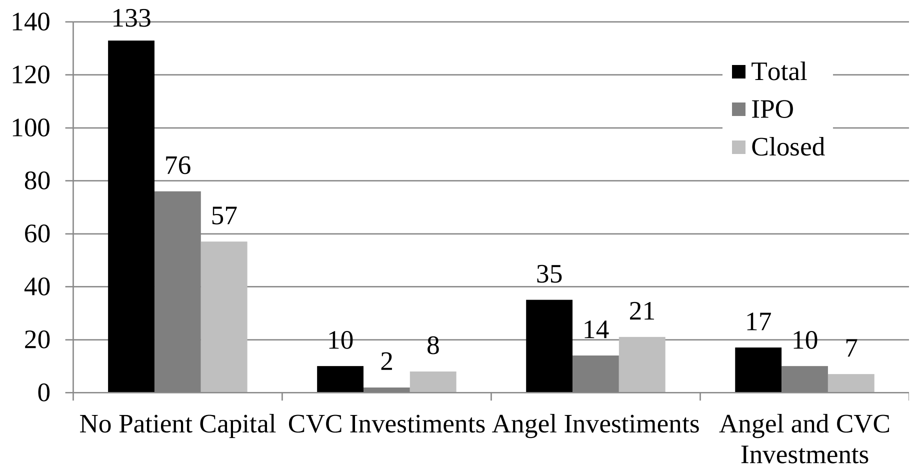

Figure 10: Energy Startups and Patient Capital

Regarding geographical location, Figure 11 shows that most startups (69%) are located in the United States, the country with the most dynamic venture capital and startups system in the world, followed by Canada, the United Kingdom and China. Within the US, the region with the highest number of startups is California / Silicon

Valley, followed by Massachusetts (Harvard and MIT headquarters) and Texas, an American reference state in the oil and gas field.

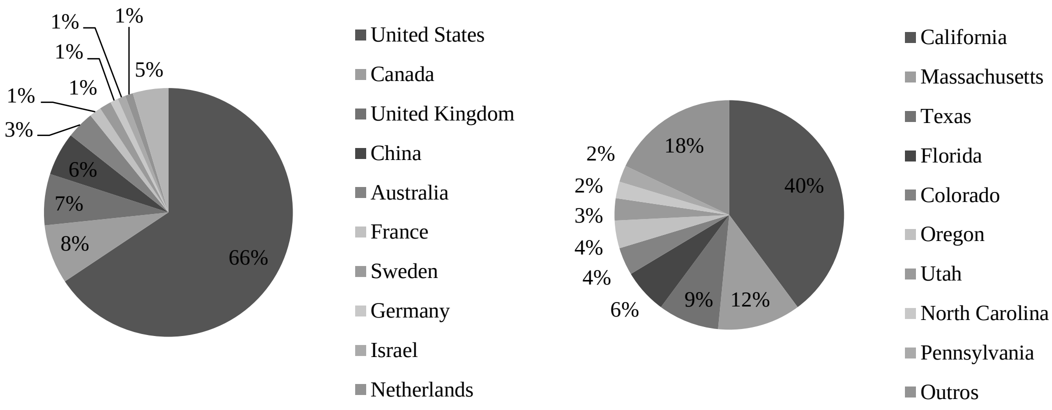

Figure 11: Energy Startups and Location

Once the samples having been characterized, we proceed to the model and the hypotheses. For H1, there was a significant improvement in predictive power relative to the base model as presented in Table 8. The hit ratio rose from 56.5% to 74.7% in the training data and from 36.6% to 63.4% in the holdout sample in the second step of the backward elimination process.

Table 8: Classification Table[a] - Base Model (Step 0) vs. Proposed Model (Step 2)

			Predicted					
			Selected Cases			Unselected Cases		
			Status		Percentage Correct	Status		Percentage Correct
Observed			Closed	IPO		Closed	IPO	
Step 0 (Begin)	Status	Closed	0	67	0%	0	26	0%
		IPO	0	87	100%	0	15	100%
	Overall Percentage				56.5%			36.6%
Step 2	Status	Closed	44	23	65.7%	15	11	57.7%
		IPO	16	71	81.6%	4	11	73.3%
	Overall Percentage				74.7%			63.4%

a. The cut value is .500

The statistics and tests obtained also validate the results achieved. The -2 Log Likelihood, Nagelkerke R^2 and Hosmer and Lemeshow Test present adequate values, as observed in Table 9.

Table 9: Logistic Regression Tests and Model Summary

-2 Log Likelihood	153.455
Nagelkerke R^2	.417
Hosmer and Lemeshow chi-squared ratio	11.253
	(.188)

In this way, we can consider that not only are there identifiable differences between the group of startups that reached the IPO and the group that ended its activities in the last 20 years, but also it is possible to significantly improve the ex-ante forecast through the proposed model. These observations allowed us to confirm the general hypothesis H1 and, thus, continue evaluating the other hypotheses through the β and p-values of the proposed model presented in Table 10.

Table 10: Proposed Model Variables

Status	Variables	Dummies Coding	β	exp(β)	Sig.
Variables in the Equation	1. Previous Investments		.617	1.854	.002
	2. Innovation for Cleantech: Country		-.347	.707	.064
	3. Patient Capital				.005
		(1)	-1.855	.156	.002
		(2)	-1.500	.223	.105
	5. New Business Model				.001
		(1)	3.244	25.626	.000
		(2)	3.353	28.580	.000
	6. Foundation Date		-.140	.870	.008
	Constant		280.189	4.838	.008
Not in the Equation	4. Sustainable Business		.904		.637
		(1)	.506		.477
		(2)	.018		.894

Among Step 0 variables, three are categorical. For the logistic model, they were transformed into specific dummy variables. For the variable “3. Patient Capital”,

(1) means having either angel or CVC investment and (2) means having both angel and CVC investment. For “5. New Business Models”, (1) identifies that the startup is based on a new business model and (2) that the startup is linked to high technological intensity. For the variable “4. Sustainable Business”, (1) indicates sustainability-related businesses and (2) indicates that their businesses are antagonistic to the concept of sustainability.

Involving two of these categorical variables and one of the most surprising results of the model, the H2 hypothesis was only partially supported. Values of β are significant for energy startups that have new business models or advanced technologies, and these attributes positively influence the performance of startups toward reaching the IPO. However, contrary to the mainstream literature, the fact that the business is linked to sustainability did not positively affect the IPO's achievement, as well as being at the opposite end also did not negatively influence startup performance in the last 20 years.

The literature points to some possibilities to explain the lack of influence of sustainability on performance. For instance, there is no functional venture capital (or equivalent) model for cleantech startups yet (GADDY et al., 2017), neither is there clarity on the types of public policies which are most effective to promote sustainable development in the energy sector. A number of authors have recently attempted to identify which policies may be more efficient(ARGENTIERO et al., 2017; JARAITE; KARIMU; KAZUKAUSKAS, 2017; POLZIN et al., 2015), but without reaching consensus thus far.

The variable that supports hypothesis H3, “2. Innovation for Cleantech: Country”, which indicates the degree of development of the innovation environment for cleantech in the startup host country, was included in the model. However, its significance was very close to the limit, being accepted only in the case of $\alpha = 0.1$ and having a very low β value. Interestingly, the value of β was negative, indicating that being located in the countries with the best cleantech innovation scores such as Sweden and Canada (CLEANTECH GROUP; WWF, 2017) did not influence startup performance positively, leading us to reject hypothesis H3, and to a reflection on whether and which other geographic factors could affect startups to reach the IPO.

In the case of hypothesis H4, the model makes it clear that the number of rounds and the volume of investments prior to the classification event (IPO or closure) positively influenced the performance of energy startups in the last 20 years, with positive β and significant p-value for the variable "1. Previous Investments". In the case of the profile of these investors, contrary to the dominant literature, the presence of patient capital, CVC or angel investors, has negatively affected the performance of energy startups, which leads us to reject H4 and seek reflections on the reasons that lead energy startup companies that have patient capital have lower chances of reaching the IPO.

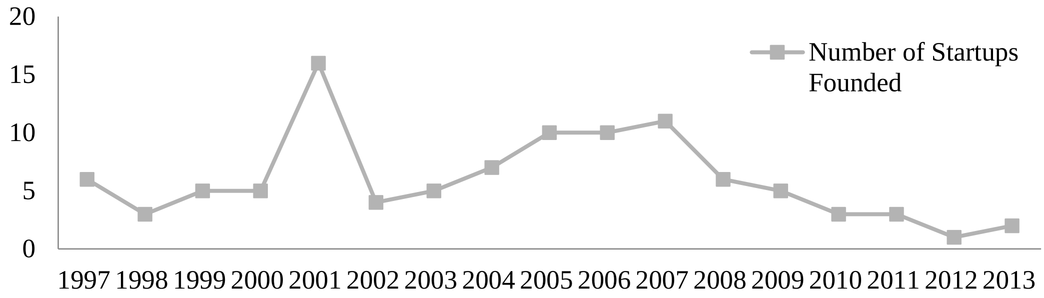

Figure 12: Number of Startups that Reached the IPO by Foundation Date

Finally, regarding hypothesis H5, the foundation date significantly influences startup performance, but without a very clear tendency with β close to zero (0) in module. The curve in Figure 12 shows the number of startups founded in a given year that managed to reach the IPO later. Even considering that the average number of years for the IPO of the sample is 6.04 years, by a visual examination, there is no noticeable upward or downward trend, alternating between peaks and valleys at the time of the period. Such behavior probably linked to economic cycles and other exogenous factors is consonant with concept of "vintage year" of venture capital funds (MEYER; MATHONET, 2005).

In general, it is possible to note that some hypotheses based on the literature were confirmed while others led to surprising results, considering the expectations outlined by the mainstream literature. This divergence generates the opportunity for future qualitative reflections about the theme. Nonetheless, the general model displayed reasonable potential predictive power and it can be used as an optimization mechanism for investors, startups and other stakeholders in the energy sector who seek to understand the role of energy startups during the energy transition.

3.7. Conclusions

In this study, we collected data of energy startups that either reached the IPO or closed down their activities in recent years. Through the proposed statistical model it is possible to note that there is an identifiable pattern among the most successful startups and that some of their common characteristics can indeed be mapped. The model achieved was able to improve the hit ratio by 18.2% using only six factors. Confirmation of hypothesis H1 has allowed us to proceed with the test of other hypotheses and suggest future research that includes new endogenous variables in order to increase the explanatory capacity of the model. Table 11 shows a general picture of the hypotheses and their conclusions.

Table 11: Hypothesis Tests Consolidated

#	Hypothesis	Status	Evidence
H1	There is a specific group of startups in the energy sector that has greater chance of being more successful in the energy transition scenario.	Confirmed	R^2 (NagelKerke) = 0,417; Hosmer & Lemeshow Sig. = 0,188; "Hit Ratio" Increase +18,2%
H2	Startups linked to renewable energy and sustainability, or to new business models, tend to perform better in the energy transition scenario.	Partially Supported	Sustainability: Sig. β = 0.637 New Business Model: Sig. β = 0.001; β(1) = 3.244; β(2) = 3.353
H3	Startups located in countries where the innovation environment for cleantechs is more developed have better performance.	Rejected	Sig. β = 0.064; β = -0.347
H4	The volume and profile of the investments received influence the likelihood of energy startups reaching the IPO	Partially Supported	Previous Investments: Sig. β = 0.002; β = 0.617 Patient Capital: Sig. β(1) = 0.002; β(1) = -1.85 Sig. β(2) = 0.105; β(2) = -1.5
H5	The date of the startup’s foundation influences its performance.	Confirmed	Sig. β = 0.008; β = -0.140

Confirming the theoretical predictions of the literature, the number of rounds and the volume of external investments positively affect the likelihood of reaching the

IPO. This finding is important because it reinforces empirically that energy startups have more capital-intensive investment cycles. The utilization of new business models also led to a higher chance of IPO among the energy startups founded in the last 20 years. At this point, the growth of new trends related to digitization and decentralization of the sector, such as smart grids, blockchain/smart contracts, distributed generation, big data, data analytics, among others, shows enabling new business models that were previously unviable.

The startup's foundation date also affects the success rate, probably due to exogenous factors to the startup, such as the economic environment, the existence of specific policies for the sector, etc. However, there is no clearly defined linear trend. The foundation date affects success rate across the cycles, as reported in economic theories and the vintage year concept adopted by the venture capital industry (MEYER; MATHONET, 2005).

The startup's host country also influences success, but it is not as significant as the cleantech-specific innovation environment. The results indicate that being based in countries at the top of cleantech ranking (CLEANTECH GROUP; WWF, 2017), like Sweden and Canada, did not contribute much to a company to reach the IPO. This result can be considered a little biased, given the sizeable relative share of US startups at the base (66%). We may consider this limitation of this research as an opportunity for future research involving databases focused on other countries.

However, two of the main findings of this study are related to the partial rejection of two hypotheses that are traditionally supported by the literature. Based on the empirical data of the last 20 years, having the business focus linked to sustainability, or even operating in areas that are antagonistic to sustainability, both are not significant for a startup's performance in terms of reaching the IPO. Here is a new suggestion for future research that qualitatively analyzes the reason for the low significance of the energy startups' sector in their performance in relation to IPOs.

The same occurs with the presence of angel investors and corporate venture capital units, the so-called patient capital, which empirically exerted a negative influence on performance, in a clear contrast to the literature, which predicted the opposite in theoretical terms. The longer cycles of energy startups should point to a positive difference in this regard, which leads us to another research suggestion related to a qualitative investigation into the phenomenon.

Finally, given the scenario whereby intense efforts to contain climate change after the Paris Agreement are being made (UNFCC, 2017), investments related to new sources of renewable energy, smart grids and energy efficiency are in constant growth, and startups are playing an increasingly pivotal role, the proposed model can be posed as a starting point, being of practical use for investors, policy makers, startups and researchers interested in improving the concept through the introduction of new variables or by deepening the understanding of those variables already discussed in this study.

4
UNRAVELING THE 5TH WAVE OF CORPORATE VENTURE CAPITAL

Abstract

Corporate venture capital (CVC) activity reached its historical investment peak in 2018 (US$ 53 billion) after sustaining a compound annual growth rate of 38% since 2013. The literature usually named this time the fourth wave of CVC, which started in the middle of the 2000s and lasts until the present. In our research, we have identified two different waves underlying to this period. The actual fourth wave (2003-2009) could be described as a learning period. During this time the CVC units started to leave their financial focus and began to be more strategic and innovation-oriented. On the other hand, the fifth wave (2010-Present) consolidated the previous learning and increased the stakes on strategic innovation. Using Multivariate k-Means Cluster Analysis and ANOVAs, we dive deeply into data from the world most active CVC units. The goal was to identify the general patterns and the group formation across the three last CVC waves. We have discovered that CVC units in the fifth wave have unusual behavior. The new standards include raising their overall investments exponentially, taking more risks with startups in the early stages, and spreading across new sectors and world regions.

4.1. Introduction

In the early 2000s, both the growing number and the mobility of skilled professionals increased the knowledge exchange stock exponentially. In addition, the explosion of venture capital available for innovative new companies ushered in a period known as the era of open innovation (CHESBROUGH, 2003b). Among the many possible models of open innovation, the instruments of cooperation between startups and large corporations, also known as corporate-startup engagement (CSE) (KOHLER, 2016; WEIBLEN; CHESBROUGH, 2015) or corporate venturing (CV) (GUTMANN, 2019; NARAYANAN; YANG; ZAHRA, 2009), have gained particular prominence in recent years.

