

UNIVERSIDADE DE LISBOA

ISEG Lisbon School of Economics & Management

**The effects of the 2030 Climate and Energy Framework Agreement on  
the energy sector**

**João Manuel Jorge Estevão**

Orientadoras: Professora Doutora Clara Patrícia Costa Raposo

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To my family



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## Abstract

The doctoral thesis is composed by three empirical studies that can be read independently, plus an introduction and a concluding chapter.

The purpose of this piece of research is to investigate the impact that the Climate and Energy 2030 Agreement has had in the electricity sector, in markets and companies. The study addresses three specific goals: i) firstly, to understand the dimension of the awareness around the topic according to its presence in the academic literature. This thesis examines whether there is a trend in the literature regarding the necessary changes to implement the Paris Agreement and combat damaging climate changes. This is an important step in this thesis, since research that brings together environmental concerns into managerial practices is recent, despite the climate emergency; ii) second, to understand the reaction of the market of derivatives of electricity to the imposition of new goals related to greenhouse gas and consumption of renewable energies when countries signed the Paris agreement; and iii) thirdly, to analyze whether, under the new framework of the Paris agreement, companies in the energy sector adjusted their R&D policies, which factors can contribute to R&D intensity in these companies, and how these changes were seen by companies, keeping in mind that, to achieve the 2030 Agreement goals, it is necessary to reduce greenhouse gas emissions, increase the consumption of renewable energies and increase the energy efficiency – which may require increasing innovation.

The dissertation uses different methodological approaches, developed in three research papers. The first one presents an analytical review of the literature (publications) in order to assess the attention and awareness focused on the Paris Agreement and, specifically, the electricity sector. The focus of the analysis is on the Scopus and WoS databases, with the propose of checking the state of the art in the academic literature. The

second paper, using the database of spot prices of the Iberian electricity derivatives market MIBEL, examines and compares the behavior of spot electricity prices in MIBEL before and after the signing of the 2030 Paris Agreement. This chapter adopts a mixed- methods approach that combines a more “traditional” (in the finance literature) GARCH model with the qualitative fsQCA methodology. The third contribution of this thesis analyzes the behavior of R&D intensity of companies related to the electricity sector, before and after the signing of the 2030 Paris Agreement. This empirical chapter uses panel data, comparing listed companies with headquarters in European Union countries with companies headquartered in other countries in Europe, for the periods before and after 2014.

## Resumo

Esta tese de doutoramento é composta por três estudos empíricos independentes, ao qual acresce um capítulo de introdução e outro de conclusões.

O objetivo desta pesquisa é investigar o impacto que o Climate and Energy 2030 Agreement teve o sector da eletricidade, em termos de mercados e empresas. O estudo tem três objetivos específicos: em primeiro lugar, compreender a dimensão da consciencialização sobre o tópico do ponto de vista da sua presença na literatura científica/académica. Esta tese analisa se existe uma tendência na literatura relativamente às mudanças necessárias que é preciso efetuar para implementar o Acordo de Paris e combater as alterações climáticas. Isto é um aspeto importante na tese, uma vez que só recentemente é que a investigação junta as preocupações ambientais com as práticas de gestão, apesar da emergência climática; ii) em segundo lugar, para perceber a reação dos mercados de derivados de eletricidade à imposição de novos objetivos relacionados gás de efeito de estufa e o consumo de energias renováveis quando os países assinaram o Acordo de Paris, e iii) em terceiro lugar, para analisar onde, no âmbito do novo quadro do Acordo de Paris, as empresas do sector energético ajustaram as suas políticas de I&D, que fatores podem contribuir para a intensidade de I&D nessas empresas e como essas alterações foram vistas por estas, tendo em conta que para atingir os objetivos do 2030 Agreement é necessário reduzir os efeitos do gás de estufa, aumentar o consumo de energias renováveis e aumentar a eficiência energética – o que pode requerer aumentar a inovação.

Esta dissertação usa diferentes abordagens metodológicas, que são desenvolvidas em três artigos. O primeiro apresenta uma revisão da literatura analítica (publicações científicas) de forma a avaliar a atenção dada e a sensibilização para o Acordo de Paris,

em particular, no sector da eletricidade. O foco da análise é nas bases de dados da SCOPUS e WoS com o objetivo de verificar o estado da arte na literatura académica. O segundo artigo, através da base de dados dos preços spot do mercado ibérico de derivados de eletricidade MIBEL, analisa e compara o comportamento dos preços spot de eletricidade no MIBEL antes e depois da assinatura do 2030 Agreement. Este capítulo adota uma abordagem de métodos mistos que combina uma metodologia mais tradicional (na literatura de finanças), modelos GARCH, com uma metodologia qualitativa, fsQCA. A terceira contribuição desta tese é a análise do comportamento da intensidade de I&D nas empresas relacionadas com o sector da eletricidade, antes e depois da assinatura do mencionado Acordo. Este capítulo empírico usa dados de painel, comparando empresas que têm sede em países da União europeia com empresas com sede em outros países da Europa, nos períodos antes e depois de 2014.

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## **List of Acronyms**

ADF - Augmented dickey-fuller

CoP – Convention of the Parties

EPSRC - Engineering and Physical Sciences Research Council

EU - European Union

FE – Fixed Effects

FsQCA – Fuzzy set Qualitative Comparative Analyze

GARCH - Generalized Autoregressive Conditional Heteroscedasticity

GDP - Gross Domestic Product

HDI - Human Development Index

IPCC - Intergovernmental Panel on Climate Change

LLC - Levin-Lin-Chu tests

MIBEL – Mercado Ibérico de Electricidade

OLS - Ordinary Last Squares

R&D - Research and Development

RE – Random Effects

RQ - Research Question

SDG - Sustainable Development Goals

UCL - University College London

UN - United Nations

WDI - World Bank's Development Indicators

WGI - Worldwide Governance Indicators

WoS - Web of Science

# **Chapter 1. Introduction and research overview**

## **1.1 Overview**

Research on the energy sector addresses several interesting questions, not only from a scholarly perspective but also from the viewpoints of consumers, producers, and policy makers. Topics related to pollution, the use of renewable energies, energy efficiency and the electricity transmission network have drawn global attention for many years, but more recently, they have become even more central due to the so-called “climate emergency” cited by the United Nations’ Secretary-General António Guterres.

One of the main questions that has arisen in the energy sector concerns the effects of different types of energy and their use on global climate change. As a consequence of this debate, legislation has been issued to address such concerns in an attempt to further sustainable development. Examples include the Kyoto Protocol, the 2030 Agreement, the Paris Agreement, and others.

The present dissertation examines the 2030 Climate and Energy Framework Agreement (hereafter the 2030 Agreement) from different perspectives illustrated over three chapters. This Agreement has the purpose of setting out EU-wide targets to curtail dangerous climate change by limiting global warming. The 2030 Agreement sets a required EU target of an at least 40% domestic reduction in greenhouse gas emissions by 2030 relative to 1990 levels. The second main goal is for the share of renewable energy consumed in the EU in 2030 to be at least 27%. The last main goal is to improve energy efficiency in 2030 by at least 27% relative to forecasts of forthcoming energy consumption.

An integrated approach has been developed for the period up to 2030 as an attempt to guarantee regulatory certainty for investors and to harmonize EU countries' efforts. The framework aims to help drive progress towards the development of a low-carbon economy and an energy system that guarantees reasonable energy supplies for all consumers, improves the security of the EU's energy supplies, decreases dependence on energy imports, produces new opportunities for growth and job creation and brings environmental and health benefits, e.g., by decreasing air pollution. Chapter 2 presents a bibliometric analysis of the latest approaches adopted to study this phenomenon and to characterize the evolution of related publications, topics that are considered most relevant, main contributors, and degrees of multidisciplinary and international collaboration. Chapter 3 uses both quantitative and qualitative methodologies to analyse impacts of the 2030 Agreement on the electricity derivative markets of Iberian countries and to examine volatility in markets, peak prices and seasonality. Chapter 4 presents an exploratory analysis of the impact of the 2030 Agreement on the R&D activities of companies in the energy sector, namely, in terms of research and development (R&D) intensity and the determinants of R&D intensity. The three empirical works presented in this thesis consider different methodologies and types of data focused on a common theme: the energy sector and the 2030 Agreement.

This thesis contributes to the literature by combining diverse techniques and advancing knowledge as follows:

- 1) This work studies the latest literature on energy, specifically on the electricity sector in terms of the Paris Agreement, to demonstrate the importance of this sector for academics, practitioners, and policy makers. To this end, it compiles publications such as academic articles, books and conference proceedings produced from 2016 to 2019 from around the

world. In doing so, we document the state of the art in this area, determine what has already been studied in this area and which approaches have been adopted, and identify what remains to be studied in the future.

- 2) This work provides evidence of the impact of the 2030 Agreement on the behaviour of spot electricity prices and on the volatility of electricity in the Portuguese and Spanish markets. The study helps assess whether a convergence of the two markets has occurred within the framework of a single electricity market in the European Union. In doing so, this study:
  - a) identifies the configurations that lead to a more stable price in MIBEL (Mercado Ibérico de Electricidade).
  - b) highlights the relevance of the 2030 Agreement as a policy mechanism for combating climate change and promoting the United Nations (UN) Sustainable Development Goals (SDGs).
- 3) This work advances research on the impacts of the 2030 Agreement in terms of R&D intensity by determining variables that explain R&D in the energy sector by compiling a database on R&D expenditures of energy sector companies before and after the 2030 Agreement. Differences in the R&D behaviour of energy companies headquartered in EU28 countries versus others are identified from the perspective of R&D.