This “open” mindset led corporations to realize that cooperating could be a more effective way of protecting themselves from startup disruptions. In fact, in the current context, the relationship between corporations and other stakeholders in their external environment becomes somewhat interdependent in managing innovation. (ADNER; KAPOOR, 2010; JACOBIDES; CENNAMO; GAWER, 2018). Repeating the past behavior of facing them in the competitive field would not be the best strategy after all (INSEAD; 500 STARTUPS, 2016). By embracing startup engagement as a possible way to innovate, large corporations can add to their material resources, scalability, market power, and consolidated processes a good deal of startups' positive traits such as creativity, agility, risk propensity, and rapid growth in new markets (WEIBLEN; CHESBROUGH, 2015). Because of these characteristics, in the innovation environment, startups tend to be more prepared institutions to deal with the volatile, uncertain, complex, and ambiguous (VUCA) world we live in today (SCHOEMAKER; HEATON; TEECE, 2018).

To optimize and manage these interactions, corporations have created a variety of instruments, ranging from one-off events, shared spaces, support services, corporate incubators and accelerators to capital investments and acquisitions (INSEAD; 500 STARTUPS, 2016). These instruments - represented by Figure 13 - often serve different purposes and require different levels of commitment from both startups and corporations. In general, the higher the commitment of the parties, the more the partnerships are associated with strategic objectives (MOCKER; BIELLI; HALEY, 2015).

In this context, the consistent growth in the number and volume of corporate venture capital (CVC) units in recent years can be considered a relevant indicator of the increased strategic relevance of CSE instruments for corporations (BRIGL et al., 2016). Over the past five years, investments via CVC have a compound annual growth rate of 38%, reaching a volume of US$ 53 billion in 2018 through 2,740 operations (almost ten times the pre-bubble peak of the internet during that period). (CB INSIGHTS, 2019). In addition to absolute growth, there was also a significant increase in the relative importance of CVC. From 2013 to 2018, the relative share of CVCs in the venture capital (VC) industry increased from 16% to 23%, a compound increment of 44% in 5 years. (CB INSIGHTS, 2019).

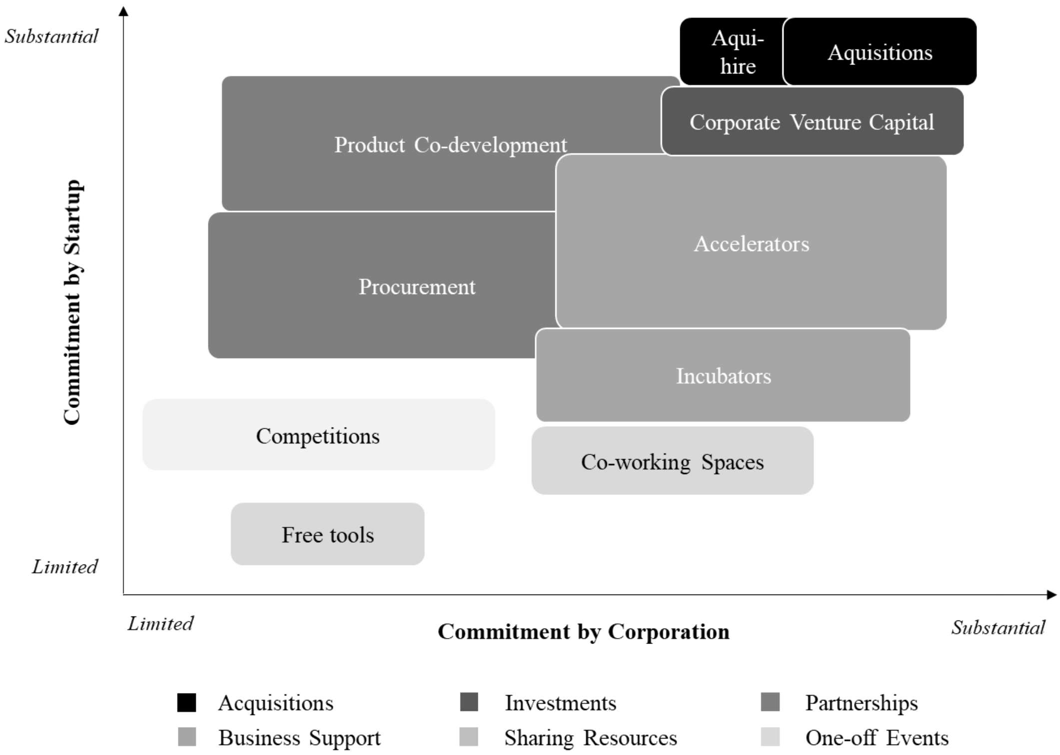

Figure 13: Corporate-Startup Engagement Tools
Source: (MOCKER; BIELLI; HALEY, 2015)

The increase in strategic relevance, investment volume, and the number of operations through CVC units in recent years has also been reflected in the academic interest in the subject. The number of publications per year about CVCs in the Scopus Base was less than one during the before 2003 (0.71 articles per year). This number jumped to 9.33 in the period 2003-2009, and to 14.67 per year since 2010 (SCOPUS, 2019).

The accelerated growth in the volume of investments and the number of publications on CVC topic in recent years are important indicators of the increasing relevance of the activity from both the market and academic point of view. However, the investment cycles of CVC units take, on average, more than eight years to be completed (GUO; LOU; PÉREZ-CASTRILLO, 2015). These long investment cycles bring us to a scenario where we can identify the relevance of the theme, and also find several theoretical gaps about the most recent cycle (wave), even with the growing number of publications on the subject (SCOPUS, 2019).

The specific gap we will explore in this research is the lack of understanding of using CVC units as a strategic innovation tool. Recent literature points out that CVC units have been used as a tool for innovation by corporations, and that there is a great diversity of investment focus, exit strategies, investment durations, positioning in relation to pre-existing R&D structures, approach related to the geographical aspect, etc. (BELDERBOS; JACOB; LOKSHIN, 2018; DA GBADJI; GAILLY, 2009; GUO; LOU; DAVID, 2012; LIVIERATOS; LEPENIOTIS, 2017).

However, the use of CVC by corporations has not always been associated with innovations. In the first three waves (the 1960s, 1980s, and 1990s), there was a predominance of financial motivations where corporations operating with CVC tended to follow other moves from the venture capital industry and the financial market (BIELESCH et al., 2012). From the 2000s onwards, companies began to realize that CVC units could also be great strategic tools for searching and internalizing innovations (BARRETTO-KO, 2011; DA GBADJI; GAILLY, 2009; MAULA, 2007).

Thus, the first objective of this research is to understand the pathway of use of CVCs units, from a financial focus to their use as an innovation tool. To achieve this first objective, we have conducted an exploratory analysis of the characteristics of 13,012 investments made by CVC units between 1995 and 2019 (March) (CRUNCHBASE, 2019). We have considered variables such as investment stage, geographic region, sectors, investment values, presence of co-investors, etc.

Once we have identified the general aspects of the cycles (waves), we have analyzed the strategic positioning of the most active CVC units in the world, according to Crunchbase (CRUNCHBASE, 2019). For this, we deepen the investigation of the CVC units themselves through the cluster analysis method, where we have compared their empirical characteristics with those predicted by the clustering model. The combination of both procedures - exploratory wave analysis with clustering of CVC units - pointed to important insights into the current context of the use of CVC units as a tool for corporate innovation.

4.2. The Corporate Venture Capital Evolution

Several authors investigating the characteristics and evolution of CVC around the world divide this story into cycles or “waves” (BARRETTO-KO, 2011; BENSON; ZIEDONIS, 2010; BIELESCH et al., 2012; CB INSIGHTS, 2017; DUSHNITSKY, 2011; FAN, 2018; GOMPERS, 2002; MA, 2016). Although there are disagreements about the exact periods of each wave, there was some consensus on the existence of four of them.

Until the early 2000s, CVC was just considered a secondary force in the venture capital industry (FAN, 2018), and its cycles generally followed the movements of independent VC funds and the financial market (BIELESCH et al., 2012; DUSHNITSKY, 2011). This macro period encompassed the first three waves of CVC reported in the literature (BENSON; ZIEDONIS, 2010; BIELESCH et al., 2012; CB INSIGHTS, 2017). The first, in the 1960s, was led by large industrial conglomerates that, using their success in the capital markets, sought to diversify their businesses. Because of this focus, we call the first wave by “Conglomerate Diversification Wave”. The second one, in the 1980s, we call it “Silicon Valley Rising Wave” because it coincides with the emergence of the first tech companies like Apple, HP, Oracle, and others that shaped Silicon Valley as we know it today. The third, from 1995 to 2002, we named "Venture Capital Euphoria Wave" due to its association with the fast growth of venture capital in the period called "dotcom companies boom".

Only in the fourth wave reported in the literature, after the year 2002, we began to have CVC activity mainly as a corporate innovation tool (BARRETTO-KO, 2011; BIELESCH et al., 2012; CB INSIGHTS, 2017; DUSHNITSKY, 2011; LIVIERATOS; LEPENIOTIS, 2017). This view is closely related to the diffusion of the concept of open innovation and corporate-startup engagement (CSE) among corporations, which is why we call it “Open Innovation Learning Wave”. Table 12 below shows in a consolidated way the four waves reported in the literature so far. We will go into the characteristics of each of these waves next.

Table 12: Review of Previous CVC Waves Literature

Wave	References	Key Points
1st Wave: *"Conglomerate Diversification"* (1960's)	- (BENSON; ZIEDONIS, 2010) ➔ 1960's - (BIELESCH et al., 2012) ➔ Mid 1960's - (CB INSIGHTS, 2017) ➔ 1960-1977	- Strongly growth of capital markets in the US (CAGR 13% between 1962 and 1966). - The financial success of the independent venture capital (VC) investors. - Large industrial conglomerates like GE, Dupont, 3M, Ford, Dow, Mobil, Monsanto, Xerox, etc.
2nd Wave *"Silicon Valley Rising"* (1980's)	- (BENSON; ZIEDONIS, 2010) ➔ 1980-1987 - (BIELESCH et al., 2012) ➔ 1st half of 1980's - (CB INSIGHTS, 2017) ➔ 1978-1994 - (BARRETTO-KO, 2011) ➔ 1978-1987	- Low returns of the capital market in the 1970's – Investors seeking alternative assets. - Pension funds more flexible regulation (Allow to invest in alternative assets, 1979). - Me too: The beginning of Silicon Valley as we know (Apple, Oracle, Microsoft, etc.).
3rd Wave *"Venture Capital Euphoria"* (1995-2002)	- (BENSON; ZIEDONIS, 2010) ➔ Mid-to-late 1990's - (BIELESCH et al., 2012) ➔ 1990-2000 - (CB INSIGHTS, 2017) ➔ 1995-2001 - (BARRETTO-KO, 2011) ➔ Mid-to-late 1990's - (GOMPERS, 2002) ➔ late 1990's - (DUSHNITSKY, 2011) ➔ 1991-2000 - (HILL; BIRKINSHAW, 2014) ➔ 1990's - (MA, 2016) ➔ 1995-2005	- The explosion of independent VCs. (five times growing between 1995 and 2000). - Strongly growth of "dotcom" companies in the capital markets (CAGR 21% between 1993 e 1999). - Dotcom bubble starts like Google, Amazon, Yahoo, Facebook, Tencent, etc. - A strong presence of pharmaceuticals companies.
4th Wave *"Open Innovation Learning"* (2003-2009)	- (BIELESCH et al., 2012) ➔ 2005-Present - (CB INSIGHTS, 2017) ➔ 2002-Present - (DUSHNITSKY, 2011) ➔ 2001-2009 - (BARRETTO-KO, 2011) ➔ Mid 2000's-Present - (LIVIERATOS; LEPENIOTIS, 2017) ➔ 2005-Present - (FAN, 2018) ➔ 2007-Present - Authors ➔ 2003-2009	- Insufficiency of in-house innovation. - Open innovation becoming an innovation strategy driver. - Globalization challenge and growing CVC internationalization; - "Industry overarching" technologies; - Learning period: How to use CVC as an innovation tool.

4.2.1. CVC as a Segment of the Venture Capital Industry and Financial Markets

The first CVC wave, the “Conglomerate Diversification” Wave, started in the mid-1960s and was primarily motivated by the growth of the capital market in the period and the financial success of the first VC funds (BIELESCH et al., 2012). Taking advantage of this environment, large industrial conglomerates sought to replicate VC fund models using their technical and market knowledge for financial gain. Another important motivation for the growth of the number of CVC units at this time was conglomerate diversification. Corporations started to use CVCs to expand the scope of their activities or to minimize the effects of the antitrust laws that emerged during the period. Companies like GE, Dupont, 3M, Ford, Dow, Exxon Mobil, Monsanto, Johnson & Johnson, etc are examples of companies that set up CVC initiatives in this first wave. (BIELESCH et al., 2012; CB INSIGHTS, 2017).

The second wave, which we called the “Silicon Valley Rising”, was also induced by capital market movements, but for different reasons. In the late 1970s, capital market returns declined substantially and the search for higher-yielding alternative assets grew in the same proportion (BIELESCH et al., 2012). The relaxation of US pension funds' regulation of alternative asset investments in 1979 resulted in a large growth in VC investments, which once again was reflected in a parallel increase in CVC activities (BARRETTO-KO, 2011). The more financial and less strategic motivation of this wave can be evidenced by the high number of funds with outsourced managers, multi-corporate funds and corporate investments in independent VC funds - 20% of the total investments of the CVCs of the period (CB INSIGHTS, 2017). From the corporate point of view, the great fact of the period was the arrival of personal computers and consumer electronics in the late 1970s and early 1980s. These technologies marked the beginning of Silicon Valley as we know it today and the origin of companies like Apple, Microsoft, Oracle etc (CB INSIGHTS, 2017). The investment peak of this wave occurred in 1986 when the total volume reached US $ 2 billion, 12% of all investment in VC that year (BARRETTO-KO, 2011).

The third wave, which began in the mid-1990s was, once again, driven by strong growth in the VC market in the period known as the dotcom boom, which spawned companies like Amazon, eBay, Google, Yahoo, Facebook, Tencent etc. The late 1990s and early 2000s were an unprecedented period of growth for the VC industry. The capital market "euphoria" with dotcom companies resulted in an average annual growth rate of 21% of the S&P 500 index between 1993 and 1999 (BIELESCH et al., 2012). At the peak of this wave in 2000, CVC investments reached $ 17 billion or 25% of total VC investments in the period, more than seven times the previous peak in 1986. During the third wave a considerable discussion about the governance models and the relationship between the corporations and their CVC units started. To avoid undue interferences from corporations in the CVC units, most of the initiatives of the period sought to replicate exactly the structures of independent VC funds, with phased investments, rounds with many co-investors and remuneration model with stakes for managers (BARRETTO-KO, 2011).

This strategy did not work as expected, and the cycles of CVC units were even shorter than the wave itself, which ended quite abruptly along with the dotcom bubble after 2001. The average time of existence of CVCs during this wave was only 2.2 years (HILL; BIRKINSHAW, 2014). However, the third wave left a significant cultural legacy. Founded and invested startups in the period became some of the most valuable companies in the world 20 years later and their "way of being" influenced business management radically, making corporations more aware of the need to continually innovate, more openly, cooperative and agile (RIES, 2017).

4.2.2. CVC as an Open Innovation Tool

Over the course of the third wave, some companies began to realize that there were potential underlying strategic gains in CVC activity. In addition to the potential financial benefits, they could create more outside-in innovations closely aligned with the concepts of open innovation (CHESBROUGH, 2002; DUSHNITSKY; LENOX, 2006; GOMPERS, 2002; WADHWA; PHELPS; KOTHA, 2016). Notably, outside the IT segment, pharmaceutical companies such as Takeda, Sanofi, Lilly, Novartis etc. have begun to stand out and make significant investments using CVC units (DUSHNITSKY, 2011; MA, 2016). This change in the direction of CVC use represented the beginning of the next wave almost immediately, and conceptually can be seen in Figure 14.

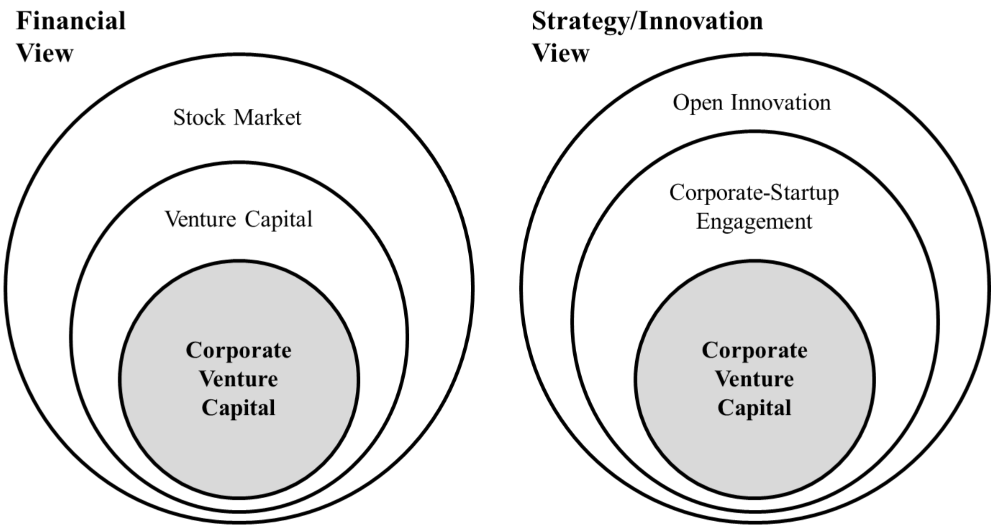

Figure 14: The Two Faces of CVC

The fourth wave, that began in year 2003, can be represented as the first phase from a predominantly financial view of CVC activity to another view, more focused on strategy and open innovation issues. The context of the "open innovation" wave happened after the startup boom of the late 1990s and early 2000s when many incumbent companies realized that the risks of continuing their established business were more real than they thought. The usual rules of business, such as market dominance, proper processes, and good management were no longer sufficient for survival in an increasingly dynamic environment (CHESBROUGH, 2003b) Thus, researchers and the companies themselves addressed the challenge of understanding how corporations should operate in a more open, globalized (CHESBROUGH, 2003a), and subject to disruption environment (CHRISTENSEN; RAYNOR, 2003). Collaboration with startups then emerged as a promising bet to deal with the challenge. These efforts allowed the incumbents: (1) to respond more quickly to market changes; (2) to set up more effective competitive intelligence frameworks; (3) to write off quickly failed projects (compared to R&D investments); (4) to leverage resources from other investors (reducing the risks and costs of innovations); (5) to leverage the corporation's complementary assets through partnerships; (6) to generate extra revenues through return on investments and/or new business partnerships; (7) to deal with the challenges of globalization (CHESBROUGH; APPLEYARD, 2007; FAN, 2018; HILL; BIRKINSHAW, 2008; WEIBLEN; CHESBROUGH, 2015).

On the startup side, besides being a relevant additional source of financial capital, corporations could provide a wide range of complementary assets such as visibility, credibility, access, market knowledge, technologies, physical infrastructure, etc. (BANNERJEE; BIELLI; HALEY, 2016; MOCKER; BIELLI; HALEY, 2015). These relationships, which are also subject to the other kinds of strategic alliances, are exacerbated in intensity precisely by the significant difference between the parties (startups and large corporations). Questions such as misalignment of strategic objectives, lack of commitment from one party, negotiation and trust, intellectual property, etc. re starting to appear more frequently now that the focus has changed to innovation and strategic instead of financial issues. (BANNERJEE; BIELLI; HALEY, 2016; MOCKER; BIELLI; HALEY, 2015).

Also, during the fourth wave, globalization and internationalization of the CVCs began to intensify. Even though most initiatives were still US-based, CVC units were beginning to expand rapidly to other continents - notably Europe and Asia - increasing their relevance not only absolutely, but also relatively (BIELESCH et al., 2012).

By the end, the exact starting-year of the fourth wave changes for many authors: 2001 for (BARRETTO-KO, 2011; DUSHNITSKY, 2011), 2002 for (CB INSIGHTS, 2017), 2005 for (BIELESCH et al., 2012; LIVIERATOS; LEPENIOTIS, 2017), and 2007 for (FAN, 2018). However, they all agree with the innovation-driven approach of most of CVC units founded in this period. These distinctive characteristics of this wave are one of the main reason to investigate the CVC phenomena at this time.

4.3. Methods

Methodologically the investigation involves two moments. The first one covers an exploratory analysis of the general characteristics, differences, and similarities of the CVC waves beginning from the last financial one (the third wave). For this stage, we have used frequency analyses and comparisons with the literature to present the topic.

Then, in a second moment, we have proceeded with a cluster analysis (K-means) using as a starting point a theoretical centroid matrix with wave segmentation characteristics to find the first centroids. Then we follow the standard procedures of this method recommended by (HAIR JR et al., 2010) to identify possible underlying patterns of CVC units based on each of these periods. For data analysis, we also used ANOVAs, posthoc tests, and crosstabs.

4.3.1. The Exploratory Analysis of CVC Waves

For the first part (exploratory), our first step was to conduct a literature review on the subject. For this purpose, we use the following combination of keywords "corporate ventur*" AND (strateg* OR innovation OR entrepreneur* OR wave OR cycle) at Scopus database in order to map articles dealing with CVCs as innovation tools. We have identified 148 articles. We have analyzed first their titles and abstracts and then the full content of selected ones. We also checked the references of the most relevant articles to generate valuable insights and additional readings, mainly books and reports.

After the literature review, we have collected data about the investment deals made by CVCs from 1995 (the beginning of the third wave). To this purpose, we have chosen Crunchbase as our preferred database, a renowned source of information on VC and CVC deals in both the market and academia (DAHLANDER; PIEZUNKA, 2014; GADDY et al., 2017; HERMANN et al., 2015; RÖHM; MERZ; KUCKERTZ, 2019). We have applied the filters "Investor Type: Corporate Venture Capital" and "Announced Date: after 12/31/1994" for the selection of investments at "Funding Rounds" tab. According to Crunchbase, "CVC is an arm of a corporation that invests in innovative start-up companies" (RÖHM; MERZ; KUCKERTZ, 2019). Using these filters, we have reached 13,012 investments made by CVCs in the indicated period.

We have indexed the found deals by wave based on their announcement date, and we have extracted the number of investments per year, geographic location of these investments, average number of co-investors, stage of such investments, etc. For this first phase, this exploratory frequency analysis was useful for indicating that there were indeed significant differences between the characteristics of each wave and that it was essential to go a step further. The use of frequency analysis in investigative exploratory steps can be an essential tool for adjusting research priorities, supporting the identification of theoretical gaps and setting new research agendas (RANDHAWA; WILDEN; HOHBERGER, 2016).

4.3.2. Setting the Variables for CVC Cluster Analysis

In the second stage, we have performed the necessary procedures for a cluster analysis (K-means) guided by the method recommended by (CARNEIRO; DA SILVA; DA ROCHA, 2011; HAIR JR et al., 2010), and based on a theoretical centroid matrix constructed from the literature and empirical evidence of the first exploratory stage. The objective of this stage is to identify differences and similarities between CVC units over the waves and to compare their expected characteristics (given by their date of foundation) with those observed by empirical behavior (clustering membership based on their actual characteristics).

For the construction of the database, we have used the Crunchbase as a reference adding data from other complementary sources such as Mattermark, Pitchbook and Capital IQ (S&P Global Market Intelligence) databases. We have identified 685 CVC units initially that were reduced to 105 CVC units after applying the following criteria: (a) has a presence in Crunchbase and at least one of the other two databases used; (b) is in fact a CVC according to the criteria set forth in this article (there were among the original CVCs some multi-corporation funds and third-party corporate managers that have classified as CVCs); and (c) has made at least 25 investments (to ensure the representativeness of this unit considering the chosen variables). We also consider the CVC units that already closed because these investors, even if no longer operational, may have been relevant in their respective periods of operation (third or fourth wave).

As the first step, we have selected 19 variables and segmented them into eight representative categories of the characteristics of the CVC units (unit of analysis) and their investment portfolio. We choose the clustering variables of this research, among many available because of their ability to reflect CVC units' investment policy choices, as well as their key characteristics. It is noteworthy that in the cluster analysis method, it is expected that the researchers choosing the variables as part of their research design preferences to achieve the related objectives.

(PARHANKANGAS; ARENIUS, 2003). The Table 13 presents the categories and key variables selected (all numerical) and how they were operationalized.

Table 13: Original Variables

# Cat	Category	# Var	Variable	Description
1	**CVC Experience**	1	**No_Deals**	Number of Deals
		2	**Deal_Year**	Number of Deals per Year
		3	**CVC_XP**	Years of Experience with CVC
2	**CVC Leadership**	4	**No_Leader**	Number of Deals as Investment Leader
		5	**Lead_Year**	Number of Deals as Investment Leader per Year
		6	**Perc_Leader**	Percentage of Deals as Leader
3	**CVC Partnerships**	7	**Perc_CoInv**	Percentage of Deals with Co-Investors
		8	**Av_Investors**	Average Number of Investors (per Deal)
4	**Location**	9	**Perc_HQ**	Percentage of Deals in HQ Country
		10	**Perc_Reg**	Percentage of Deals in HQ Continent
5	**Stage**	11	**Perc_Seed**	Percentage of Deals in Seed Stage
		12	**Perc_EarlyVC**	Percentage of Deals in Early VC Stage
		13	**Perc_LateVC**	Percentage of Deals in Late VC Stage
6	**Deal Size**	14	**Ln_Av_Round**	Ln of Average Round Size
		15	**Ln_Av_Ticket**	Ln of Average Ticket (Round Value/Number of Investors)
7	**Business Models**	16	**Perc_B2C**	Percentage of Deals with B2C Business Model
		17	**Perc_B2B**	Percentage of Deals with B2B Business Model
8	**Sectors**	18	**Av_Top3Sect**	Average of Deals in Top 3 Sectors*
		19	**Mod_Sect**	Distance between Top 3 Sectors and Main Sector of Corporation*

Most of these categories and variables are self-explanatory, but one category deserves some emphasis, the Category 8 (Sectors). Firstly, it is critical to note that we have used as sector index the Mattermark classification containing 11 categories (Energy, Finance, Food & Agriculture, Hardware, Health/Pharmaceutical, Internet, Media and Entertainment, Software, Transportation, Other Services, Conglomerates). We took this option for the sake of simplification of analysis. The traditional economic sectors classifications often have difficulty accurately portraying startups' business segments, which often operate in "gray zones" or even disrupt the borders of the traditional sectors. That said, the variable 18 (Av_Top3Sect) is represented by the average of the percentages of the three main sectors of that CVC unit. Shell Ventures, for example, has 45%, 45% and 40% in the Cleantech, Energy and Wind Power sectors, making an average of 43.3% of its investments in its three main sectors. Otherwise, Lilly Ventures fund has in its three main sectors (Healthcare, Pharmaceutical, and Biotechnology) respectively 93%, 89% and 86%, an average of 89.3%, considerably more concentrated in its core-business than the Shell Ventures.

Variable 19 (Mod_Set), on the other hand, is a modifier aiming to relate the corporate sector with that of the actual investments made. For each of the three sectors directly related to the parent corporation, the CVC unit receives one point. Conglomerates receive just 0.5 for each sector considering a certain multi-specialty. For example, consider CVC units Takeda Ventures, Alexa Fund (Amazon), BMW iVentures, and Mitsui Global Investment. The Takeda Ventures fund received the 3 points because its three main investment sectors according to Mattermark (Pharmaceutical, HealthCare, and Biotechnology) were directly related to its parent corporation's macro category (Takeda / Health/Pharmaceutical). In the case of the Alexa Fund, the score was 0 (zero) because none of the fund's three main sectors (Hardware, Consumer Electronics, and Internet of Things) were directly related to the parent corporation's leading sector (Amazon / Software / Internet). In this case, we can suppose that the objective of this fund is to diversify Amazon's business sectors out of its core e-commerce business. In the case of BMW iVentures, the score was 1 since one of the sectors is directly linked (Automotive) to the core sector of BMW (Transportation), but the others are not (Consumer Services and Mobile). Finally, Mitsui Global Investment is linked to a conglomerate with various sectors of activity receiving the overall score of 1.5, or 0.5 for each sector.

Having defined the variables and the final database, we have started the data processing phase. In this context, no treatments for missing values were necessary. For outliers, the Mahalanobis distance was used, which pointed out four cases as outliers (Prob_MAH1 <0.001). We have excluded these four cases (Intel Capital, Brand Capital, M12, and GE Capital) from the sample for the remaining process steps.

4.3.3. Factor Analysis Outputs

After variable definitions and data treatment, we have run the exploratory factor analysis technique to simplify the model and eliminate potential multicollinearity problems. In the first attempt, we have used the 19 variables, Varimax rotation, eigenvalue criterion equal to 1, and suppressing coefficients less than 0.7 in the formation of the factors. We have found unsatisfactory results (both explanatory or statistical), and some variables had MSA significantly lower than 0.5, which is not recommended according to (HAIR JR et al., 2010). By removing the lower MSA variable (Perc_EarlyVC) and setting the number of factors to eight, we have obtained an adequate result from both the statistical and explanatory/theoretical points of view. The total explained variance has reached 90.4%. The result of Table 14 points out the 8 factors and their respective compositions.

Table 14: Principal Components for CVC Units Characteristics

Factors / Variables	Component							
	1	2	3	4	5	6	7	8
	F1_ Intensity	*F2_ Stage*	*F3_ Experience*	*F4_ Location*	*F5_ Co_Investors*	*F6_ Sector*	*F7_ B_Model*	*F8_ Leadership*
No_Deals	.923							
Deal_Year	.882							
CVC_XP			.941					
No_Leader	.897							
Lead_Year	.891							
Perc_Leader								.922
Perc_CoInv					.903			
Av_Investors					.886			
Perc_HQ				.961				
Perc_Reg				.967				
Perc_Seed		-.775						
Perc_LateVC		.814						
Ln_Av_Round		.920						
Ln_Av_Ticket		.929						
Perc_B2C							-.746	
Perc_B2B							.872	
Av_Top3Sect						.847		
Mod_Sect						.796		

The first factor (F1_Intensity) aggregated four variables that represent the total number of investments, the number of investments as a leader and their relative versions (total and leadership per year). This factor represents the intensity of CVC unit operations across the period. The second factor (F2_Stage) also joins four original variables: the percentage of investments in the seed phase, the percentage in the late VC phase, the average rounds size, and the average investment ticket. The four variables represent, in different ways, the startup stage and average size at the time of investment by the CVC units. Thus, it is critical to note that the correlation with the Perc_Seed variable is negative, which makes sense considering that the factor is higher for higher investment values.