The general theme of this thesis is of utmost relevance to economists and managers, as awareness has risen regarding the impacts that might be felt in different markets and companies and on the importance of aligning activities with sustainability principles and the UN's SDGs. It is important to follow the behaviours of different nations

that have promised to improve the planet's living conditions for its citizens by 2030 by working together and ensuring that no one is left behind.

In measuring the effects of the 2030 Agreement on EU countries, this work explores the effects on markets and companies with a general research question: “what are the effects of the 2030 Agreement on the energy sector from the perspective of markets and companies?”. To do so, we start with a theoretical chapter that presents a discussion of the literature in this field on the 2030 Agreement and then summarize the questions and findings of the two subsequent empirical chapters of this work.

The contributions of this thesis can be viewed from different perspectives: at the academic, policy and managerial levels. For academia, the practical contributions of this thesis lie in it calling attention to an emerging topic that relates electricity to the political measures of the 2030 Agreement, which have been taken to mitigate climate change and contribute to a sustainable world. From a managerial point of view, specifically from the derivative market's perspective, this work explores the recent liberalization of the electricity markets of Iberian countries and the specificities of this commodity, including its seasonality, high volatility, and peak prices. Despite decreasing volatility, peak prices still exist, and thus policy makers must keep improving the grid to avoid constraints. In better understanding energy companies' policies, this thesis reveals that the 2030 Agreement in itself did not bring about an increase in expenses related to innovation, which could be a cause for concern in terms of compromising the future fight against climate change. In being attentive to these results, policy makers may wish to consider measures to promote R&D as a catalyst for global sustainability.

## 1.2 Relevance of the study

Traditional means of producing electricity are highly polluting. Thus, it has become necessary to find new forms of energy production that can be less polluting (Forero, Barrios, & Forero, 2019). Toledano, Shah, Maennling, & Lasnick, (2020) note that in 2017, electricity and heat generation were responsible for 41% of all gas emissions. The effects of climate change have been increasingly visible in our daily lives. Extreme weather events are growing more frequent and more directly visible from the rise of sea levels due to glacial melt and with increasingly frequent periods of extreme drought occurring worldwide (Erickson, 2017). These changes will impact the health of the planet as well as economic progress. To fight unwanted climate changes, it is necessary to bring to the discussion the interests of all generations. The implementation of change must rely in particular on the concerns of younger generations, whose future will rely on decarbonization and energy use (Monyei & Oladeji, 2019).

With the goal of promoting sustainable development, i.e., to not further compromise future generations, in 2015, the UN's created 17 global goals call the SDGs, for which economic and social development are integrated with environmental sustainability (Biermann, Kanie, & Kim, 2017). Each of the SDGs has a list of targets that are measured with indicators. The SDGs recognize the relationships between climate change, energy access and development (Brecha, 2019).

According to Lin and Chen (2019), the innovation of renewable energy technologies is positively associated with R&D expenditures and economic growth and in this way can contribute to the sustainable development goals and mainly SDG 7 - renewable energies and SDG 13 - climate change. Beyond the decrease in greenhouse gas emissions, the SDGs can help mitigate climate change and increase renewable energy consumption without compromising the other main goals of the 2030 Agreement or

improving energy efficiency. Encouraging the end user to be more energy efficient may reduce energy demand in peak hours to the benefit of consumers (lower energy costs) and energy utilities (improved control of energy supplies) and also improve the efficiency of the overall energy system through the installation of smart grids for the distributed generation of electricity. Therefore, the energy sector has access to several ways to help create a more sustainable world. However, one must not strictly focus on one of these objectives but on the interplay of all three to mitigate climate change in a sustainable way.

The importance of this study is further reinforced by the fact that researchers so far have not compared the evolution of markets and companies in the antecedent period with that for the period after the 2030 Agreement. This dissertation addresses this research gap and can inspire more research on the electricity sector more specifically within the 2030 Agreement framework.

### 1.3 Procedures and applied methodologies

This dissertation uses two methodological approaches: quantitative and qualitative. According to Thomas (2004), employing several methodologies can allow a researcher to strengthen interpretations of a phenomenon. The use of qualitative and quantitative techniques together can thus support a complementary analysis.

Chapter 2 applies several techniques. First, a systematic literature review allows us to identify the pertinent literature. The systematic literature review approach allows for the analysis of large quantities of information (“big data”), mapping out areas of uncertainty and identifying research gaps (Petticrew & Roberts, 2006). After our initial search for data, a bibliometric analysis was conducted to assess the actual state of research on the topic of this thesis. The bibliometric analysis involved a statistical analysis of

descriptions of the included publications and of exploratory techniques applied. These tools are considered useful for analysing new trends in the relevant literature and identifying shifts in the boundaries of disciplines (Aria & Cuccurullo, 2017).

The data collected were retrieved from Web of Science (WoS) and Scopus, and because the Paris Agreement was signed by 196 countries, the literature mostly focuses on this agreement. Note, however, that the basis for the Paris Agreement lies in the agreement signed by EU countries in the previous year. As the main difference between the two, the Paris Agreement does not set goals in terms of timing, while the 2030 Agreement establishes 2030 as the deadline for reducing greenhouse gas emissions, increasing renewable energy consumption, and increasing energy efficiency. Because the latter Agreement is restricted to the EU28 countries, consensus among countries was easier to reach. On the other hand, the Paris Agreement, having been signed by 196 countries, did not achieve consensus in relation to time targets, and countries such as the US and Brazil have already abandoned the Agreement. It has also been criticized for being unambitious and for lacking instruments that impose mandatory emission reductions. However, as the Paris Agreement has been signed by most countries and thus has more coverage, scholarly research has focused more on this agreement than on the 2030 Agreement. Therefore, our bibliometric research used the Paris Agreement and Electricity as keywords in identifying publications about these topics.

Chapter 3 also applies several methodologies. We first obtained derivative contracts for electricity from the MIBEL database. For this study, the base price of the spot price was used, and contracts created over six years were manually collected. Using a quantitative technique, an econometric approach was adopted to capture the behaviour of spot electricity prices in the time series while taking into account the timing of the signing of the 2030 Agreement.

In the second stage, a qualitative methodology was applied to determine which conditions contribute to stability and non-stability in prices in the Portuguese and Spanish markets. A fuzzy-set Qualitative Comparative Analyze (fsQCA) was adopted to develop an understanding of the circumstances under which electricity price stability can be achieved in a similar way to what has already been done in reference to other contexts (e.g., Wu, Yeh, Huan, & Woodside, 2014).

Chapter 4 explains our several procedures and techniques. First, data on companies in the energy sector were collected from the Thompson Reuters Eikon database. We focused on listed companies because there is more information available about these firms' R&D expenditures. Then, it was necessary to organize the data by company headquarters. We used that approach following (Engel, Rothgang, & Eckl, 2016), who claim that R&D activities are mainly concentrated in the headquarters of companies. Of 469 companies in the energy sector, only 90 companies have been identified as having R&D expenditures available. However, these 90 companies represent more than 50% of the revenues of the energy sector.

After identifying companies by R&D expenditures and their respective headquarters, the World Bank Development Indicators (WDI) database was accessed to gather country-level information. Finally, all the collected data were merged.

With these data, a panel data analysis was conducted. This econometric approach allows the analysis of data from the perspective of cross-sectional units over time. The main reasons for the use of panel data is that, in the first place, looking at the dynamic relationships with single cross sections is not possible. Secondly, the cross section does not allow to control for unobserved heterogeneity (Wooldridge, 2010).

Table 1.1 below summarizes the method and procedures applied in the 3 chapters presenting our empirical studies as well as the databases used for our research. For each study, the procedures and methods used are presented as well as the number of observations for each sample and their respective sources.

**Table 1.1:** Summary of procedures, methods, data collected and sources

|           | <b>Procedures and Methods</b>                                                                               | <b>Data Collected and Source(s)</b>                                           |
|-----------|-------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|
| Chapter 2 | 1) Systematic literature review (SLR)                                                                       | <b>Database 1:</b> 210 scientific publications                                |
|           | 2) Bibliometric analysis                                                                                    | Source: Web of Science (WoS) and Scopus                                       |
| Chapter 3 | 3) Synthesis techniques                                                                                     |                                                                               |
|           | 1) Manual collection of spot prices from the OMIP/OMEL database                                             |                                                                               |
|           | 2) Development of a database using Excel by compiling data from OMIP/OMEL and Datastream                    | <b>Database 2:</b> 1476 observations<br>Source: OMIP/OMEL                     |
|           | 3) Econometric analysis using Eviews                                                                        | <b>Database 3:</b> 1039 observations<br>Source: OMIP/OMEL and DataStream      |
| Chapter 4 | 4) FsQCA analysis                                                                                           |                                                                               |
|           | 1) Collection of data from Thompson Reuters Eikon                                                           |                                                                               |
|           | 2) Development of a database using Excel by compiling data from the Thompson Reuters Eikon database and WDI | <b>Database 4:</b> 557 observations<br>Source: Thompson Reuters Eikon and WDI |
|           | 3) Panel data analysis using STATA                                                                          |                                                                               |

#### 1.4 Thesis structure

The dissertation is organized into five chapters. The first chapter presents an introduction and research overview and a summary of the structure of the thesis, including an account of its contributions, relevance, and applications to the topic under analysis. This chapter also describes the methodologies and procedures that are used.