The third factor (F3_Experience) have considered a unique variable: CVC experience time, that led to the denomination of this factor. The fourth factor (F4_Location) joins the variables that indicate the percentage of investments in the country and the host region (continent) of the CVC unit. The correlation, in this case, was already expected and was quite marked.

Factor five (F5_Co_Investors) brings together the two variables that mention co-investors. The first is the percentage of investments that the CVC unit made in joint rounds with other investors. The second is the average number of co-investors per round. In different ways, these variables perform the preference for solo investments, where CVCs units choose to take more risks to have more strategic control of their investments. The sixth factor (F6_Sector) has joined the variables that refer to the characteristics of the sector. The operationalization of these variables has been explained previously.

The seventh factor (F7_B_Model) shows the preference for specific business models (B2B, business to other business or B2C, business to consumer). Although there are other categories of business models (such as B2G, business for governments), there is a predominance of these first two, and they have an expected inverse correlation. Finally, factor eight (F8_Leadership) is represented by the variable that determines the percentage of operations that the CVC units have acted as a leader in the investment round. It reflects how well the CVC unit is recognized as a leader within a new investment selection process.

Finally, after establishing the variables, the database, proceeding with the treatment of missing values, removing the outliers, and rotating the exploratory factor analysis, we proceed to the analysis part of the article results.

4.4. Discovering the Fifth Wave of Corporate Venture Capital

We have discovered one of the most significant findings of this study early on the exploratory analysis of the characteristics of the CVC waves and their transitions from a financial-based to another innovation-based view: the existence of a fifth CVC wave. Figure 15, which shows the number of CVC operations per year, points out that after the third wave, we have two valleys (2002 and 2009) and two peaks (2007 and 2017). This finding prompted us to investigate separately the periods between 1995-2002, 2003-2009 and 2010-Present as the third, the fourth, and the fifth wave of CVC, respectively. The difference in magnitude of the fifth (and most recent) wave, relative to the others, led us to consider that other underlying factors could differentiate them, as well as the CVC units based on these periods.

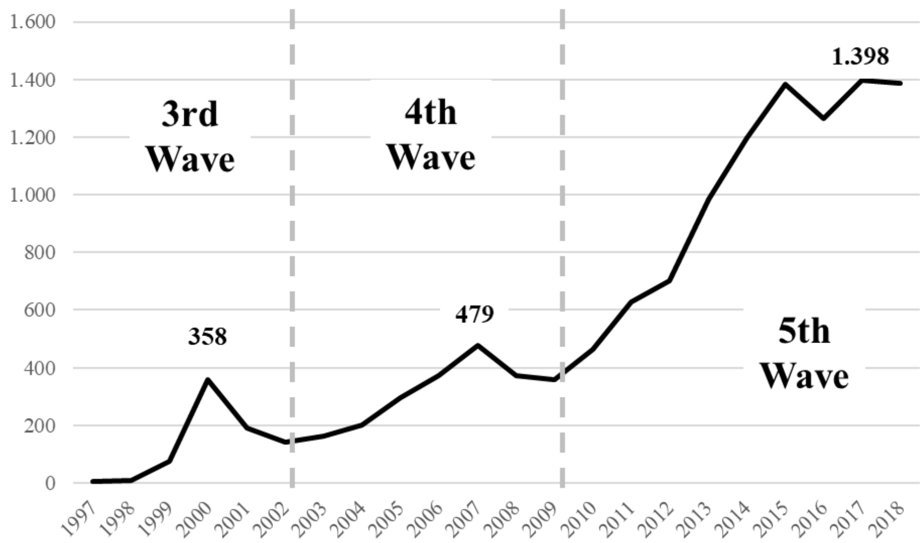

Figure 15: Number of CVC Deals per Year
Source: Crunchbase (2019)

That way, we realize that the size of each of the last three CVC waves is not the only difference between them. The characteristics of the investments made during each wave also have significant differences. As for the investment stage, for instance, the fifth wave has a significantly higher percentage of investments in the seed phase and a lower number of investments in the late-stage VC than previous waves (Figure 16). A very likely reason for these differences is the primary focus on innovation and the minor focus on financial returns (DUSHNITSKY, 2012). CVC units are now willing to take more risks by investing in early stages, looking for innovations that would be more promising to open new markets, protect against disruption or even absorb new technologies for the corporation (BANNERJEE; BIELLI; HALEY, 2016; MOCKER; BIELLI; HALEY, 2015). Another likely reason for this change is the learning acquired from the fourth wave. The previous knowledge about the use of CVC as an innovation tool made the CVC units feel more comfortable to invest and cooperate with less structured startups/businesses.

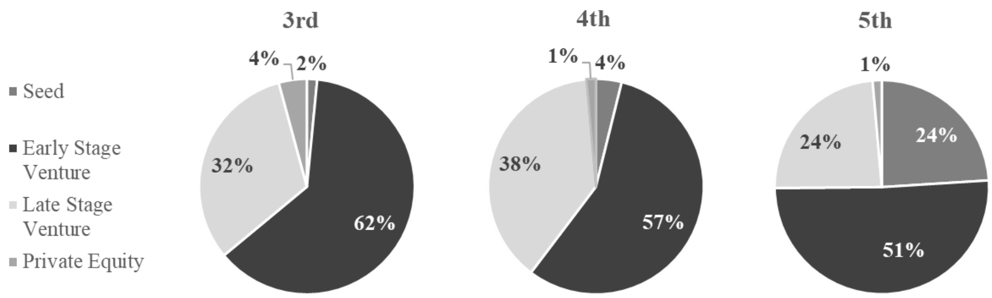

Figure 16: Investment Stages per CVC Wave
Source: Crunchbase (2019)

For the number of co-investors, there are also interesting insights into the differences between the waves. Figure 17 shows that the number of solo investments from the fourth wave (with no other co-investors) rose substantially, reflecting the importance of controlling the strategic investments from the corporations behind CVC units. However, from the fourth to the fifth wave there is a growth at the other end of the graph. The relative number of investments with more than five co-investors rose again, pointing to a growth of the syndicate model in fifth wave CVC investments.

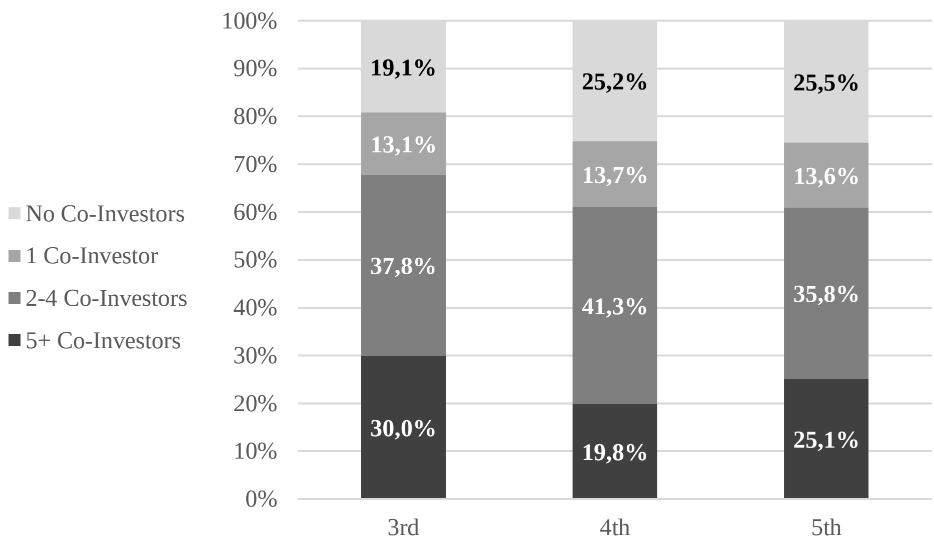

Figure 17: Co-Investors Profile per CVC Wave
Source: Crunchbase (2019)

Based on a view of geographic regions, the trend of the fifth wave is to accentuate the path of globalization and internationalization of CVCs that began in the fourth wave. Figure 18 shows a marked increase in the share of CVC activity in Asia and Europe and a reduction in the relative importance of North America, represented mostly by US operations. Although still incipient, South America is beginning to emerge with rapid growth in the fifth wave.

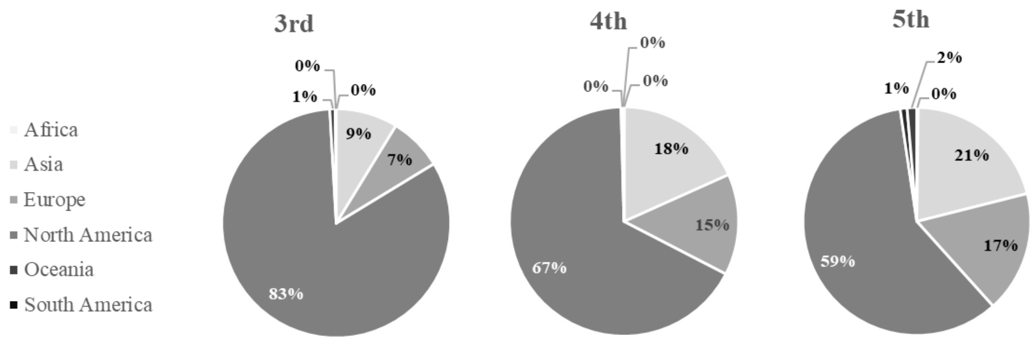

Figure 18: Geographical Distribution per CVC Wave
Source: Crunchbase (2019)

This initial effort to identify the characteristics of the last three CVC waves, as well as the perception of the remarkable differences between them at empirical field, have pushed us to check these movements also at academic fields.

We realize again that the rise of fifth wave when we have checked the absolute and relative number of published articles. They rose significantly from the third to fourth wave and again from the fourth to the fifth one as observed in Table 15. The link of CVC and entrepreneurship, innovation and strategy area have risen dramatically from the third wave (40% of the published articles) to 82% and 72%

Table 15: CVC, Strategy and Innovation Publications – Base Scopus

<table>
<tr><th colspan="2"></th><th>3rd Wave
1995-2002</th><th>4th Wave
2003-2009</th><th>5th Wave
2010-Present</th></tr>
<tr><td colspan="2">Number of Years</td><td>7</td><td>6</td><td>9</td></tr>
<tr><td rowspan="2">"Corporate Venture Capital"</td><td>Articles</td><td>5</td><td>56</td><td>132</td></tr>
<tr><td>Articles/Year</td><td>0,71</td><td>9,33</td><td>14,67</td></tr>
<tr><td rowspan="2">"Corporate Venture Capital" AND (Strateg* OR Innovation OR Entrepreneur*)</td><td>Articles</td><td>2</td><td>46</td><td>95</td></tr>
<tr><td>Articles/Year</td><td>0,29</td><td>7,67</td><td>10,56</td></tr>
<tr><td colspan="2">% related with Strategy, Innovation and/or Corporate Entrepreneurship</td><td>40,0%</td><td>82,1%</td><td>72,0%</td></tr>
</table>

Source: Scopus (2019)

The intensive search for knowledge about how CVCs should work as an innovation tool starting at the fourth wave paved the way for an unprecedented expansion in the number of operations performed by CVCs during the fifth wave.

In the fifth wave of CVC (2010-Present), which we call the “Strategic Core Innovation Wave”, CVC units become a central part of companies’ innovation strategy and are much more closely linked to the strategic core of the corporation as a whole. As noted earlier, this substantially changes the characteristics of this wave’s CVC units, which handle larger volumes of resources and operations, adopt more risk-taker behavior by investing in earlier stages, and begin to spread to other sectors and regions of the world.

The discovery of the fifth wave in the exploratory phase enabled a different and more precious analysis of CVC units than anticipated initially. The new analytical step described in the methodology allowed the more detailed analysis of the typical characteristics of the CVC units in each period, as well as the CVC units with behaviors ahead (or belated) of their own time.

4.5. Building CVC Wave Clusters

After characterizing the last three waves of CVC in an exploratory way, the next step, its time to establish the initial Theoretical Centroid Matrix corresponding to the three waves studied (Table 16). We have used the findings of the exploratory analysis phase, as well the available literature, to determine the quartiles (Q1, Q2 and Q3) limits. For F1_Intensity the empirical observations of Figure 15 and the theoretical conjectures lead to the conclusion that the intensity of investments increases in cycles from third wave (Q1) to fifth wave (Q3) (CBINSIGHTS, 2018).

Table 16: Theoretical Centroid Matrix

	F1_ Intensity	**F2_ Stage**	**F3_ Experience**	**F4_ Location**	**F5_ Co_Investors**	**F6_ Sector**	**F7_ B_Model**	**F8_ Leadership**
third Wave	Q1	Q2	Q3	Q1	Q2	Q3	Q3	Q1
fourth Wave	Q2	Q3	Q2	Q2	Q1	Q1	Q1	Q2
fifth Wave	Q3	Q1	Q1	Q3	Q3	Q2	Q2	Q3

For F2_Stage, the literature and empirical observations note that the current strategic objectives (fifth wave) of CVC units led them to invest in riskier early-stage startups (Q1). Otherwise, the fourth wave was focused on more mature startups. This decision helps the CVCs from the fourth wave to mitigate some risks of this activity and help them to learn how to invest, considering the strategic innovation focus. For F3_Experience, the division of Q1, Q2, and Q3 quartiles is practically intuitive: the older a CVC unit is, the more experience it will have with CVC activities.

Regarding location (F4_Location), the ecosystem studies, the importance of co-location (BUDDEN; MURRAY, 2017) and the aggregated empirical observations help to support the theoretical assumptions. These points suggest a relationship between strategic and innovation-driven focus and geographically close investments and network. Thus, we have for location a rising pattern of the third to fifth wave (Q1, Q2, and Q3).

For the presence of co-investors (F5_Co_Investors), the fourth wave stands out with the lowest number (Q1). During the apprenticeship phase, it is reasonable to expect higher investor control (CVC units) to absorb more knowledge. In the fifth wave, the CVC's strategic investment leadership attracts other types of investors into the rounds, increasing both the number of non-CVC investors and the frequency with which they cooperate with the CVC units (Q3).

In F6_Sector, the fifth wave (Q2) brings more sectoral proximity than the fourth wave (Q1). However, the wave where the corporations are most close to their investees is in the third wave (Q3). This characteristic is due to the significant presence of CVC units in the pharmaceutical and energy sectors founded in this period. These industries, despite the waves to which they belong, usually invest in startups more closely related to the activities of their parent corporations.

Regarding Business Models (F7_B_Model), the fourth wave has the highest B2C average. This percentage is mostly consequence of development of co-creation and co-development concepts inside the open innovation practices (Q1) (FÜLLER et al., 2009).

During this period, end consumers were often considered to be an integral part of the process of product creation, development, and management, mainly by internet companies focused on eliminating intermediaries through platform and marketplace models. (PARKER; VAN ALSTYNE; CHOUDARY, 2016). Again, the high number of pharmaceutical and energy CVC units, as well as the growth of digital B2B business, leads the third wave to have the most significant number of B2B business investments.

About the last factor, F8_Leadership, it was expected by the theory that the more strategic the CVC unit is for the corporation, the more it will tend to act as the leader in the investment rounds. Therefore, the expected centroids for the third, fourth, and fifth waves are, respectively, Q1, Q2, and Q3.

Thus, after determining the initial theoretical centroids (seeds), we have used the SPSS software to determine the final centroids, cluster membership, and case distances to the respective centers. For this, we have selected the non-hierarchical method (k-means), which reached convergence after five interactions. The results of the exploratory phases and the formation of clusters generated the results has shown us the particularities of the third, fourth, and fifth waves.