The next three chapters each correspond to a different “paper”. Chapter 2, *Toward the Paris Agreement implementation impact on electricity sector: The emerging reality*, presents our bibliometric literature review of relevant publications referring to the Paris

Agreement and electricity, identifying main authors and topics studied as well as trends emerging over time. Chapter 3, *The impact of the 2030 Climate and Energy Framework Agreement on electricity prices in MIBEL: A mixed-methods approach*, presents an analysis of the behaviour of electricity spot prices in the Portuguese and Spanish markets before and after the 2030 Agreement. Chapter 4, *Determinants of the R&D investment of listed companies that disclose R&D expenditures*, addresses the 2030 Agreement from the perspective of energy companies in terms of R&D expenditures by comparing conditions before and after the signing of the agreement.

Finally, the fifth chapter provides a brief conclusion highlighting the main findings of this research, new focuses emerging from the study, and the main limitations and implications of the investigation.

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## **Chapter 2: Towards the Paris Agreement implementation impact on the electricity sector: The emerging reality**

### **Abstract**

The signing of the Paris Agreement has created a new avenue of research because it sets out a global challenge to tackle climate change by limiting global warming.

The topic is of growing interest involving investigators from different scientific areas, with the focus being on the increase in the consumption of renewable energies and, consequently, on the reduction of carbon dioxide emissions.

From the research, most studies use simulation models to verify whether the goals set out in the Agreement are achievable. This chapter presents an analytical review of the publications in order to assess the attention and awareness focused on the Paris Agreement and, specifically, the electricity sector. For this purpose, this study uses a bibliometric analysis considering authors, the types of documents, the title of the sources, the year of publication, the institutions, the languages, the countries of origin, and related concepts.

In conclusion, the study's most frequent terms are "Paris Agreement", "carbon", "climate change" and "renewable energy". It also concludes that the topic is of growing interest within academia. The results of this paper provide to energy researchers a relevant overview of the tendencies and scope of the Paris Agreement.

**Keywords:** Paris Agreement; Electricity; Bibliometric analysis

## 2.1 Introduction

There is a growing awareness that human actions are affecting life on the planet. This is reflected in the climatic changes seen in recent times. In order not to further compromise future generations, it is necessary that the new generations have a more relevant role in relation to decarbonization and energy use (Monyei & Oladeji, 2019) and an effort must be made to find less polluting forms of energy production (Forero et al., 2019), as it is clear that electricity is one of the world's major assets. However, the energy sector is responsible for 41% of the gas emissions (Toledano, Shah, Maennling, & Lasnick, 2020).

With the goal of safeguarding the future for coming generations, on October 24<sup>th</sup>, 2014 European Union (EU) member states signed the 2030 Climate and Energy Policy Framework. This agreement was the basis the following year for the signing of the Paris Agreement. After 2014, several other agreements have been signed by numerous countries; in particular, the United Nations Agreement in 2015. However, the agreement between the EU member states is the most ambitious, showing the greatest commitment to reach the goals set in 2014. The 5<sup>th</sup> Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) gives a broad view of the key economic sectors affected by the Paris Agreement such as energy, water services, transports, tourism, insurance and financial services, among others. The IPCC report demonstrates the impacts of climate change on development by making a global and sectoral assessment (Gomez-Echeverri, 2018). As mentioned by Arto, Capellán-Pérez, Lago, Bueno, & Bermejo (2016), the use of energy is associated to the level of the human development index (HDI) thus being a key economic sector in the degree of development of a country. The energy sector (in particular the fossil energy) will suffer a change due to the climate policies, i.e., the switch to production of clean energies. On the other hand, clean energies could be boosted by

the established goals of higher energy consumption. The Paris Agreement is an important milestone and has given rise to a new avenue for the publication of research related to the Paris Agreement and its links to markets and companies in the electricity sector. According to Sattler, Clemmer, Richardson, & Cowin (2020), the decarbonization of the electricity sector is one of the cost-effective ways to reduce CO<sub>2</sub>. Hence the reason for analyzing the research that has been conducted in the electricity area since then.

This work analyzes the characteristics of publications related to the Paris Agreement and electricity topics. Using a bibliometric analysis, a descriptive review has been carried out to identify the main topics, authors, the types of documents, the title of the sources, the publications over time, the institutions, and the country of origin of these publications.

## 2.2 Towards the Paris Agreement

Climate change has become an increasingly pressing issue on the political agenda around the world. This is not only due to environmental sustainability matters, but also because sustainability has an economic and financial impact. These economic-financial issues are mainly those that generate less agreement among the different countries. Whereas developed and major polluting countries are aware that they should care about climate change and adopt measures that promote greater environmental and economic sustainability (Cooper, 2016), the poorest countries feel that these impositions are causing a greater gap between rich and poor nations. According to Diffenbaugh and Burke (2019), wealthy countries benefit more from the activities that cause global warming than poor countries. This process of recognizing the need to take measures that have a real impact on the planet's sustainability has been gradual, with the first major agreement being

signed by UN countries, the Kyoto Agreement, in 1997. The signatories of the Agreement introduce, for the first time, quantitative and achievable targets that can reduce carbon dioxide emissions by each country in order to combat climate change (Wei, Mi, & Huang, 2015). The Kyoto Agreement also introduced a sustainable solidarity mechanism in which those countries that were required to reduce their levels of carbon dioxide emissions could help developing countries by implementing appropriate projects in those countries, and thus be compensated for not achieving the reduction established in their own countries. The Kyoto Agreement established that industrialized countries should reduce their carbon dioxide emissions by 5.2% compared to 1990 levels. Taking carbon dioxide emissions into account has opened the door for countries to negotiate with each other, thereby creating a new regulated emissions trading market (Thomas, 2014).

Although the Kyoto Agreement was the first major attempt to address the problems of climate change, since 1995 UN countries have been meeting regularly, and these meetings have been called Convention of the Parties (CoP). For the first time, UN countries sought to reach consensus on how to mitigate climate change (Rocha & Santos, 2018). Despite the countries' commitment, the results obtained were limited, as countries such as the United States did not ratify the Agreement, while Canada withdrew from it when it saw that it was not going to meet the established goals. Additionally, the Agreement also failed to engage citizens and companies.

Consensuses are hard to reach among the UN's 190 countries. For that reason, the EU has shown greater flexibility (consensus between 28 countries is easier than 196), commitment, and granted greater freedom in terms of the timing of actions to be taken. To reach an agreement, they know they must acknowledge the singularities of each country.

In order to reach this Agreement, which aims at achieving sustainable development, there have been regular CoP's since 1995 designed to reach an agreement that is attainable by all countries, and at the same time there is a commitment to achieve it. According to article 2, 1a) United Nations, (2015) the objective is "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels". Countries have submitted comprehensive national action plans on climate change to reduce their emissions. Governments have agreed to report every five years on their contribution to setting more ambitious targets, reporting to other governments and the public on their performance in achieving their goals to ensure transparency and oversight. The EU and other developed countries will continue to provide climate change funding to help developing countries reduce emissions and build resilience to climate change impacts.

In the aftermath of the Paris Agreement, the countries agreed that responsibilities and capabilities are not the same for all countries. Nevertheless, the target should be shared across the board. Therefore, each country's specific conditions should be taken into consideration, as well as their differing responsibilities and obligations (Falconí, Burbano, Ramos-Martin, & Cango, 2019). Each country has the freedom and responsibility to define policies and measures to combat climate change. These policies and measures can be at the level of transport, buildings and efficiency, or agriculture, for example. In terms of transport, conditions can be created for reducing transport needs by promoting public transport or avoiding transport based on fossil fuels. From the point of view of buildings, support can be provided for promoting building refurbishment and alterations by introducing more efficient heating and cooling systems. At agricultural level, too, encouragement can be given to more eco-friendly agricultural practices, for

example, while taking into consideration that policies and measures should not be in isolation, but adopted in a holistic way (Köppl & Schleicher, 2018). The implementation of these policies may have a tax component, but also a strong technological side (Falconí et al. 2019), which requires investments. As a result of the regular meetings to discuss and prevent climate change and promote sustainable development, in 2014 the countries established a goal that the temperature of the planet should not rise by more than 2°C, and preferably not surpass 1.5°C by 2030. To achieve this target, the increase in the consumption of renewables should increase by at least 27%; the reduction in carbon dioxide emissions should be in the order of 40% compared to 1990 levels, and there should be an increase in energy efficiency to mitigate climate change (European Council, 2014).

In this way, the European Union thus wants to show that it is a world leader in combating climate change, seeking to work towards cleaner, safer, more accessible and more sustainable energy, and this has been endorsed by the European Commission as one of its main objectives. As stated by Moedas, (2018), these objectives can be verified by strengthening the research on clean energies that can be verified in the areas of renewable energies, energy storage, increasing electric mobility, and decarbonizing existing buildings. To achieve these goals, funding for projects related to climate change involving the energy, transport, environment and/or agriculture sectors has been made available through the Horizon 2020 program. The energy sector, in particular the electricity, will be transformed by climate policy because the production of electricity through fossil fuels will be forced to reduce and will emerge the production of electricity by renewable sources. Political measures have been taken to foster the use of renewable energies such as feed-in tariffs, tenders and tax incentives that have positive effects (Kilinc-Ata, 2016).

### 2.3 Data collection and selection criteria

This study uses a bibliometric analysis to advance the knowledge related to publications associated with the Paris Agreement and the electricity sector. The bibliometric analysis consists of the collection, treatment and quantitative analysis of scientific output (Verbeek, Debackere, Zimmermann, & Luwel, 2002), and according to Petticrew and Roberts (2006) allows mapping out areas of uncertainty and identifying what has been done in a particular field of research and what can be done. The data are retrieved from the Web of Science (WoS) and Scopus databases because they are the principal and largest collections of articles and publishers at global level (Dangelico, 2016; Alves & Mariano, 2018; Ertz & Leblanc-Proulx, 2018; Ochoa, Alvarez, & Acevedo, 2019).

The topic of electricity is vast and has been studied from different perspectives. However, with the signing of the Paris Agreement, a new avenue of investigation emerged that could be explored by academics. The Paris Agreement is often associated solely with climate change, as reflected by the growing number of publications on this topic (Haunschild, Bornmann, & Marx, 2016). Nevertheless, the Agreement goes beyond climate change, addressing several sectors of the economy, with one of them being electricity. The search strategy is thus to combine the keywords of the “Paris Agreement” and “Electricity”, following the rationale of Haunschild et al. (2016), with a view to delimiting the scope of this work. These two keywords (Paris Agreement and electricity) cover this work’s major themes, and so all the explorations it contains begin with their combination. A special mention should be made of the fact that all research fields were considered, therefore considering all the works in the different areas that refer to these two keywords.

Based on the rationale of Martin & Assenov, (2012), the search involved the intersection of the publications that interconnected the Paris Agreement and the electricity to books and/or chapters of books, articles in scientific journals, conferences papers and reviews in journals. Masters or doctoral theses were not included, nor were government and not-for-profit organization reports, working papers and magazine publications because they were not available in the databases used. Likewise, when research could not be authenticated, it was regretfully excluded.

In addition to the keywords, another filter that limited the scope of the searches was that only abstracts written in English were considered (Liu, Wang, Li, Chen, & Sun, 2019), because according to Bocanegra-valle research, (2014) publishing in English guarantees both a large number of readers and a focus of research and opportunities for international cooperation and recognition (Alves & Mariano, 2018). In order to delimit this analysis of the existing scientific output on these subjects, it was decided to consider the publications issued between 2015 and 2019, in the last case because it's the most recent full year available. It is important to study the literature produced because it shows whether the Agreement is having recognized implications or not and can give clues to future addenda to the Agreement, or on the contrary, to its abandonment.

## 2.4 Data Analysis and Results

A possible way to evaluate whether the research is up to date is by analyzing the temporal distribution of publications. Table 2.1 presents the evolution of the several types of publications.

**Table 2.1:** Evolution of scientific publications (2016-2019)

|      | <u>Articles</u> | <u>Book</u> | <u>Book Chapter</u> | <u>Review</u> | <u>Conference paper</u> | <u>Total</u> |
|------|-----------------|-------------|---------------------|---------------|-------------------------|--------------|
| 2016 | 4               | 0           | 0                   | 1             | 0                       | 5            |
| 2017 | 27              | 0           | 2                   | 1             | 6                       | 36           |
| 2018 | 50              | 2           | 4                   | 7             | 13                      | 76           |

|              |            |          |          |           |           |            |
|--------------|------------|----------|----------|-----------|-----------|------------|
| 2019         | 74         | 0        | 1        | 7         | 11        | <b>93</b>  |
| <b>Total</b> | <b>155</b> | <b>2</b> | <b>7</b> | <b>16</b> | <b>30</b> | <b>210</b> |

According to Figure 1, out of the 210 publications, 155 are articles in journals, 16 are review, 9 are books and book chapters and 30 are conference papers. Looking only at published articles it is possible to verify that the number tripled from 2017 compared to 2019.

Following the rationale of Hansen, Liu, and Morrison (2019), another bibliometric analysis involves the number of publications in peer-reviewed journals. In the case of the 155 articles, they were published in journals covering different scientific areas. Considering the three scientific journals with more publications in these topic (Energy Policy, Applied Energy, and Energies) (see table 2.2), it should also be pointed out that they involve major fields (Energy, Environmental Science, and Engineering), which indicates the presence of a common read in several areas (see table 2.3). It's also important to mention that 43 of the documents are classified as "other" in journals from fields of study such as Law, Urban Studies, Geography, and Applied Physics, among others, which gives a degree of transversal importance in the academy.

**Table 2.2:** Top journals by number of articles published between 2016 and 2019

| <b>Journal</b>                                                                                    | <b>2016</b> | <b>2017</b> | <b>2018</b> | <b>2019</b> | <b>Total</b> |
|---------------------------------------------------------------------------------------------------|-------------|-------------|-------------|-------------|--------------|
| Energy Policy                                                                                     | 0           | 6           | 3           | 8           | 17           |
| Applied Energy                                                                                    | 0           | 4           | 5           | 7           | 16           |
| Energies                                                                                          | 0           | 1           | 2           | 7           | 10           |
| Journal of Clean Production                                                                       | 0           | 0           | 3           | 5           | 8            |
| Environmental Research Letters                                                                    | 0           | 0           | 3           | 4           | 7            |
| Renewable and Sustainable Energies Review                                                         | 0           | 0           | 2           | 4           | 6            |
| Sustainability Switzerland                                                                        | 1           | 2           | 1           | 2           | 6            |
| Joule                                                                                             | 0           | 1           | 1           | 3           | 5            |
| Climate Policy                                                                                    | 1           | 0           | 0           | 2           | 3            |
| Energy Economics                                                                                  | 0           | 0           | 0           | 3           | 3            |
| International Journal Of Greenhouse Gas Control                                                   | 0           | 0           | 1           | 2           | 3            |
| Philosophical Transactions Of The Royal Society: A Mathematical Physical And Engineering Sciences | 0           | 0           | 3           | 0           | 3            |

**Table 2.3:** Documents by subject

| <b>Documents by subject area</b>    |     |
|-------------------------------------|-----|
| Energy                              | 133 |
| Environmental Science               | 109 |
| Engineering                         | 72  |
| Social Sciences                     | 32  |
| Economics, Econometric and Finance  | 17  |
| Mathematics                         | 17  |
| Business, Management and Accounting | 14  |
| Earth and Planetary Sciences        | 13  |
| Physics and Astronomy               | 12  |
| Computer Science                    | 10  |
| Others                              | 43  |

As regards the articles' keywords, there are 160 different keywords in the 210 documents, with an average of 8.6 keywords per document. The most popular keywords are “Climate Change”, “Greenhouse Gases”, “Carbon Dioxide”, “Emission Control”, and the expression “Gas Emissions” (see table 2.4).

**Table 2.4:** Top ten keywords in the articles

| <b>Keywords</b>        | <b>Total</b> |
|------------------------|--------------|
| Climate Changes        | 70           |
| Greenhouse Gases       | 57           |
| Carbon Dioxide         | 49           |
| Emission Control       | 45           |
| Gas Emissions          | 36           |
| Electricity Generation | 34           |
| Energy Policy          | 34           |
| Carbon Emission        | 32           |
| Fossil Fuels           | 32           |
| Global Warming         | 32           |

Through bibliometric analysis it was also possible to understand which topics are most covered by the journals that publish the most about Paris Agreement and Electricity. Based on the ranking of the top five scientific journals by number of publications, table 2.5 shows the most researched topics. The most common keywords are Climate Change

and Greenhouse Gases, and they are common to several journals. Energy Policy, Fossil Fuels, Electricity, Electricity Generation and International have several appearances in this top five journals.

**Table 2.5:** Top keywords in the main journals in terms of the number of publications

| Journal                           | Top Keywords<br>1 <sup>st</sup> | Total | Top Keywords<br>2 <sup>nd</sup> | Total | Top Keywords<br>3 <sup>rd</sup> | Total |
|-----------------------------------|---------------------------------|-------|---------------------------------|-------|---------------------------------|-------|
| Energy Policy                     | Climate Change                  | 11    | Energy Policy                   | 10    | Electricity<br>Generation       | 8     |
| Applied Energy                    | Climate Change                  | 8     | Electricity                     | 7     | International<br>Agreement      | 7     |
| Energies                          | Greenhouse Gases                | 5     | Gas Emissions                   | 4     | Energy Management               | 3     |
| Journal of Clean<br>Production    | Climate Change                  | 4     | Greenhouse Gases                | 4     | Carbon Dioxide                  | 3     |
| Environmental<br>Research Letters | Fossil Fuels                    | 8     | Climate Change                  | 6     | Carbon Emission                 | 4     |

Another aspect to take in considerations is the main authors that published on the Paris Agreement in terms of electricity for the period 2015-2019. According to table 2.6, the number of authors is diverse and small, albeit suggesting some specialization in the topic, with five or more publications on the subject. The main contributors are Dmitrii Bogdanov and Christian Breyer, with seven and six publications each in journals and ten and nine if we consider all types of documents used in the sample.