Finllay, we have applied two statistical tests to verify the consistency of the results. The first one, the Wilks' Lambda test, indicates that there are at least two different clusters in the solution ($p = 0.000$). The second one, the non-parametric Wilcoxon test, shows that the initial and final matrix are equal for all eight factors, even considering $\alpha = 0, 1$ ($p > 0.1$ for all factors). These tests validate the solution for the difference between clusters, and for the similarity between the initial theoretical matrix and the final solution matrix.

4.6. Strategic Groups for CVC Units

Separating the period from 2003 into two distinct waves is essential to understand that there was a learning period on the fourth wave that enabled new strategies and patterns on the fifth wave that begins in 2010 and lasts until the present moment. However, it is also strategical to understand the characteristics and new patterns of the actors that drove this change: the CVC units. Some characteristics of CVC activity are given by elements outside of the CVC unit, such as the stage of the invested companies, the average value of investments and business models, etc. Figure 19 illustrates the difference and relationships between CVC units and CVC activity (DUSHNITSKY, 2012).

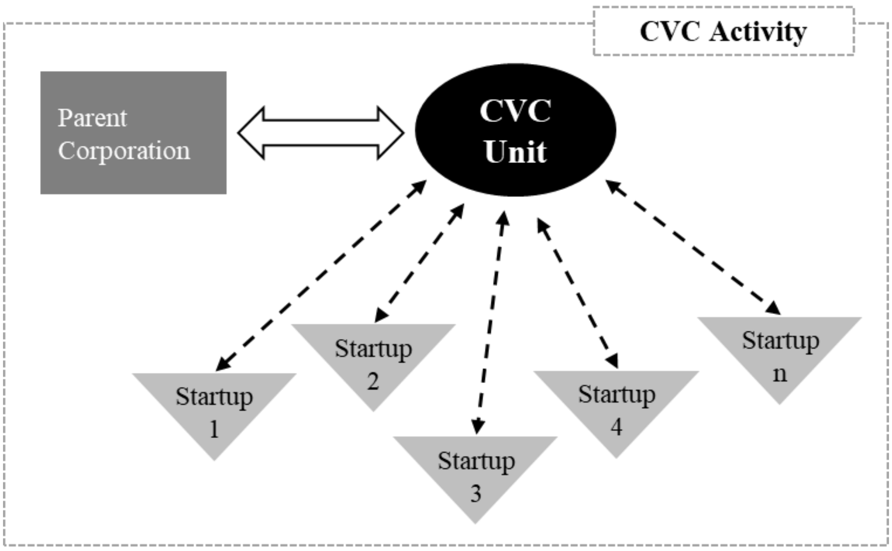

Figure 19: CVC Units and CVC Activity
Source: Adapted from (DUSHNITSKY, 2012)

Thus, based on the eight strategic factors identified through exploratory factor analysis, we sought to classify the 101 selected CVC units based on their distinctive empirical characteristics. At this point, it is essential to highlight the differences between being considered belonging to the third, fourth or fifth waves based on their respective years of foundation and considered belonging to these waves due to their empirical characteristics obtained by the clustering process.

Table 17: Waves – Year Foundation versus Cluster Characteristics

		Wave by Clustering Characteristics			TOTAL
		Third	Fourth	Fifth	
Wave by Year Foundation	Third	**23**	14	2	**39**
	Fourth	9	**9**	9	**27**
	Fifth	5	3	**27**	**35**
TOTAL		**37**	**26**	**38**	**101**

Crossing the two classifications, it is clear that 58.4% of the units have empirical characteristics similar to those expected by their foundation years, i.e., they were founded on the third wave and had the characteristics of the third wave and the same for the fourth and fifth waves. We can see these CVC units in the diagonal of Table 17. It is also possible to observe that 24.8% of the CVC units had characteristics "ahead of their time", that is, they belong to the third wave but have consolidated typical characteristics of the fourth or fifth (or belong to the fourth and have typical characteristics of the fifth). Similarly, 16.8% of units go in the opposite direction and have previous wave consolidated characteristics than they belong considering their founding years.

We also figured out that the third and fifth waves have very distinctive characteristics, with most of the units established in the period with typical characteristics of their own waves (59.0% and 77.1% respectively). Unlike the fourth wave, which was considered a transitional wave by the previous theoretical and exploratory analysis, this discovery points to a less defined pattern with exactly 33.3% of each wave characteristics (including the own fourth wave).

Regarding the characteristics of clusters, Table 18 shows that there is no statistically significant difference (considering $\alpha = 0.05$) between wave averages just in two factors: “F1_Intensity” and “F8_Leadership”. In practice, this means that the amount and frequency of investments, as well as the leading role of CVC units vis-à-vis other investors in investment rounds, did not vary significantly between waves.

Table 18: Principal Components ANOVA Table

	Cluster		Error			
	Mean Square	df	Mean Square	df	F	Sig.
F1_Intensity	2.529	2	.969	98	2.610	.079
F2_Stage	9.193	2	.833	98	11.039	.000
F3_Experience	17.495	2	.663	98	26.374	.000
F4_Location	3.405	2	.951	98	3.581	.032
F5_Co_Investors	3.584	2	.947	98	3.784	.026
F6_Sector	8.797	2	.841	98	10.462	.000
F7_B_Model	22.046	2	.570	98	38.645	.000
F8_Leadership	1.109	2	.998	98	1.111	.333

From Table 18 it is also possible to observe that the factors that most explain the differences between the waves are the previous experience (which has a natural correlation with time), the business model of the investees and the stage the startup was at investment. Figure 20 points out these differences between the centroid coordinates of the cluster by factor.

The "F2_Stage" factor shows that, comparatively, fourth wave CVC units were the ones that invested the most in mature startups, while in the fifth wave the focus of early-stage investments was the predominant stage (77.0% of seed or early-stage investments). The fifth wave CVC units made 27.0% of their investments in the seed phase, more than three times the percentage of investments made by fourth wave CVCs (8.4%). At the same time, the average investment per startup made by the fourth wave CVCs was $ 12.54 million, while those for the fifth wave was $ 4.51 million (more compatible with early-stage investments).

These findings make sense since the fourth wave was considered a transition phase from the predominantly financial outlook to a new strategy/innovation mindset. It is reasonable to imagine risk-averse behavior from corporations in this learning phase (the risks of mature startups tend to be smaller). In turn, during the fifth wave, the investments had been reported more associated with strategic, market and technology fields dominated by parent corporations. In these areas, corporations had more accumulated knowledge, and investments in seed and early-stage business made more sense.

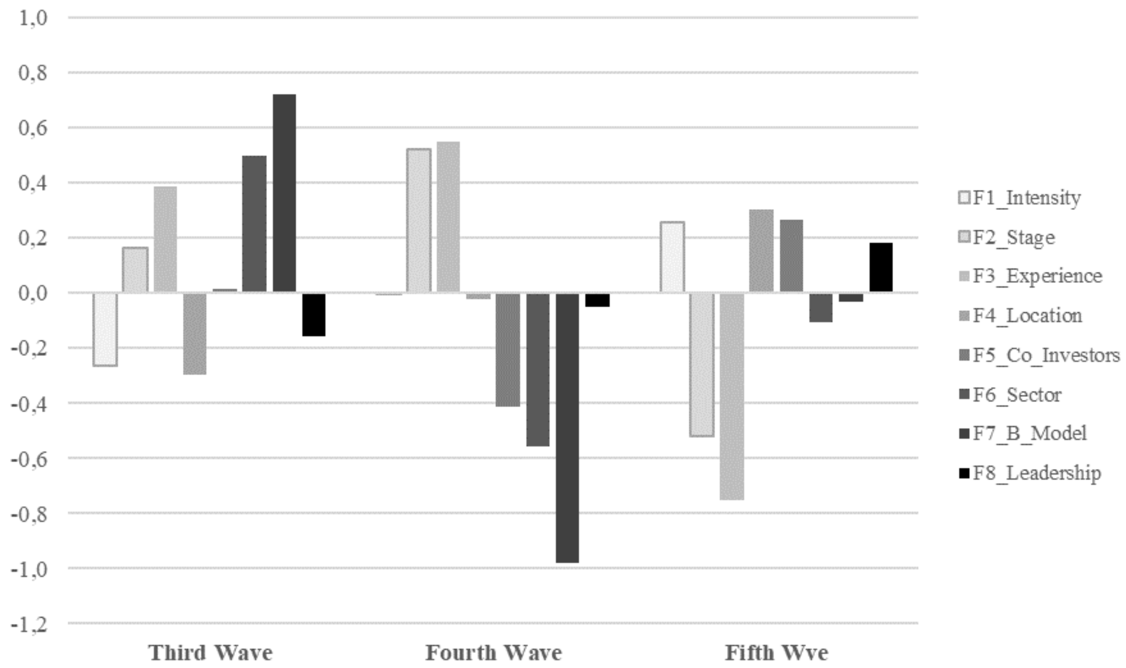

Figure 20: Cluster Centers per Wave

The "F3_Experience" factor has shown the predicted theoretical correlation between the founded date of CVC units and the CVC waves. We have confirmed that the third wave CVC units being the most experienced respectively followed by the fourth and fifth. The average years of experience of the third, fourth, and fifth wave funds are 15.5, 14.5, and 7.3 years, respectively.

The factor "F4_Location" pointed out a significant difference between the fifth wave and the other waves concerning the proximity of the parent corporation headquarter (HQ). The investments made by CVCs in this wave are significantly closer to the corporation than in the other waves. This finding corroborates the wish of corporations to make their investments closer to where their strategic decisions are made. Another factor that supports this distinctive feature of the fifth wave is the emergence of the concept of innovation ecosystems in recent years. This approach shows that being physically close is favorable for fostering corporate innovation (BUDDEN; MURRAY, 2017). That way, the average investment made by CVC units in the parent corporation's HQ country is 75.1% for the fifth wave and 51.3% and 63.0% for the third and fourth wave, respectively. A different view is put by Belderbos, Jacob & Lokshin (2018) who point out that geographical variations can increase the diversity and consequently the performance of CVC units.

Analyzing the factor "F5_Co_Investors" once again, we notice the transitional character and desire for learning that guided the decisions by the fourth wave CVCs. The number of co-investors and partners in the third and fifth waves is higher than in the fourth wave but for different reasons. In the third, the motivation was following the growth of independent VCs activity. In fifth wave CVC units, the strategic/innovation-related issues were the drivers to co-invest more. The average number of investors and the percentage of rounds with co-investors in the third and fifth wave were 4.69 and 4.98 / 86% and 83% respectively. The mean and the percentage in the fourth wave, in turn, were 3.83 and 78% respectively.

Table 19: Characteristics of CVC Units by Sector

	Investments on Top 3 Subsectors	Proximity of Corporate Sector	CVC Units	Third Wave Units	Fourth Wave Units	Fifth Wave Units
Health/Pharmaceutical	71,5%	2,83	18	13	1	4
Media and Entertainment	30,4%	0,59	17	1	10	6
Software	34,9%	1,69	13	6	0	7
Other Services	35,2%	0,50	12	3	5	4
Finance	34,8%	0,82	11	1	4	6
Energy	46,5%	2,63	8	6	0	2
Internet	30,7%	1,63	8	0	3	5
Hardware	33,3%	1,00	6	4	1	1
Conglomerate	30,8%	1,50	4	2	1	1
Transportation	43,7%	1,00	2	1	0	1
Food & Agriculture	34,9%	1,00	2	0	1	1
TOTAL	**38,8%**	**1,38**	**101**	**35**	**22**	**44**

The factor "F6_Sector" points out that the fourth wave is the one with the most significant difference between the investee and parent corporation sectors. We can understand this fact considering the diversity of strategies of the CVC units during this "learning curve" period. CVCs of this period tested various types of diversification strategies until they reach their best strategic fit. At this point, we have noted that the greater proximity was in the third wave. It happened due to the significant presence of funds linked to pharmaceuticals and energy in this wave. CVC units in these sectors had a much higher focus on investments in their own sectors than the other sectors, as shown in Table 19.

Finally, the factor "F7_B_Model" follows a pattern close to that observed in the previous factor (Figure 21) because there is a natural relationship between business models and specific sectors. We have realized that the third wave has shown the largest business concentration for other businesses (B2B) (73.8%). The rising of the dotcom boom generated significant opportunities for digital business-to-business through the internet. The fourth wave, which has the lowest number of investments in B2B business (only 37.9%), was greatly influenced by the concepts of open innovation and disruptive innovation that emerged and spread in the period (CHESBROUGH, 2003b; CHRISTENSEN; RAYNOR, 2003). During this period, the most successful companies grew based in B2C (business for consumers) models and "the-winner-take-it-all" goals. The fifth wave has shown a better balance between the B2C and B2B models, with 53.3% of the investments of CVC units made in B2B startups.

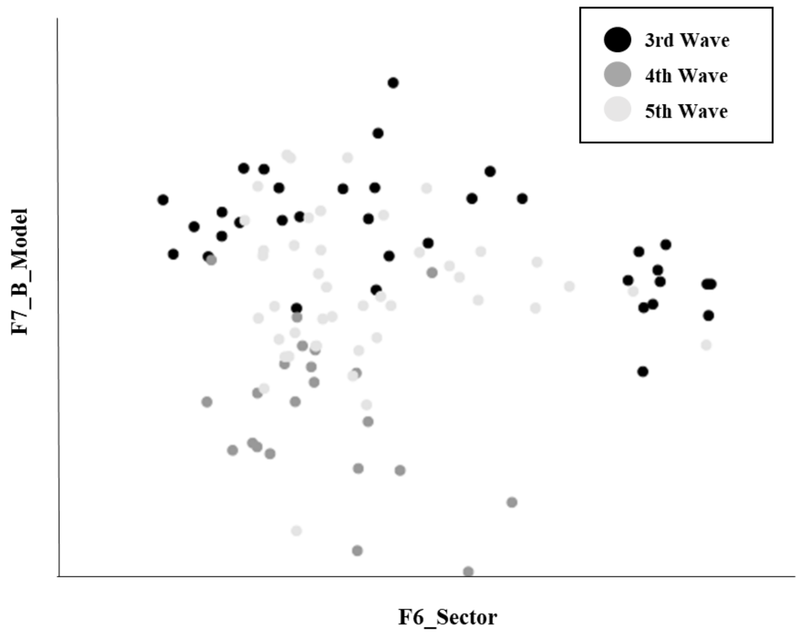

Figure 21: Wave Clusters – Business Model x Sectors

Analyzing the characteristics of CVC unit groups along the waves showed that patterns and strategies of one period are not precisely replicable in others. CVC units are influenced over time by movements in the capital markets and the VC industry, but also by corporate innovation strategies, with increasing weight on corporative goals. These identified and analyzed differences help to establish a relevant analytical framework for understanding the current scenario of the global CVC activity.

4.7. Results and Conclusions

Realizing that the characteristics of CVC units after the dotcom boom (third wave, 1995-2003) showed two distinct moments (fourth wave, 2003-2009 and fifth wave, 2010-present) was one of the most significant findings of this search. Contrary to what has been advocated by the literature so far, the separation of this entire period in two different ones can bring relevant insights. They can help to clarify how the modern CVCs are investing now, how their trajectories were built, and what are the main trends for the future. Our analysis, based on 13,012 investment operations and 19 distinct variables, made up the eight identified factors and gives us a robust sample of the behavior of the world's leading CVC units over the past 25 years.