**Table 2.6:** Top authors by articles and documents (2016 – 2019)

| Author               | Nº. Articles | Author               | Nº. of Documents |
|----------------------|--------------|----------------------|------------------|
| Brayer, C.           | 7            | Brayer, C.           | 10               |
| Bogdanov, D.         | 6            | Bogdanov, D.         | 9                |
| Mac Dowell, N.       | 5            | Mac Dowell, N.       | 5                |
| Daggash, H.          | 4            | Daggash, H.          | 4                |
| Guillén-Gosálbez, G. | 3            | Child, M.            | 4                |
| Krey, V.             | 3            | Jaguer-Waldau,<br>A. | 4                |
| Aghahosseini,        | 2            | Frafan, J.           | 3                |
| Akimoto, K.          | 2            | Fasihi, M.           | 3                |

|                |   |                      |   |
|----------------|---|----------------------|---|
| Algunaibet, I. | 2 | Guillén-Gosálbez, G. | 3 |
| Burandt, T.    | 2 | Hanak, D.            | 3 |

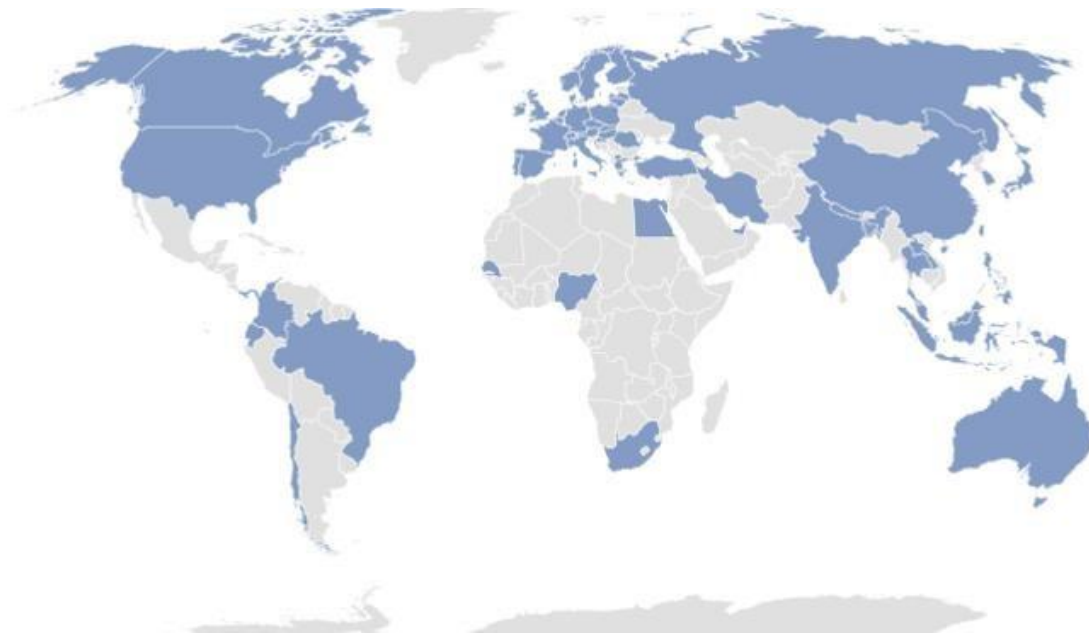
Additional way to analyze whether the publication of an article is relevant to the area is through the number of citations where a higher number of citation indicates a higher impact (Liu et al., 2019; Penela, Morais, & Gregory, 2019). In order to capture each publication's impact, the number of individual citations was retrieved from Scopus, as shown in table 2.7. The most cited article is “100% Clean and Renewable Wind, Water, and Sunlight All-Sector Energy Roadmaps for 139 Countries of the World” by Mark Jacobson and their colleagues which was published in 2017 in the journal “Joule” and has been cited 160 times. This article develops roadmaps to transform the all-purpose energy infrastructures (electricity, transportation, heating/cooling, industry, agriculture/forestry/fishing) of 139 countries to ones powered by wind, water, and sunlight. The second most cited article is by Christian Breyer and Dmitrii Bogdanov with 58 citations until the end of 2019, focusing in a model based on hourly resolution for an entire year, the world structured in 145 regions, high spatial resolution of the input renewable energy resource data, and transition steps of 5-year periods. Most studies of journals in the sample are based on simulation models, but no studies have been developed where it is exposed that has already been changed due the implementation of the Agreement.

**Table 2.7:** Top 10 most cited academic papers on timeshare by Scopus at 31 of December 2019

| Title                                                                                                                                                              | Pub. Year | Citations | Authors                                                                                                                                                                                                                                                                                                           |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 100% Clean and Renewable Wind, Water, and Sunlight All-Sector Energy Roadmaps for 139 Countries of the World                                                       | 2017      | 160       | Jacobson, M., Delucchi, M., Bauer, Z., Goodman, S., Chapman, W., Cameron, M., Bozonnat, C., Chobadi, L., Clonts, H., Enevoldsen, P., Erwin, J., Fobi, S., Goldstrom, O., Hennessy, E., Liu, J., Lo, J., Meyer, C., Morris, S., Moy, K., O'Neill, P., Petkov, I., Redfern, S., Schucker, R., Sontag, M. & Wang, J. |
| Solar photovoltaics demand for the global energy transition in the power sector                                                                                    | 2018      | 58        | Breyer, C., Bogdanov, D., Aghahosseini, A., Gulagi, A., Child, M., Oyewo, A., Farfan, J., Sadovskaia, K. & Vainikka, P.                                                                                                                                                                                           |
| Photovoltaics and wind status in the European Union after the Paris Agreement                                                                                      | 2018      | 45        | Lacal Arantegui, R., Jäger-Waldau, A.                                                                                                                                                                                                                                                                             |
| A review of technology and policy deep decarbonization pathway options for making energy-intensive industry production consistent with the Paris Agreement         | 2018      | 36        | Bataille, C., Åhman, M., Neuhoﬀ, K., Nilsson, L., Fishedick, M., Lechtenböhmer, S., Solano-Rodriguez, B., Denis-Ryan, A., Stiebert, S., Waisman, H., Sartor, O., & Rahbar, S.                                                                                                                                     |
| The need for national deep decarbonization pathways for effective climate policy                                                                                   | 2016      | 33        | Bataille, C., Waisman, H., Colombier, M., Segafredo, L., Williams, J. & Jotzo, F.                                                                                                                                                                                                                                 |
| Can Australia power the energy-hungry asia with renewable energy?                                                                                                  | 2017      | 28        | Gulagi, A., Bogdanov, D., Fasihi, M. & Breyer, C.                                                                                                                                                                                                                                                                 |
| A review of developments in technologies and research that have had a direct measurable impact on sustainability considering the Paris agreement on climate change | 2017      | 25        | Foley, A., Smyth, B.M., Pukšec, T., Markovska, N., Duić, N.                                                                                                                                                                                                                                                       |
| Climate Impacts in Europe Under +1.5°C Global Warming                                                                                                              | 2018      | 24        | Jacob, D., Kotova, L., Teichmann, C., Sobolowski, S., Vautard, R., Donnelly, C., Koutroulis, A., Grillakis, M., Tsanis, I., Damm, A., Sakalli, A. & van Vliet, M.                                                                                                                                                 |
| Snapshot of photovoltaics-March 2017                                                                                                                               | 2017      | 23        | Jäger-Waldau, A.                                                                                                                                                                                                                                                                                                  |
| Pathways limiting warming to 1.5°C: A tale of turning around in no time?                                                                                           | 2018      | 22        | Kriegler, E., Luderer, G., Bauer, N., Baumstark, L., Fujimori, S., Popp, A., Rogelj, J., Strefer, J., & Van Vuuren, D.                                                                                                                                                                                            |

A further aspect to consider is the geographic spread of the journals that publish articles on the Paris Agreement. The location of the authors' institutions indicates whether a subject attracts interest in global research; whether there is a geographic spread or a concentration in certain countries. According to this research, there are up to fifty seven different nationalities of affiliation, with a predominance of Europe-based authors with about half of the publications, although all the continents are represented (see figure 2.1).

**Figure 2.1:** Nationality of the author's institutions



**Legend:** In blue the countries of author's institutions, in grey the countries without author's institutions.

The Paris Agreement has created interest among researchers from around the world, because every continent has at least one instance of research with at least one publication. When the articles in co-authorship are considered, European authors are responsible for around 58% of the publications, but every continent has researchers pursuing these topics. Another highlight is that 59 of the 155 articles published are co-authored with researchers from other countries, reflecting a concern for the internationalization of research, and thereby enriching it. This fact can be interpreted as a sharing of knowledge. By contrast, only fourteen articles have a single author, while the others have coauthors. In the case of books and chapters, the sample has two cases of publications by single individuals, and all the other publications have more than one author.

To analyze the impact of academia to these topics it's interesting to check the distributions by affiliations. Table 2.8 presents the authors' affiliation to a research center

or university. According to the table, universities in the United Kingdom have the highest output related to the topic. Other countries such as Germany, the Netherlands, and Japan have a relative weight in global terms.