Thus, the first relevant output of this research would be the possibility of classifying CVC units by their profiles and investment thesis. By comparing the unit's foundation year with its wave classification done by the clustering process, we can classify CVC units as visionary (characteristics ahead of their time), balanced (with typical characteristics of their foundation period) or conservative (with predominant characteristics from previous waves). To do this, we have created a profile scale for CVC units ranging from -2 (more conservative) to +2 (more visionary) considering a relative innovation oriented mindset. This scale is determined by the difference between the wave classification, as shown in the following formula.

$$\underset{\text{(CVC Investment Profile)}}{\text{CVC\_Profile}} = \underset{\text{(Wave by Clustering Characteristics)}}{\text{Wave\_Cluster}} + \underset{\text{(Wave by Year Foundation)}}{\text{Wave\_Year}}$$

Figure 22: CVC Units by Wave Profile Characteristics

At this point, it is relevant to consider that we analyze CVC units by their overall consolidated characteristics. Some of these units may have changed their investment patterns over time and/or may change it from now on. This finding can be seen both as a research limitation and as a suggestion for future research, notably longitudinal studies on the characteristics of CVC units using this classification.

It is essential to note that this scale could be used as a relevant parameter when we are considering the investment profile, but the scale is not able to analyze the internal particularities of each unit. By other distinctive criteria, we could classify a CVC as visionary or conservative using another logical framework. At this point, we may even suggest that future research look at the internal aspects of CVC units such as governance, processes, and absorptive capacity. Other works have been dealing with the subject of governance and processes in CVC such as (ANOKHIN; PECK; WINCENT, 2016; COOPER, 2008; HILL; BIRKINSHAW, 2008; LIN; LEE, 2011), but the separation of the last three waves made in this article may help elucidate substantial questions about the learning curve and future pathways inside the CVC units, the invested startups, and the parent corporations.

Using the developed scale, we have performed the exercise of classifying the 101 units of CVC used in this study as shown in Figure 22. As we can see, the vast majority of units (58.4%) are in scale 0, showing a considerable fit between theory and practice. However, we can also observe that there is a small amount of high conservative (5) or high visionary (2) units.

Another critical finding is the detailed characterization of the last three waves that can be used as a comparative guide for CVC units in operation today or other ones that will be created in the future. In a general analysis, the fourth wave, which began in the same year as the concept of open innovation, can be considered a transition phase from CVCs based on independent VC practices (financial focus typical from the third wave and previous ones) to an innovation-driven CVC mindset. The strategic and innovation-related approach has become the mainstream in the CVC area during the fifth wave. The learning curve provided by the fourth wave concludes that the mutual advantages of cooperation between corporations and startups for innovation are very relevant. The combination of access to capital, market, and complementary assets of corporations with the flexibility and agility of startups results in very consistent outputs for both, but only when well executed.

Regarding the distinctive features inherent in the fifth wave, the emphasis is given primarily to volume and range. The number of CVC investments in 2018, for example, is almost three times the peak of the fourth wave and almost four times the peak of the third wave. The exponential growth of the fifth wave is largely caused by the proximity of the CVC units to the corporate strategic core. From the 2000s on, innovation decisions became a fundamental part of corporate strategies, and from 2010 onwards, CVC units began to become a fundamental tool in the innovation efforts of these corporations. These observations indicate that CVC initiatives are becoming the core of innovation platforms for the most visionary companies. Table 20 consolidates these and other distinctive features of each of the last three waves of CVC.

Table 20: Consolidated CVC Waves Characteristics

Factor \ Wave Cluster		**Third Wave (1995-2002)**	**Fourth Wave (2003-2009)**	**Fifth Wave (2010-Present)**
		“Venture Capital Euphoria”	**”Open Innovation Learning”**	**“Strategic Core Innovation”**
F1	**Intensity**	Medium Investment Intensity	High Investment Intensity	Highest Investment Intensity
F2	**Stage**	Focus on Early-Stage Investments	Focus on Late-Stage Investments	Focus on Seed Investments
F3	**Experience**	More CVC Experience	Medium CVC Experience	Less CVC Experience
F4	**Location**	Farest from parent corporation HQ	Far from parent corporation HQ	Close to parent corporation HQ
F5	**Co_Investors**	High Number of Co-Investors	Low number of Co-Investors	Highest Number of Co-Investors
F6	**Sector**	Low Sector Differentiation (Energy and Pharma Bias)	High Sector Differentiation	Low Sector Differentiation (Strategic Bias)
F7	**B_Model**	Primary Focus on B2B Investments	Primary Focus on B2C Investments	Balance between B2B and B2C Investments
F8	**Leadership**	Low Leadership Role	Lowest Leadership Role	Assumed Leadership Positioning

From the third wave to the present day, we also can see a continuous geographic and sectoral expansion of CVC units. They are becoming less and less concentrated in the US and the information technology sector, expanding rapidly to other regions and other sectors. Regarding the characteristics of the investments made, the learning provided by the fourth wave, and the increasing appetite for new technologies and innovations, made the investments in startups in earlier phases grow considerably. Seed phase investments nearly tripled in relative share between fourth and fifth wave investments (8.3% versus 24.7%). Otherwise, the investments in late-stage VC fell by almost a third following the same comparison (33.4% versus 22.8% respectively).

The strategic approach of startup investments has also made the corporations increase their positions as leaders in investment rounds during the fifth wave. The percentage of rounds led by CVC units in the third wave was 22.9% and rose to 29.9% in the fifth wave. The percentage of solo rounds, i.e., without any co-investor, rose from 14% in the third wave to 22.5% in the fourth and fell again, going to 17.4% in the fifth wave. We can explain this latest move against an upward linear trend in many ways. The CVCs have found ideal partners along previous waves, they have expanded to other sectors, or they have tried to mitigate their risk through diversification strategies when they lead investment rounds. For the scope of this research, we have not explored these reasons in depth, which would undoubtedly be an interesting topic to investigate in future research.

The most active sectors considering the number of CVC units are Health (18), Media / Entertainment (17), Software (13), Finance (11), Energy (8) and Internet (8) and there is no pre-established standard common to all. First of all, we have to highlight the Media/Entertainment and Internet sectors. These sectors had recently experienced major disruptions and had almost no presence in the third wave. In a general way, they were just starting their CVC activity during the fourth wave, already with innovation bias.

Another interesting factor is the absence of Health, Energy, and Software CVC units in the fourth wave. These sectors, older than the Internet companies, apparently jumped the fourth wave from a more financial logic to one directly linked to strategic innovations in their core business. The reason why could be that these sectors were less pressured by the rapid disruption than the Media/Entertainment or Finance sectors, for instance. This unsurprising, as they are the three sectors that have the highest percentage of investments in startups linked to core sectors (Health 71.5%, Energy 46.5% and Software 34.9%).

In this analysis, Health and Energy deserve special mention because of their unique characteristics. They are sectors that involve investments in what are called "hardtech startups", i.e., startups that go beyond the digital world and deal with physical world problems such as scientific research, manufacturing, supply chain, verticalization, expansion adjustment, and others (WERWATH, 2019). Thus, the CVC units in these sectors have quite different characteristics, such as the lowest B2C business percentages (12.8% and 11.2%) and the highest business percentages within their own sector. Building a qualitative comparison between these sectors with each other and with Software/Internet from the perspective of CVCs and the fifth wave may be an interesting object for future research and it could complement the independent VC view presented by (GADDY et al., 2017).

Finally, the current volume of investments, the accelerated growth in recent years, the strategic focus of investments, and the higher degree of commitment among the parties (startups and corporations) are leading the CVC activity to another level. We can conclude in this context that the fifth wave is paving the way for CVC units acting as central platforms for a broader network of strategic innovation. These structures could be one of the best ways to capture value in co-development and other cooperation with startups in the primary and adjacent parent corporations' chains.

In the past, the R&D centers, the innovation funnels and, most recently, the open innovation process all played a central role in the innovation management field. At the current rate, the proliferation of CVC units is becoming more and more relevant in the context of corporate innovation, and it could become a new mainstream in a few years. The correct identification and characterization of the fifth wave of CVC can have been a relevant step in this path.

5 CONCLUSIONS

Throughout the three articles, we have observed different perspectives and the role of the main actors in the open innovation process facing the great challenge of the energy transition. In the last article, we have analyzed the phenomenon of the fifth wave without the restricted sectorial energy view because the use of CVCs as a strategic innovation tool is still a recent phenomenon. An analysis with the specific energy cut would address only eight CVC units (CRUNCHBASE, 2019). However, ignoring the CVCs phenomena during the energy transition would be a mistake considering that the cooperation between corporations and startups in the energy sector is readily increasing in the context of open innovations (GLOBAL CORPORATE VENTURING, 2016; LIVIERATOS; LEPENIOTIS, 2017).

The energy sector will invest trillions of dollars in the coming years (BP 2018; IEA 2019a). The standards set over the last century in the energy sector are expected to change in the coming decades, but there is still no consensus on the exact ways. We have just established today the macro trend of the three "Ds": Decarbonization, Decentralization, and Digitization.

This context, including the certainty about directions but uncertainty about the path, is pretty similar to the internet diffusion way. That similarity favors the adoption of the open innovation model where multiple collaborative fronts can be executed simultaneously in an organized fashion, both inside and outside incumbent companies in the sector. The platform strategy present in eight of the ten most valuable companies in the world today (PARKER; VAN ALSTYNE; CHOUDARY, 2016) proved to be the "right way" for internet companies after the dotcom boom. However, the "right way" is not clear enough for energy companies. To understand this way is critical to understanding the role of the top five actors in the open innovation process throughout the energy transition: universities, corporations, government, startups, and venture capitalists.

In the first article, we realized the importance of the government's role in the face of significant challenges such as the post by the energy transition. Mission-oriented program structures such as the used in the development of the atomic bomb (Project Manhattan) and the man-to-moon travel (Project Apollo), when correctly adapted, gave us relevant insights into how to address the decarbonization challenge of the energy matrix. In this paper, we review the literature on mission-oriented public policies, adapting these findings to the context of the energy sector. We also have established an analytical framework that can guide the construction of future mission-oriented programs by funding agencies. Applying the framework to three real Brazilian cases (PAISS, PAISS 2 and Inova Energia Programs), we realize the importance of coordinated actions between instruments to foster innovation, from different government entities, and among corporations and universities.

In the second article, our focus was on the other two actors who are not part of the original triple-helix: startups and venture capital funds. We have analyzed ten variables related to energy startups that received venture capital investments and that have reached the IPO or closed their activities in the last 20 years. We realize that the volume invested before the IPO and the existence of new business models are the two main factors that determine the success of an energy startup. However, the most significant value of this study is the very operation of the model, which can improve by 18% the accuracy of the selection process of a successful energy startup. Considering that a cleantech investor looks at about 100 business plans to make a single investment (MARCUS; MALEN; ELLIS, 2013), applying and improving this model can be an excellent opportunity for venture capitalists and innovation agencies.

In the third article, our focus was on characterizing the fifth wave of corporate venture capital (CVC). The previous literature reports that the first waves of CVC were motivated for financial reasons. However, recently, the CVC units have been used more widely as tools for fostering innovation within large companies. We realize that this change of mindset is radically changing this industry. They are bringing it to much higher levels than previous waves due to the current proximity of CVC units to the strategic core of corporations. The current key characteristics of the fifth wave include more seed-stage investments, more global CVC presence (but the CVC units are getting closer to their headquarters), more sectoral diversification with particular pharmaceutical and energy CVC profiles. In this article, we had a limitation trying to analyze energy funds alone because there were not enough cases for an industry-focused cluster analysis. However, this initial limitation has turned out to be a good thing. The comparison with other sectors has generated valuable insights into how this phenomenon may expand in different areas.

The overall conclusion from the joint analysis of the three articles is that all five key players in the innovative process (university, business, government, startups and venture capitalists) will play critical roles during the energy transition. In the internet revolution in the early 2000s, there was a vast preponderance of startups and venture capitalists over the other players of the traditional triple-helix (universities, corporations, and government). There have even been cases of specific antagonisms between these institutions. Some well-known entrepreneurs were positively recognized for leaving their universities to set up their companies such as Mark Zuckerberg (Facebook), Steve Jobs (Apple) and Bill Gates (Microsoft). At the same time, some startups were focused on creating disruptions that could wipe out established corporations in traditional industries. About government, The idea of free enterprise and the visionary ability of venture capitalists sometimes contrasted with the slower and more centralized design common to governments. However, the perception built over the three articles leads us to consider that this will be different during the energy transition.

The diffusion of innovations in the energy sector requires a large amount of accumulated capital, usually found in large corporations. In this sense, we realize that the cooperation between startups and corporations through the CVC units (third article) is multiplying and should play a critical role in the energy transition. The learning absorbed during the fourth wave of CVC makes the fifth wave's units operate much more efficiently in the generation, the diffusion, and the absorption of innovations.

Likewise, the prioritizing process, the coordination of incentive mechanisms, and also the regulatory issues (critical in the context of the energy sector) highlights the crucial role to be played by governments. The mission-oriented approach (First article) when facing big challenges seems to us to be very promising in this scenario because of its multi-effort and stakeholder coordination characteristics. The role of the State in the energy matrix decarbonization has been and will continue to be vital.

Finally, the startups and venture capitalists will also be relevant in the energy transition context. The second article shows that some patterns of success are beginning to emerge. The business model innovations generated by energy startups can set new standards, especially regarding digitization and decentralization of the energy sector. With the perception of an equalized importance among the Penta-helix stakeholders, the great challenge will become the construction of the even more complex model of cooperation between the parties, a great suggestion for future researches.

REFERENCES

ABDI. **Plano Brasil Maior: Balanço Executivo 2011-2014.** Brasília, DF: 2012.

ABDMOULEH, Z.; ALAMMARI, R. A. M.; GASTLI, A. Review of Policies Encouraging Renewable Energy Integration & Best Practices. **Renewable and Sustainable Energy Reviews**, v. 45, n. 1, p. 249–262, 2015.

ADNER, R.; KAPOOR, R. Value Creation in Innovation Ecosystems: How the Structure of Technological Interdependence Affects Firm Performance in New Technology Generations. **Strategic Management Journal**, v. 31, n.1 p. 306–333, 2010.

ALEXANDER, B. et al. Alphabet Energy: Thermoelectrics and Market Entry. **California Management Review**, v. 55, n. 1, p. 1–19, 2012.

ALLAIRE, M.; BROWN, S. P. A. The Green Paradox of U.S. Biofuel Subsidies: Impact on Greenhouse Gas Emissions. **Economics of Energy and Environmental Policy**, v. 4, n. 2, 2015.

ALMEIDA, C. M. V. B. et al. Cleaner Production towards a Sustainable Transition. **Journal of Cleaner Production**, v. 142, n. 2017 p. 1–7, 2017.

AMANATIDOU, E. et al. Using Evaluation Research as a Means for Policy Analysis in a ‘New’ Mission-Oriented Policy Context. **Minerva**, v. 52, n. 4, p. 419–438, 2014.

ANADÓN, L. D. Missions-Oriented RD&D Institutions in Energy between 2000 and 2010: A comparative analysis of China, the United Kingdom, and the United States. **Research Policy**, v. 41, n. 10, p. 1742–1756, 2012.

ANOKHIN, S.; PECK, S.; WINCENT, J. Corporate Venture Capital: The Role of Governance Factors. **Journal of Business Research**, v. 69, n. 11, p. 4744–4749, 2016.

ARGENTIERO, A. et al. Comparing Renewable Energy Policies in E.U.15, U.S. and China : A Bayesian DSGE Model. **The Energy Journal**, v. 38, n. SI1, p. 77–96, 2017.