**Table 2.8:** List of researchers' main affiliations (2016-2019)

| Affiliation by articles                               | N° Publications | Affiliation by documents                              | N° Publications |
|-------------------------------------------------------|-----------------|-------------------------------------------------------|-----------------|
| UCL                                                   | 11              | UCL                                                   | 12              |
| Imperial College London                               | 10              | Imperial College London                               | 10              |
| Leppeenrannan                                         | 7               | Leppeenrannan                                         | 10              |
| Technical University of Berlin                        | 6               | Technical University of Berlin                        | 7               |
| International Institute for Applied Studies           | 6               | International Institute for Applied Studies           | 7               |
| Potsdam Institut                                      | 6               | Potsdam Institut                                      | 6               |
| Tshingua University                                   | 5               | Utrecht University                                    | 5               |
| ETH Zurich                                            | 5               | ETH Zurich                                            | 5               |
| National Institute for Environmental Studies of Japan | 5               | National Institute for Environmental Studies of Japan | 5               |
| Utrecht Universuty                                    | 4               | Stanford university                                   | 5               |

It is worth mentioning that agencies that have sought to encourage research on certain topics are sometimes linked to universities and/or research centers through funding. Table 2.9 presents the funding agencies that contribute to the development of studies related to these subjects. Government agencies such as the Engineering and Physical Sciences Research Council (EPSRC), Tekes, European Union, and the National Natural Science Foundation of China often subsidize projects in partnership with universities to seek an independence perspective from academic researchers.

**Table 2.9:** List of the main affiliations of researchers and funding agencies (2016-2019)

| Funding Sponsor                                    | N° Documents |
|----------------------------------------------------|--------------|
| Engineering and Physical Sciences Research Council | 12           |
| Tekes                                              | 8            |
| Natural Environment Research Council               | 7            |
| National Natural Science Foundation of China       | 6            |
| European Commission                                | 5            |
| Agence Nationale de la Recherche                   | 3            |
| Bundesministerium für Bildung und Forschung        | 3            |

|                                    |   |
|------------------------------------|---|
| Deutsche Bundesstiftung Umwelt     | 3 |
| Deutsche Forschungsgemeinschaft    | 3 |
| Energimyndigheten                  | 3 |
| European Regional Development Fund | 3 |
| Horizon 2020 Framework Programme   | 3 |
| National Eye Research Centre       | 3 |

## 2.5 Discussion

The results of the analysis of publications on this topic show a year-on-year increase. The year 2019 accounts for 44% of the publications. Articles are the main contributors, with 73% of the publications. The figure also shows an increase in articles, and between 2016 and 2019 this growth was almost twenty times higher than the initial analysis period. They show a big increase in 2019 compared to 2016, when four articles were published compared to 2019, when 74 were published. Regarding the three journals with the most publications (Energy Policy, Applied Energy and Energies), it can be inferred from their titles that they involve different core areas (Energy, Environmental Science and Engineering), indicating a presence of a topic that is mainstream to several areas of study and can be explored in different ways.

The dedicated publications cover two predominant areas, energy and the environment. These main areas reveal that 2019 was the year with the most publications in the period under analysis. Almost all the other areas record a strong growth of results in 2019 over previous years, except for the economics area, which was similar between 2017 and 2018. These results may reflect researchers' perception of a new line of research that has emerged with the Paris Agreement. In terms of articles, the number has been growing from year to year; however, the journals with the most publications are Energy Policy, Applied Energy and Energies. The difference between these journals and the others can be explained by the fact that the former already published on these topics in

2017 while the other journals had almost no publications, which only started to appear in 2018.

Regarding the articles' keywords, they reflect each one's content, so based on Table 2.2 there are three keywords with more frequent citations in the articles under analysis. Climate Changes itself stands out, such as (Obregón, Orozco, Camargo, Duarte, & Valencia, 2019), but then the keywords that relate to the Paris Agreement's objectives and goals appear, such as combating greenhouse gases to ensure the average global temperature increases by no more than 2°C or ideally 1.5°C, by reducing emissions through the increased consumption of renewable energy such is suggested by Forero et al., (2019).

Regarding the number of citations, the top articles in terms of citations address the goals set by the Paris Agreement and how to achieve them by 2030 or 2050, according to the timeframe set in an attempt to combat global climate change. Most of them focus on renewable energy issues through simulation models, setting consumption targets and seeking sustainable development in accordance with the principles of Glavas and Mish (2015), which are social development, economic development, and sustainable development, in other words, the triple bottom line approach.

The Paris Agreement was signed by UN countries in 2015, and after that the academic community has paid it increasing attention, with the majority of publications emerging from research conducted by at least one author from a European institution. This can be explained by the fact the EU has paid special attention to climate change, and in 2014 signed an agreement similar to this with the goal of combating climate change and thereby alerting the European scientific community to these issues. Furthermore, academia in the US and Asian countries such as China and Japan have also paid considerable attention to this subject. A reflection of its multidisciplinary nature is

measured by the circumstance of the increasing number of publications with co-authors from different nationalities, giving different perspectives to the research and due to the nature of the issues involved (Foley, Smyth, Pukšec, Markovska, & Duić, 2017).

Based on table 2.6, it is worth highlighting the clearly leading role in research on the topics of the Paris Agreement and electricity played by European universities compared to the rest of the world. A special mention should be made of universities in London, with a combined total of 17 publications. In a similar vein, the same is true for research institutions funding these topics, where there is a predominance of European agencies, with emphasis on the EU as the main funding agency for publications in the period mentioned.

## 2.6 Conclusions and Policy Implications

This study uses a bibliometric analysis to advance the state-of-the-art related to publications associated with the Paris Agreement and the electricity sector with a trend for conducting research on the Agreement. First, 44% of the publications identified were published in 2019, and second, articles in journals account for nearly 73% of the sample.

Although the Agreement was signed in 2015, these topics have gained increasing interest over time in academia, bringing a new emerging reality. The Paris Agreement and electricity are studied from different perspectives and various research fields, and the results show that the areas of most interest in these topics are energy and the environment. A reflection of this interest is the fact that the keywords most cited apart from Paris Agreement are carbon, climate change, and renewable. These keywords are consistent with the Agreement's main objectives.

The main journals are from different fields of research (Energy Policy, Applied Energy and Energies), and the results show a predominance of keywords related to climate changes, greenhouse gases. There is an increased use of renewable energy, particularly photovoltaic, because the cost of production is relatively lower than other renewable energies. This increase was fostered by the Paris Agreement.

It is also perceptible that as the years go by there are more and more publications on these subjects and how they affect society at large. It is worth mentioning that countries in Europe are the ones that have more authors and more publications on these subjects, perhaps reflecting their greater commitment to the goals established in the Agreement. However, there are no authors with numerous publications yet, and the two most prolific ones have ten publications each. This reflects a new field of research in which scholars have much to explore. The study also shows that the behaviors need to be changed in order to achieve the goals set with the Agreement in order to have greater acceptance by all stakeholders because the simulations models. Most studies propose forecasting models in order to determine how the targets set by the Agreement in terms of carbon dioxide emissions or the increase in renewable energy consumption will be achieved. This is demonstrated by simulation models where it is necessary to increase renewable energy consumption and reduce carbon dioxide emissions to achieve the set objectives and this way combat the climate change and achieve a sustainable development. However, no studies were found to show the evolution of the situation before the Agreement and the post-agreement as a way to understand if what is being done allows to reach the established goals. This analysis could be done both at the level of the electricity markets as well as in companies, particularly in the energy sector because the energy sector is responsible for 41% of the gas emissions (Toledano et al., 2020) and as such political decisions will have to go through these companies.

This study has made a number of important contributions to this new and global energy subfield, namely, the Paris Agreement. First, it contributes by collecting the academic publications related to this recent issue, and by serving as the first-ever compilation of journals and chapters in books on energy and the Paris Agreement. It then uses this information to further study and understand the trends that are emerging in the energy sector related to the Paris Agreement and this way contributes for a sustainable development.

Another important contribution is related to the identification of key authors and institutions in this topic. These data are valuable as they provide opportunities for exchange and collaboration among researchers to advance this body of literature, which is in considerable need of further research.

The research also contributes to the perception that is necessary implement measures to achieve the goals of the Paris Agreement because several studies show the way of reach the goals set, through simulation models, but few studies have been published about the results of that measures in the real world by countries and/or companies on the planet. Also, to check the implementation of the Sustainable Development Goals (SDG's) that come from the Paris Agreement.

Finally, this study shows that these subjects can be explored from different perspectives, with different fields of research interest. This is revealed by the fact that there are publications from different areas and by the increase in the number of journals starting to pay attention to this subject. However, it was found that at both market and company levels the current situation has not yet been analyzed in comparison with the period before the Agreement.

It's a study that will help policy making and influencing social actors to take a position on the Paris agreement.

As in any study, this work also has its limitations. The first limitation is due to the language used for the research/paper selection. Following common practice (Bocanegra-Valle, 2014), the study has considered only those studies published in English. Thus, works in other languages, and which may be relevant to these topics, were not selected or analyzed, so a more complete analysis is pending (Liu et al., 2019). Like the results obtained by Gatto & Drago, (2020) it is not expected that the results will change significantly. Nevertheless, the replication of the bibliometric analysis methodology is advised to other areas of electricity and Paris Agreement, such as renewable energies, to improve the understanding of the main contributors to each research theme is critical to the growth of research on this field, as collaborative work and discussion of information can lead to theoretical expansion.

Similarly, the choice of just two databases, the WoS and the Scopus, means there are other works that were not taken into consideration. A further study could be conducted based on other bibliometric sources to verify whether there is a similar tendency to that presented here of a greater number of authors and works in Europe. There is also a need to verify whether the works not indexed in the databases used here have an equal dispersion of scientific areas on this topic.

Since this is a recent topic, more research should emerge over the coming years, and in five years from now a similar study should be conducted and the results compared.