ATKINSON, R. D.; MCKAY, A. S. **Digital Prosperity: Understanding the Economic Benefits of the Information Technology Revolution**. Washington, D.C.: The Information Technology and Innovation Foundation, 2013.

BANNERJEE, S.; BIELLI, S.; HALEY, C. **Scaling Together: Overcoming Barries in Corporate-Startups Collaboration**. London: NESTA, 2016.

BARRETTO-KO, P. **Corporate Venture Capital: Transforming CVC into an Effective Corporate Strategic Tool for Seeking Innovation and Growth in the 21st Century**. p. 77, M.Sc. - Sloan School of Management, Massachusetts Institute of Technology, 2011.

BELDERBOS, R.; JACOB, J.; LOKSHIN, B. Corporate Venture Capital (CVC) Investments and Technological Performance: Geographic Diversity and the Interplay with Technology Alliances. **Journal of Business Venturing**, v. 33, n. 1, p. 20–34, 2018.

BELLIDO, M. M. H. et al. Maturity-Based Analysis of Emerging Technologies in the Brazilian Power Sector. **Journal of Cleaner Production**, v. 243, n. 1 p. 118-132, 2019.

BENSON, D.; ZIEDONIS, R. H. R. H. Corporate Venture Capital and the Returns to Acquiring Portfolio Companies. **Journal of Financial Economics**, v. 98, n. 3, p. 478–499, 2010.

BIELESCH, F. et al. **Corporate Venture Capital: Avoid the Risk, Miss the Rewards**. Boston, MA: BCG, 2012.

BIERWERTH, M. et al. Corporate Entrepreneurship and Performance: A Meta-Analysis. **Small Business Economics**, v. 45, n. 2, p. 255–278, 2015.

BLOOMBERGNEF. **New Energy Outlook 2019**. New York, NY: 2019.

BNDES. **Plano Inova Empresa Website**. Retrieved from: <http://www.bndes.gov.br/wps/portal/site/home/financiamento/plano-inova-empresa/plano-inova-empresa>. Access at: August, 24th. 2017.

BORRÁS, S.; EDQUIST, C. The Choice of Innovation Policy Instruments. **Technological Forecasting and Social Change**, v. 80, n. 8, p. 1513–1522, 2013.

BP. **BP Energy Outlook 2014**. London, UK: 2014.

BP. **BP Energy Outlook 2016**. London, UK: 2016.

BP. **BP Energy Outlook 2017**. London, UK: 2017.

BP. **BP Energy Outlook 2018**. London, UK: 2018.

BRAZIL. **Estratégia Nacional de Ciência, Tecnologia e Inovação 2012 - 2015.** Brasília, DF: Ministério da Ciência, Tecnologia e Inovação, 2012.

BRAZIL. **Plano Inova Empresa.** Brasília, DF: Ministério da Ciência, Tecnologia e Inovação, 2013.

BRIGL, M. et al. **Corporate Venturing Shifts Gears: How the Largest Companies Apply a Broad Set of Tools to Speed Innovation**. Boston, MA: BCG, 2014.

BUDDEN, P.; MURRAY, F. **A Systematic MIT Approach for Assessing "Innovation-Driven Entrepreneurship" in Ecosystems (iEcosystems).** Cambridge, MA: MIT Lab for Innovation Science and Policy, 2017.

CANTNER, U.; PYKA, A. Classifying Technological Policy from an Evolutionary Perspective. **Research Policy**, v. 30, p. 759–775, 2001.

CARNEIRO, J.; DA SILVA, J. F.; DA ROCHA, A. Strategic Profiles of Brazilian Exporters and Performance Implications. **Journal of Business Research**, v. 64, n. 3, p. 250–257, 2011.

CB INSIGHTS. **The History Of CVC: From Exxon And DuPont To Xerox And Microsoft, How Corporates Began Chasing 'The Future'.** New York, NY: 2017.

CB INSIGHTS. **The 2018 Global CVC Report**. New York, NY: 2018.

CB INSIGHTS. **The 2017 Global CVC Report**. New York, NY: 2017.

CHESBROUGH, H. GE's Ecomagination Challenge: An Experiment in Open Innovation. **California Management Review**, v. 54, n. 3, p. 140–154, 2012.

CHESBROUGH, H. W. Making Sense of Corporate Venture Capital. **Harvard Business Review**, v. 80, n. 3, p. 90, 2002.

CHESBROUGH, H. W. **Open Innovation: The New Imperative for Creating and Profiting from Technology**. Watertown, MA: Harvard Business School Press, 2003a.

CHESBROUGH, H. W. The Era of Open Iinnovation. **Management Review**, v. 44, n. 3, p. 35–41, 2003b.

CHESBROUGH, H. W. Open Innovation: A New Paradigm for Understanding Industrial Innovation. In: **Open Innovation: Researching a New Paradigm**. Berkeley, CA: Oxford University Press, 2006. p. 1–12.

CHESBROUGH, H. W.; APPLEYARD, M. M. Open Innovation and Strategy. **California Management Review**, v. 50, n. 1, p. 57–76, 2007.

CHIANG, J. T. From "Mission-Oriented" to "Diffusion-Oriented" Paradigm: The New Trend of U.S. Industrial Technology Policy. **Technovation**, v. 11, n. 6, p. 339–356, 1991.

CHOUNG, J. Y.; HWANG, H. R.; SONG, W. Transitions of Innovation Activities in Latecomer Countries: An Exploratory Case Study of South Korea. **World Development**, v. 54, n. 1, p. 156–167, 2014.

CHRISTENSEN, C.; RAYNOR, M. **The Innovator's Solution: Creating and Sustaining Successful Growth**. Watertown, MA: Harvard Business Press, 2003.

CHRISTIDIS, K.; DEVETSIKIOTIS, M. Blockchains and Smart Contracts for the Internet of Things. **IEEE Access**, v. 4, n. 1, p. 2292–2303, 2016.

CLEANTECH GROUP; WWF. **The Global Cleantech Innovation Index 2017**. San Francisco, US: 2017.

COOPER, R. G. Perspective: The Stage-Gate Idea-to-Launch Process - Update, What's New, and NexGen Systems. **Journal of Product Innovation Management**, v. 25, n. 3, p. 213–232, 2008.

COVIN, J. G.; MILES, M. P. Strategic Use of Corporate Venturing. **Entrepreneurship: Theory and Practice**, v. 31, n. 2, p. 183–207, 2007.

CRUNCHBASE. **Crunchbase: Discover innovative companies and the people behind them.** Retrieved from <https://www.crunchbase.com/>. Access at: April, 11st. 2017.

CZARNITZKI, D.; DICK, J.; HUSSINGER, K. **The Contribution of Corporate Ventures to Radical Innovation**. Leuven, Belgium: Katholieke Universiteit Leuven, 2010.

DA GBADJI, L. A. G.; GAILLY, B. **The Use of Corporate Venture Capital as a Strategic Tool : Literature Review and Key Characteristics of CVC Investments**. Louvain, Belgium: Univerité Catholique de Louvain, 2009.

DAHLANDER, L.; PIEZUNKA, H. Open To Suggestions: How Organizations Elicit Suggestions through Proactive and Reactive Attention. **Research Policy**, v. 43, n. 5, p. 812–827, 2014.

DASGUPTA, P.; STONEMAN, P. **Economic Policy and Technological Performance**. Cambridge, UK: Cambridge University Press, 2005.

DAVILA, A.; FOSTER, G.; GUPTA, M. Venture Capital Financing and the Growth of Startup Firms. **Journal of Business Venturing**, v. 18, n. 6, p. 689–708, 2003.

DONADA, C.; LEPOUTRE, J. How can Startups Create the Conditions for a Dominant Position in the Nascent Industry of Electromobility 2.0? **International Journal of Automotive Technology and Management**, v. 16, n. 1, p. 16–29, 2016.

DOSI, G. Beyond the 'Magic Of The Market'. The Slow Return of Industrial Policy (But Not Yet in Italy). **Economia e Politica Industriale**, v. 43, n. 3, p. 261–264, 2016.

DUSHNITSKY, G. Riding the Next Wave of Corporate Venture Capitial. **Business Strategy Review**, v. 22, n. 3, p. 44–49, 2011.

DUSHNITSKY, G. Corporate Venture Capital in the 21st Century: An Integral Part of Firms' Innovation Toolkit. In: **The Oxford Handbook of Venture Capital**. Oxford, UK: Oxford University Press, 2012.

DUSHNITSKY, G.; LENOX, M. J. When Do Incumbents Learn from Entrepreneurial Ventures?: Corporate Venture Capital and Investing Firm Innovation Rates. **Research Policy**, v. 34, n. 5, p. 615–639, 2005.

DUSHNITSKY, G.; LENOX, M. J. When does corporate venture capital investment create firm value? **Journal of Business Venturing**, v. 21, n. 6, p. 753–772, 2006.

DUTTA, S. **The Global Innovation Index 2011: Accelerating Growth and Development**. Fontainebleau, France: INSEAD, 2011.

EDQUIST, C.; ZABALA-ITURRIAGAGOITIA, J. M. J. M. Public Procurement for Innovation as Mission-Oriented Innovation Policy. **Research Policy**, v. 41, n. 10, p. 1757–1769, 2012.

ELEFTHERIADIS, I. M.; ANAGNOSTOPOULOU, E. G. Identifying Barriers in the Diffusion of Renewable Energy Sources. **Energy Policy**, v. 80, n. 1, p. 153–164, 2015.

EPE. **Balanço Energético Nacional 2015**. Rio de Janeiro, RJ: 2015.

ERGAS, H. The Importance of Technology Policy. In: **Economic Policy and Technological Performance**. Cambridge, UK: Cambridge University Press, 1987. p. 45.

ETZKOWITZ, H.; LEYDESDORFF, L. The Dynamics of Innovation: From National Systems and "Mode 2" to a Triple Helix of University–Industry–Government Relations.

Research Policy, v. 29, n. 2, p. 109–123, 2000.

FAN, J. S. Catching Disruption: Regulating Corporate Venture Capital. **Columbia Business Law Review**, v. 341, n. 1, p. 342–425, 2018.

FARFAN, J.; BREYER, C. Structural Changes of Global Power Generation Capacity towards Sustainability and the Risk of Stranded Investments Supported by a Sustainability Indicator. **Journal of Cleaner Production**, v. 141, n. 1, p. 370–384, 2017.

FERREIRA-LEITAO, V. et al. Biomass Residues in Brazil: Availability and Potential Uses. **Waste and Biomass Valorization**, v. 1, n. 1, p. 65–76, 2010.

FINANCIAL TIMES. **FT Global 500 2011**. London, UK: 2011.

FINEP. **PAISS Website**. Retrieved from: <http://www.finep.gov.br/apoio-e-financiamento-externa/programas-e-linhas/programas-inova/paiss>. Access at: August, 23rd. 2017.

FINEP. **Inova Energia Website**. Retrieved from: <http://www.finep.gov.br/apoio-e-financiamento-externa/programas-e-linhas/programas-inova/inova-energia>. Access at: August, 23rd. 2017.

FINEP. **PAISS Agrícola Website**. Retrieved from: <http://www.finep.gov.br/apoio-e-financiamento-externa/programas-e-linhas/programas-inova/paiss-agricola>. Access at: August, 23rd. 2017.

FINEP; BNDES. **Edital FINEP/BNDES - Plano Conjunto de Apoio à Inovação Tecnológica Industrial dos Setores Sucroenergético e Sucroquímico (PAISS).** Rio de Janeiro, RJ: 2011.

FINEP; BNDES. **Edital FINEP/BNDES - Plano Conjunto de Apoio à Inovação Tecnológica Agrícola dos Setores Sucroenergético e Sucroquímico (PAISS Agrícola).** Rio de Janeiro, RJ: 2014.

FINEP; BNDES; ANEEL. **Edital ANEEL/BNDES/FINEP - Plano Conjunto de Apoio à Inovação Tecnológica no Setor Elétrico - Inova Energia.** Rio de Janeiro, RJ: 2013.

FORAY, D.; MOWERY, D. C.; NELSON, R. R. Public R&D and Social Challenges: What Lessons from Mission R&D Programs? **Research Policy**, v. 41, n. 10, p. 1697–1702, 2012.

FÜLLER, J. et al. Consumer Empowerment Through Internet-Based Co-creation. **Journal of Management Information Systems**, v. 26, n. 3, p. 71–102, 2009.

GADDY, B. et al. Venture Capital and Cleantech: The Wrong Model for Energy Innovation. **Energy Policy**, v. 102, n. July, p. 385–395, 2017.

GLENNIE, A.; BOUND, K. **How Innovation Agencies Work: International lessons to inspire and inform national strategies**. London, UK: NESTA, 2016.

GLOBAL CORPORATE VENTURING. **Oil and Gas Sector Review Venturing 2016**. London, UK: 2016.

GOMPERS, P. A. Corporations and the Financing of Innovation: The Corporate Venturing Experience. **Economic Review**, v. 1, n. 4, p. 1–23, 2002.

GRECO, M.; LOCATELLI, G.; LISI, S. Open Innovation in the Power & Energy Sector: Bringing together government policies, companies' interests, and academic essence. **Energy Policy**, v. 104, n. 3, p. 316–324, 2017.

GREENPEACE. **Energy [R]evolution**. Sttutgart, Germany: 2015.

GUO, B.; LOU, Y.; DAVID, P. Investment , Duration , and Exit Strategies for Corporate and Independent Venture. **Barcelona GSE Working Paper Series**, p. 1–54, 2012.

GUO, B.; LOU, Y.; PÉREZ-CASTRILLO, D. Investment, Duration, and Exit Strategies for Corporate and Independent Venture Capital-Backed Start-Ups. **Journal of Economics and Management Strategy**, v. 24, n. 2, p. 415–455, 2015.

GUTMANN, T. Harmonizing Corporate Venturing Modes: An Integrative Review and Research Agenda. **Management Review Quarterly**, v. 69, n. 2, p. 121–157, 2019.

HAHN, Y.-H.; YU, P.-I. Towards a New Technology Policy: The Integration of Generation and Diffusion. **Technovation**, v. 19, n. 3, p. 177–186, 1999.

HAIR JR, J. F. et al. **Multivariate Data Analysis**. 7th. ed. London, UK: Pearson Prentice Hall, 2010.

HARTLEY, P. R.; MEDLOCK, K. B. The Valley of Death for New Energy Technologies. **The Energy Journal**, v. 38, n. 3, p. 34–61, 2017.

HERMANN, B. L. et al. **The Global Startup Ecosystem Ranking 2015**. San Francisco, US: 2015.

HILL, S. A.; BIRKINSHAW, J. Strategy-Organization Configurations in Corporate Venture Units: Impact on Performance and Survival. **Journal of Business Venturing**, v. 23, n. 4, p. 423–444, 2008.

HILL, S. A.; BIRKINSHAW, J. Ambidexterity and Survival in Corporate Venture Units. **Journal of Management**, v. 40, n. 7, p. 1899–1931, 2014.

HUISINGH, D. et al. Recent Advances in Carbon Emissions Reduction: Policies, Technologies, Monitoring, Assessment and Modeling. **Journal of Cleaner Production**. v. 103, n. 2015, p. 1–12, 2015.

IEA/USP. **Plano Inova Empresa**. Retrieved from: <www.iea.usp.br/midiateca/apresentacao/plano-inova-empresa-melo-e.../at.../file>. Accesso at: August, 23rd. 2017.

IEA. **World Energy Investment Outlook 2014**. Paris, France: 2014.