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## Appendix A: Summary of publications collected

|   | Authors                                                | Year | Title                                                                                                                                                    | Journals                                 | Type    |
|---|--------------------------------------------------------|------|----------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|---------|
| 1 | Aghahosseini, A., Bogdanov, D. & Barbosa, L.           | 2019 | Analyzing the feasibility of powering the Americas with renewable energy and inter-regional grid interconnections by 2030                                | Renewable and Sustainable Energy Reviews | Article |
| 2 | Aguacil, S., Lufkin, S. & Rey, E.                      | 2019 | Active surfaces selection method for building-integrated photovoltaics (BIPV) in renovation projects based on self-consumption and self-sufficiency      | Energy and Buildings                     | Article |
| 3 | Alassi, A., Banales, S. & Ellabban, O.                 | 2019 | HVDC Transmission: Technology Review, Market Trends and Future Outlook                                                                                   | Renewable and Sustainable Energy Reviews | Article |
| 4 | Alghamdi, A., Bahaj, A. & Wu, Y.                       | 2017 | Assessment of Large Scale Photovoltaic Power Generation from Carport Canopies                                                                            | Energies                                 | Article |
| 5 | Algunaibet, I. & Guillen-Gosalbez, G.                  | 2019 | Life cycle burden-shifting in energy systems designed to minimize greenhouse gas emissions: Novel analytical method and application to the United States | Journal of Cleaner Production            | Article |
| 6 | Algunaibet, I., Pozo, C. & Galan-Martin, A.            | 2019 | Quantifying the cost of leaving the Paris Agreement via the integration of life cycle assessment, energy systems modeling and monetization               | Applied Energy                           | Article |
| 7 | Ali, Saleem H.; Perrons, Robert K.; Toledano, Perrine; | 2019 | A model for "smart" mineral enterprise development for spurring investment in climate change mitigation technology                                       | Energy Research & Social Science         | Article |

|    | Authors                                                                                                                                                                     | Year | Title                                                                                                                                                      | Journals                                    | Type    |
|----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|---------|
| 8  | Ameli, N., Pisu, M. & Kammen, D.                                                                                                                                            | 2017 | Can the US keep the PACE? A natural experiment in accelerating the growth of solar electricity                                                             | Applied Energy                              | Article |
| 9  | Amjath-Babu, T., Sharma, B. & Brouwer, R.                                                                                                                                   | 2019 | Integrated modelling of the impacts of hydropower projects on the water-food-energy nexus in a transboundary Himalayan river basin                         | Applied Energy                              | Article |
| 10 | Andiappan, V., Foo, D. & Tan, R.                                                                                                                                            | 2019 | Process-to-Policy (P2Pol): using carbon emission pinch analysis (CEPA) tools for policy-making in the energy sector                                        | Clean Technologies and Environmental Policy | Article |
| 11 | Arcos-Vargas, A., Cansino, J. & Román-Collado, R.                                                                                                                           | 2018 | Economic and environmental analysis of a residential PV system: A profitable contribution to the Paris agreement                                           | Renewable and Sustainable Energy Reviews    | Article |
| 12 | Baek, S., Kim, H. & Chang, H. J.                                                                                                                                            | 2016 | Optimal Hybrid Renewable Airport Power System: Empirical Study on Incheon International Airport, South Korea                                               | Sustainability (Switzerland)                | Article |
| 13 | Baek, Y., Jung, T. & Kang, S.                                                                                                                                               | 2019 | Low carbon scenarios and policies for the power sector in Botswana                                                                                         | Climate Policy                              | Article |
| 14 | Bartholdsen, H., Eidens, A. & Loeffler, K.                                                                                                                                  | 2019 | Pathways for Germany's Low-Carbon Energy Transformation Towards 2050                                                                                       | Energies                                    | Article |
| 15 | Bataille, C., Åhman, M., Neuhoff, K., Nilsson, L. Fishedick, M., Lechtenböhmer, S., Solano-Rodriquez, B., Denis-Ryan, A., Steiber, S., Waisman, H., Sartor, O. & Rahbar, S. | 2018 | A review of technology and policy deep decarbonization pathway options for making energy-intensive industry production consistent with the Paris Agreement | Journal of Cleaner Production               | Article |

|    | Authors                                                                          | Year | Title                                                                                                           | Journals                                                                                                                                 | Type       |
|----|----------------------------------------------------------------------------------|------|-----------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|------------|
| 16 | Bataille, C., Waisman, H., Colombier, M., Segafredo, L. Williams, J. & Jotzo, F. | 2016 | The need for national deep decarbonization pathways for effective climate policy                                | Climate Policy                                                                                                                           | Article    |
| 17 | Bauer, A. & Menrad, K.                                                           | 2019 | Standing up for the Paris Agreement: Do global climate targets influence individuals' greenhouse gas emissions? | Environmental Science & Policy                                                                                                           | Article    |
| 18 | Belkhir, L. & Elmeligi, A.                                                       | 2018 | Assessing ICT global emissions footprint: Trends to 2040 & recommendations                                      | Journal of Cleaner Production                                                                                                            | Article    |
| 19 | Bhardwaj, A., Joshi, M. & Khosla, R.                                             | 2019 | More priorities, more problems? Decision-making with multiple energy, development and climate objectives        | Energy Research & Social Science                                                                                                         | Article    |
| 20 | Bhuvaneswari, N., Ramesh, L. & Ramakrishnan, R.                                  | 2017 | Indian railways carbon emission reduction and energy performance                                                | 2016 International Conference on Control Instrumentation Communication and Computational Technologies, ICCICCT 2016 7988051, pp. 746-749 | Conference |
| 21 | Bodis, K. Kougias, I. & Taylor, N.                                               | 2019 | Solar Photovoltaic Electricity Generation: A Lifeline for the European Coal Regions in Transition               | Sustainability                                                                                                                           | Article    |
| 22 | Boffino, L., Conejo, A. & Sioshansi, R.                                          | 2019 | A two-stage stochastic optimization planning framework to decarbonize deeply electric power systems             | Energies                                                                                                                                 | Article    |

|    | Authors                                                                                                                    | Year | Title                                                                                                                              | Journals                                                                                         | Type         |
|----|----------------------------------------------------------------------------------------------------------------------------|------|------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|--------------|
| 23 | Breyer, C., Bogdanov, D., Aghahosseini, A., Gulagi, A., Child, M., Oyewo, A. S., Farfan, J., Sadovskaia, K. & Vainikka, P. | 2018 | Solar photovoltaics demand for the global energy transition in the power sector                                                    | Progress in Photovoltaics: Research and Applications                                             | Article      |
| 24 | Breyer, C., Khalili, S. & Bogdanov, D.                                                                                     | 2019 | Solar photovoltaic capacity demand for a sustainable transport sector to fulfil the Paris Agreement by 2050                        | Progress in Photovoltaics                                                                        | Article      |
| 25 | Brook, B. W., Blees, T., Wigley, T. & Hong, S.                                                                             | 2018 | Silver Buckshot or Bullet: Is a Future "Energy Mix" Necessary?                                                                     | Sustainability (Switzerland)                                                                     | Article      |
| 26 | Brown, M. & Li, Y.                                                                                                         | 2019 | Carbon pricing and energy efficiency: pathways to deep decarbonization of the US electric sector                                   | Energy Efficiency                                                                                | Article      |
| 27 | Burandt, T., Xiong, B. & Loeffler, K.                                                                                      | 2019 | Decarbonizing China's energy system - Modeling the transformation of the electricity, transportation, heat, and industrial sectors | Applied Energy                                                                                   | Article      |
| 28 | Carvajal, P. & Li, F.                                                                                                      | 2019 | Challenges for hydropower-based nationally determined contributions: a case study for Ecuador                                      | Climate Policy                                                                                   | Article      |
| 29 | Castiella, I.                                                                                                              | 2018 | Support for renewable energies and the creation of a truly competitive electricity market: The case of the European Union          | Innovation in Energy Law and Technology: Dynamic Solutions for Energy Transitions<br>pp. 305-320 | Book Chapter |
| 30 | Cherdkeattikul, S. & Ida, T.                                                                                               | 2019 | The influence of additional hemicellulose on Japanese cedar based pre-carbonized solid biofuel properties                          | Mechanical Engineering Journal                                                                   | Article      |

|    | Authors                                                 | Year | Title                                                                                                                                | Journals                                        | Type       |
|----|---------------------------------------------------------|------|--------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|------------|
| 31 | Child, M. Bogdanov, D. & Breyer, C.                     | 2018 | The role of storage technologies for the transition to a 100% renewable energy system in Europe                                      | Energy Procedia<br>155, pp. 44-60               | Conference |
| 32 | Child, M., Kemfert, C. & Bogdanov, D.                   | 2019 | Flexible electricity generation, grid exchange and storage for the transition to a 100% renewable energy system in Europe            | Renewable Energy                                | Article    |
| 33 | Choi, Y., Lee, H. & Mastur, A.                          | 2019 | Are Sustainable Development Policies Really Feasible? Focused on the Petrochemical Industry in Korea                                 | Sustainability<br>(Switzerland)                 | Article    |
| 34 | Clancy, J., Curtis, J. & Ó'Gallachóir, B.               | 2018 | Modelling national policy making to promote bioenergy in heat, transport and electricity to 2030-Interactions, impacts and conflicts | Energy Policy                                   | Article    |
| 35 | Cooper, M.                                              | 2016 | Renewable and distributed resources in a post-Paris low carbon future: The key role and political economy of sustainable electricity | Energy Research and Social Science              | Article    |
| 36 | Cooper, M.                                              | 2018 | Governing the global climate commons: The political economy of state and local action, after the US flip-flop on the Paris Agreement | Energy Policy                                   | Article    |
| 37 | Da Silva, S., Miralles-Wilhelm, F. & Munoz-Castillo, R. | 2019 | The Paris pledges and the energy-water-land nexus in Latin America: Exploring implications of greenhouse gas emission reductions     | Plos One                                        | Article    |
| 38 | Daggash, H., Heuberger, C. & Mac Dowell, N.             | 2019 | The role and value of negative emissions technologies in decarbonising the UK energy system                                          | International Journal of Greenhouse Gas Control | Article    |