IEA. **World Energy Outlook 2015**. Paris, France: 2015.

IEA. **Global EV Outlook 2016: Beyond one million electric cars**. Paris, France: 2016.

IEA. **World Energy Investment 2017**. Paris, France: 2017.

IEA. **Perspectives for the Clean Energy Transition: The Critical Role of BuildingJournal of Chemical Information and Modeling**. Paris, France: 2019a.

IEA. **World Energy Investment 2019**. Paris, France: 2019b.

IEA. **Global EV Outlook 2019**. Paris, France: 2019c.

INSEAD; 500 STARTUPS. **How do the World's Biggest Companies Deal with the Startup Revolution**. Fontainebleau, France: INSEAD. 2016.

IPCC. **Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change**. Cambridge, UK: 2014.

JACOBIDES, M. G.; CENNAMO, C.; GAWER, A. Towards a Theory of Ecosystems. **Strategic Management Journal**, v. 39, n. 8, p. 2255–2276, 2018.

JARAITE, J.; KARIMU, A.; KAZUKAUSKAS, A. Policy-Induced Expansion of Solar and Wind Power Capacity: Economic Growth and Employment in EU Countries. **The Energy Journal**, v. 38, n. 5, p. 197–222, 2017.

KIM, J.-H.; WAGMAN, L. Portfolio Size and Information Disclosure: An Analysis of Startup Accelerators. **Journal of Corporate Finance**, v. 28, n. 12, p. 520–534, 2014.

KOHLER, T. Corporate Accelerators: Building Bridges between Corporations and Startups. **Business Horizons**, v. 59, n. 3, p. 347–357, 2016.

KÖHN, A. The Determinants of Startup Valuation in the Venture Capital Context: A Systematic Review and Avenues for Future Research. **Management Review Quarterly**, v. 68, n. 1, p. 1–34, 2017.

KOLLMANN, T.; KUCKERTZ, A. Evaluation Uncertainty of Venture Capitalists' Investment Criteria. **Journal of Business Research**, v. 63, n. 7, p. 741–747, 2010.

KPMG. **On the Road to Corporate-Startup Collaboration**. Amstelveen, Holland: 2015.

KPMG. **Global Automotive Executive Survey 2016**. Amstelveen, Holland: 2016.

KPMG. **Global Executive Automotive Survey 2018**. Amstelveen, Holland: 2018.

LAHR, H.; MINA, A. Venture Capital Investments and the Technological Performance of Portfolio Firms. **Research Policy**, v. 45, n. 1, p. 303–318, 2016.

LEE, S. U.; KANG, J. Technological Diversification Through Corporate Venture Capital Investments: Creating Various Options to Strengthen Dynamic Capabilities. **Industry and Innovation**, v. 22, n. 5, p. 349–374, 2015.

LEMBER, V.; KATTEL, R.; KALVET, T. Quo Vadis Public Procurement of Innovation? **Innovation: The European Journal of Social Science Research**, v. 28, n. 3, p. 403–

421, 2015.

LIEDTKE, C. et al. User-Integrated Innovation in Sustainable LivingLabs: An Experimental Infrastructure for Researching and Developing Sustainable Product Service Systems. **Journal of Cleaner Production**, v. 97, p. 106–116, 2015.

LIN, S. J.; LEE, J. R. Configuring a Corporate Venturing Portfolio to Create Growth Value: Within-Portfolio Diversity and Strategic Linkage. **Journal of Business Venturing**, v. 26, n. 4, p. 489–503, 2011.

LIVIERATOS, A. D.; LEPENIOTIS, P. Corporate Venture Capital Programs of European Electric Utilities: Motives, Trends, Strategies And Challenges. **Electricity Journal**, v. 30, n. 2, p. 30–40, 2017.

MA, S. **The Life Cycle of Corporate Venture Capital**. p. 123, Ph.D. Department of Business Administration, Duke University, 2016.

MACEDO-SOARES, T. D. VAN A. DE; PAULA, F. DE O.; MENDONÇA, H. L. Leveraging Firm Innovation Performance Through Alliance Portfolios in Emerging Economies: the Role of Absorptive Capacity. **Journal of Technology Management & Innovation**, v. 12, n. 4, p. 10–21, 2017.

MAKHOBA, X.; POURIS, A. Scientometric Assessment of Selected R&D Priority Areas in South Africa: A Comparison with Other BRICS Countries. **African Journal of Science, Technology, Innovation and Development**, v. 8, n. 2, p. 187–196, 2016.

MARCUS, A.; MALEN, J.; ELLIS, S. The Promise and Pitfalls of Venture Capital as an Asset Class for Clean Energy Investment. **Organization & Environment**, v. 26, n. 1, p. 31–60, 2013.

MAULA, M. V. J. Corporate Venture Capital as a Strategic Tool for Corporations. In: **Handbook of Research on Venture Capital**. Cheltenham, UK: Edward Elgar Publishing. 2007.

MAZZUCATO, M. **The Entrepreneurial State: Debunking Public vs. Private Sector Myths**. London, UK: Anthem Press, 2013.

MAZZUCATO, M. From Market Fixing to Market-Creating: A New Framework for Innovation Policy. **Industry & Innovation**, v. 23, n. 2, p. 140–156, 2016.

MAZZUCATO, M.; PENNA, C. C. R. **Mission-Oriented Finance for Innovation: New Ideas for Investiment-Led Growth**. London, UK: Rowman & Littlefield International, 2015.

MAZZUCATO, M.; PENNA, C. C. R. **The Brazilian Innovation System: A Mission-Oriented Policy Proposal**. Brasília, DF: CGEE, 2016.

MENDONÇA, H. L. O Impacto das Startups no Setor de Energia. **Boletim de Conjuntura Energética FGV**, v. 5, n. 9, p. 7–11, 2017.

MENDONÇA, H. L.; FERREIRA, J.; VINICIUS, M. Energy Startups : Identifying Winning Standards During the Energy Transition. In: **Congresso de Administração**

Sociedade e Inovação 2018. Anais... Rio de Janeiro, RJ: 2018

MENDONÇA, H. L.; FONSECA, M. V. DE A.; FRENKEL, J. B. Biorefinarias de Cana-de-Açúcar : Mapas Conceituais como Método de Análise Estratégica para sua Difusão. In: **VIII Simpósio Internacional de Gestão de Projetos, Inovação e Sustentabilidade.** Anais... São Paulo, SP: 2017.

MENDONÇA, H. L.; VAN ADUARD DE MACEDO-SOARES, T. D. L.; FONSECA, M. V. DE A. Working Towards a Framework Based on Mission-Oriented Practices for Assessing Renewable Energy Innovation Policies. **Journal of Cleaner Production**, v. 193, p. 709–719, 2018.

MEYER, T.; MATHONET, P. Y. **Beyond the J-Curve: Managing a Portfolio of Venture Capital and Private Equity Funds**. Chichester, UK: John Wiley & Sons Ltd, 2005.

MILANEZ, A. Y. et al. De Promessa a Realidade : Como o Etanol Celulósico Pode Revolucionar a Indústria da Cana-de-Açúcar - Uma Avaliação do Potencial Competitivo e Sugestões de Política Pública. **Biocombustíveis BNDES setorial**, v. 41, n. 1, p. 237–294, 2015.

MOCKER, V.; BIELLI, S.; HALEY, C. **Winning Together: A Guide to Successful Corporate-Startup Collaborations**. London, UK: NESTA. 2015.

MOORE, B.; WUSTENHAGEN, R. Innovative and Sustainable Energy Technologies: The Role of Venture Capital. **Business Strategy and the Environment**, v. 13, n. 4, p. 235–245, 2004.

MORONI, I.; ARRUDA, A.; ARAUJO, K. The Design and Technological Innovation: How to Understand the Growth of Startups Companies in Competitive Business Environment. **Procedia Manufacturing**, v. 3, n. 1, p. 2199–2204, 2015.

MOWERY, D. C. Defense-Related R&D as a Model for "Grand Challenges" Technology Policies. **Research Policy**, v. 41, n. 10, p. 1703–1715, 2012.

NARAYANAN, V. K.; YANG, Y.; ZAHRA, S. A. Corporate Venturing and Value Creation: A Review and Proposed Framework. **Research Policy**, v. 38, n. 1, p. 58–76, 2009.

NASA. **NASA's Journey to Mars**. Retrieved from: <https://www.nasa.gov/content/nasas-journey-to-mars/>. Access at: December, 18th. 2016.

NASDAQ. **Sugar Price: Latest Price / Chart for Sugar - NASDAQ.com**. Retrieved from: <http://www.nasdaq.com/markets/sugar.aspx?timeframe=5y>. Access at em: December, 23th. 2016.

NYKO, D. et al. Planos de Fomento Estruturado Podem Ser Mecanismos Mais Eficientes de Política Industrial? Uma Discussão à Luz sa Experiência do PAISS e seus Resultados. **BNDES Setorial**, v. 38, n. 1, p. 55–78, 2013.

OLMOS, L.; RUESTER, S.; LIONG, S. J. On the Selection of Financing Instruments to

Push the Development of New Technologies: Application to Clean Energy Technologies. **Energy Policy**, v. 43, n. 1, p. 252–266, 2012.

PARENTE, P. Petrobras, Mercado de Combustíveis e Mudança Climática. **UNICA Fórum 2016.** Anais... São Paulo, SP: UNICA, 2016

PARHANKANGAS, A.; ARENIUS, P. From a Corporate Venture to an Independent Company: A Base for a Taxonomy for Corporate Spin-Off Firms. **Research Policy**, v. 32, n. 3, p. 463–481, 2003.

PARKER, G. G.; VAN ALSTYNE, M. W.; CHOUDARY, S. P. **Platform Revolution – How Networked Markets Are Transforming the Economy–and How to Make Them Work for You**. New York, NY: Norton & Company, 2016.

POLZIN, F. et al. Public Policy Influence on Renewable Energy Investments: A Panel Data Study Across OECD Countries. **Energy Policy**, v. 80, n. 1, p. 98–111, 2015.

PWC. **Global Top 100 Companies by Market Capitalisation**. London, UK: 2019.

RANDHAWA, K.; WILDEN, R.; HOHBERGER, J. A Bibliometric Review of Open Innovation: Setting a Research Agenda. **Journal of Product Innovation Management**, v. 33, n. 6, p. 750–772, 2016.

RAO, S.; KEPPO, I.; RIAHI, K. Importance of Technological Change and Spillovers in Long Term Climate Policy. **The Energy Journal**, v. 27 n. SI, p. 123–139, 2006.

REN21. **RENEWABLES 2016 - Global Status Report**. Paris, France: 2016.

RIES, E. **The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses**. New York, NY: Crown Publishing, 2011.

RIES, E. **The Startup Way: How Modern Companies Use Entrepreneurial Management to Transform Culture and Drive Long-Term Growth**. New York, NY: Random House, 2017.

RÖHM, P.; MERZ, M.; KUCKERTZ, A. Identifying Corporate Venture Capital Investors – A Data-Cleaning Procedure. **Finance Research Letters**. Article In Press, 2019.

RUMPF, G. Setting Priorities for Innovation Policy and Evaluating their Performance: Evidence from Europe and Lessons for Ukraine. **Foresight and STI Governance**, v. 6, n. 3, p. 28–39, 2012.

SANTOS, M. S. D.; IANDA, T. F.; PADULA, A. D. Bioenergy as a Means to Social And Economic Development in Guinea-Bissau: A Proposal for a Biodiesel Production and Use Program. **International Journal of Sustainable Development and World Ecology**, v. 21, n. 6, p. 495–502, 2014.

SCHOEMAKER, P. J. H.; HEATON, S.; TEECE, D. Innovation, Dynamic Capabilities, and Leadership. **California Management Review**, v. 61, n. 1, p. 15–42, 2018.

SCOPUS. **Scopus Database**. Retrieved from: <https://www.scopus.com/>. Access at:

May, 18th. 2019.

SMIL, V. **Energy Transitions: History, Requirements, Prospects**. Santa Barbara, US: Greenwood Publishing Group, 2010.

SPENDER, J. C. et al. Startups and Open Innovation: A Review of the Literature. **European Journal of Innovation Management**, v. 20, n. 1, p. 4–30, 2017.

TEECE, D. J.; PISANO, G.; SHUEN, A. Dynamic Capabilities and Strategic Management. **Strategic Management Journal**, v. 18, n. 7, p. 509–533, 1997.

TEPPO, T.; WÜSTENHAGEN, R. Why Corporate Venture Capital Funds Fail: Evidence from the European Energy Industry. **World Review of Entrepreneurship, Management and Sustainable Development**, v. 5, n. 4, p. 353–375, 2009.

THE NEW YORK TIMES. **What to Expect as U.S. Leaves Paris Climate Accord**. Retrieved from: <https://www.nytimes.com/2017/06/01/climate/us-paris-accord-what-happens-next.html?mcubz=0>. Access at: September, 9th. 2017.

TIDD, J.; BESSANT, J.; PAVITT, K. **Managing Innovation: Integrating Technological, Market and Organizational Change**. Chichester, UK: John Wiley & Sons, 2005.

UFPE; CEPEL; CHESF. **Atlas Solarimétrico do Brasil: Banco de Dados Terrestres** Recife, PE: 2000.

UNEP; BLOOMBERG; FRANKFURT SCHOOL. **Global Trends in Renewable Energy Investment**. Frankfurt, Germany: 2016.

UNFCC. **The Paris Agreement - Main Page**. Retrieved from: <http://unfccc.int/paris_agreement/items/9485.php>. Access at: November, 26th. 2017.

UNFCCC. **Adoption of the Paris Agreement - Proposal by the President.** Paris, France: United Nations (UN), 2016.

VEUGELERS, R. Which Policy Instruments to Induce Clean Innovating? **Research Policy**, v. 41, n. 10, p. 1770–1778, 2012.

VOLANS. **Investing in Breakthrough Corporate Venture Capital**. London, UK: 2014.

WADHWA, A.; PHELPS, C.; KOTHA, S. Corporate Venture Capital Portfolios and Firm Innovation. **Journal of Business Venturing**, v. 31, n. 1, p. 95–112, 2016.

WEIBLEN, T.; CHESBROUGH, H. W. Engaging with Startups to Enhance Corporate Innovation. **California Management Review**, v. 57, n. 2, p. 66-90, 2015.

WERWATH, M. Lean Startup and the Challenges with “Hard Tech” Startups. **IEEE Engineering Management Review**, v. 47, n. 1, p. 22, 2019.

WEST, J. Too Little, too Early: California’s Transient Advantage in the Photovoltaic Solar Industry. **Journal of Technology Transfer**, v. 39, n. 3, p. 487–501, 2014.

WORLD BANK. **Projects : Renewable Energy Scale-up Program (CRESP) | The World Bank**. Retrieved from: <http://projects.worldbank.org/P067828/renewable-energy-scale-up-program-cresp?lang=en>. Access at: November, 15th. 2016.

WORLD ECONOMIC FORUM. **Renewable Infrastructure Investment Handbook: A Guide for Institutional Investors**. Gevene, Switzerland: WEF, 2016.

WORLD ENERGY COUNCIL. **World Energy Council: Issues Monitor 2019**. London, UK: 2019.

WWF; ECOFYS; OMA. **The Energy Report: 100% Renewable Energy by 2050**. Gland, Switzerland: 2011.

ZELENBABIC, D. Fostering Innovation through Innovation Friendly Procurement Practices: A Case Study of Danish Local Government Procurement. **Innovation**, v. 28, n. 3, p. 261–281, 2015.