|    | Authors                                     | Year | Title                                                                                                             | Journals                                         | Type    |
|----|---------------------------------------------|------|-------------------------------------------------------------------------------------------------------------------|--------------------------------------------------|---------|
| 39 | Daggash, H. & Mac Dowell, N.                | 2019 | Higher Carbon Prices on Emissions Alone Will Not Deliver the Paris Agreement                                      | Joule                                            | Article |
| 40 | Daggash, H. & Mac Dowell, N.                | 2019 | The implications of delivering the UK's Paris Agreement commitments on the power sector                           | International Journal of Greenhouse Gas Control  | Article |
| 41 | Daggash, H. & Mac Dowell, N.                | 2019 | Structural Evolution of the UK Electricity System in a below 2 degrees C World                                    | Joule                                            | Article |
| 42 | Dal Maso, M., Olsen, K. & Dong, Y.          | 2019 | Sustainable development impacts of nationally determined contributions: assessing the case of mini-grids in Kenya | Climate Policy                                   | Article |
| 43 | de Melo, F., Silvestre, A. & Carvalho, M.   | 2019 | Carbon footprints associated with electricity generation from biomass syngas and diesel                           | Environmental Engineering and Management Journal | Article |
| 44 | Dhar, S., Pathak, M. & Shukla, P.           | 2018 | Transformation of India's transport sector under global warming of 2 degrees C and 1.5 degrees C scenario         | Journal of Cleaner Production                    | Article |
| 45 | Diaz, F. & Cilinskis, E.                    | 2019 | Use of Multi-Criteria TOPSIS Analysis to Define a Decarbonization Path in Colombia                                | Environmental and Climate Technologies           | Article |
| 46 | Duarte, R., Sánchez-Chóliz, J. & Sarasa, C. | 2018 | Consumer-side actions in a low-carbon economy: A dynamic CGE analysis for Spain                                   | Energy Policy                                    | Article |
| 47 | Erickson, L.                                | 2017 | Reducing Greenhouse Gas Emissions and Improving Air Quality: Two Global Challenges                                | Environmental Progress & Sustainable Energy      | Article |

|    | Authors                                                                                  | Year | Title                                                                                                                                                 | Journals                                                                                           | Type       |
|----|------------------------------------------------------------------------------------------|------|-------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|------------|
| 48 | E. Erickson, L. & Jennings, M.                                                           | 2017 | Energy, Transportation, Air Quality, Climate Change, Health Nexus: Sustainable Energy is Good for Our Health                                          | AIMS Public Health                                                                                 | Article    |
| 49 | Efimova, A., Ruchkina, M. & Tereshina, O.                                                | 2018 | Transformation of the energy sector in conditions of digital economy                                                                                  | Light & Engineering                                                                                | Article    |
| 50 | Ehara, T., Shigetomi, Y., Yamamoto, Y., Ochi, Y., Shiraki, H., Matsumoto, K. & Ogawa, Y. | 2018 | Driving forces underlying sub-national carbon dioxide emissions within the household sector and implications for the Paris Agreement targets in Japan | Applied Energy                                                                                     | Article    |
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| 52 | Esparta, A., Villanueva, L., Fraga, D., Lucon, O. & Dos Santos, E.                       | 2017 | Greenhouse gases emissions and official energy planning in Brazil - Natural gas contribution                                                          | International Gas Research Conference Proceedings 2, pp. 807-816                                   | Conference |
| 53 | Estevão, J., Raposo, C. & Dias Lopes, J.                                                 | 2018 | The Paris Agreement and electricity markets outside the EU                                                                                            | Contemporary Economics                                                                             | Article    |
| 54 | Evans, J., Kay, M., Prasad, A. & Pitman, A.                                              | 2018 | The resilience of Australian wind energy to climate change                                                                                            | Environmental Research Letters                                                                     | Article    |
| 55 | Eyre, N., Darby, S., Grünewald, P., McKenna, E. & Ford, R.                               | 2018 | Reaching a 1.5 degrees C target: socio-technical challenges for a rapid transition to low-carbon electricity systems                                  | Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences | Article    |

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| 56 | Falchetta, G., Gernaat, D. & Hunt, J.                                             | 2019 | Hydropower dependency and climate change in sub-Saharan Africa: A nexus framework and evidence-based review                                                        | Journal of Clean Production                                                                                                                                      | Article    |
| 57 | Farfan, J., Fasihi, M. & Breyer, C.                                               | 2019 | Trends in the global cement industry and opportunities for long-term sustainable CCU potential for Power-to-X                                                      | Journal of Clean Production                                                                                                                                      | Article    |
| 58 | Fernandez-Guillamon, A., Das, K. & Cutululis, N.                                  | 2019 | Offshore Wind Power Integration into Future Power Systems: Overview and Trends                                                                                     | Journal of Marine Science and Engineering                                                                                                                        | Article    |
| 59 | Fiorelli, M., Sanseverino, E., Massaro, F., Favuzza, S., Ippolito, M. & Zizzo, G. | 2018 | The energy market impact of climate change on electricity generation in Europe                                                                                     | 2018 IEEE International Conference on Environment and Electrical Engineering and 2018 IEEE Industrial and Commercial Power Systems Europe (EEEIC / I&CPS Europe) | Conference |
| 60 | Foley, A., Smyth, B., Pukšec, T., Markovska, N. & Duić, N.                        | 2017 | A review of developments in technologies and research that have had a direct measurable impact on sustainability considering the Paris agreement on climate change | Renewable and Sustainable Energy Reviews                                                                                                                         | Article    |
| 61 | Fortes, P., Simoes, S., & Gouveia, J.                                             | 2019 | Electricity, the silver bullet for the deep decarbonisation of the energy system? Cost-effectiveness analysis for Portugal                                         | Applied Energy                                                                                                                                                   | Article    |

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| 63 | Fujita, T., Ginting, G., Uchida, K., Chandran, R., Maki, S., Ashina, S., Yabe, N., Boer, R. & Fujii, M. | 2018 | Employing electricity-consumption monitoring systems and integrative time-series analysis models: A case study in Bogor, Indonesia | Frontiers in Energy                                                                        | Article      |
| 64 | Galán-Martín, A., Pozo, C., Azapagic, A., Grossmann, I., Mac Dowell, N. & Guillén-Gosálbez, G.          | 2018 | Time for global action: an optimised cooperative approach towards effective climate change mitigation                              | Energy and Environmental Science                                                           | Article      |
| 65 | Gambhir, A., Rogelj, J. & Luderer, G.                                                                   | 2019 | Energy system changes in 1.5 degrees C, well below 2 degrees C and 2 degrees C scenarios                                           | Energy Strategy Reviews                                                                    | Article      |
| 66 | García-Labiano, F., García-Díez, E., de Diego, L.F., (...), Gayán, P., Adánez, J.                       | 2018 | The uses of bioethanol in chemical looping processes                                                                               | Bioethanol and Beyond: Advances in Production Process and Future Directions<br>pp. 315-344 | Book Chapter |
| 67 | García-Labiano, F., Izquierdo, M., Adánez, J., Mendiara, T., de Diego, L., Abad, A. & Gayán, P.         | 2018 | Negative CO2 emissions through the use of biofuels in chemical looping technology: A review                                        | Applied Energy                                                                             | Article      |
| 68 | Gellert, A., Florea, A. & Fiore, U.                                                                     | 2019 | A study on forecasting electricity production and consumption in smart cities and factories                                        | International Journal of Information Management                                            | Article      |
| 69 | Gerres, T., Chaves Avila, J. & Martin Martinez, F.                                                      | 2019 | Rethinking the electricity market design: Remuneration mechanisms to reach high RES shares. Results from a Spanish case study      | Energy Policy                                                                              | Article      |

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| 70 | González-Aparicio, I., Kapetaki, Z. & Tzimas, E.                               | 2018        | Wind energy and carbon dioxide utilization as an alternative business model for energy producers: A case study in Spain               | Applied Energy                         | Article     |
| 71 | Gonzalez-Mahecha, E., Lecuyer, O., Hallack, M., Bazilian, M. & Vogt-Schilb, A. | 2019        | Committed emissions and the risk of stranded assets from power plants in Latin America and the Caribbean                              | Environmental Research Letters         | Article     |
| 72 | Gorjian, S., Zadeh, B. & Eltrop, L.                                            | 2019        | Solar photovoltaic power generation in Iran: Development, policies, and barriers                                                      | Renewable & Sustainable Energy Reviews | Article     |
| 73 | Goundar, A., Newell, A., Nuttall, P., Rojon, I. & Samuwai, J.                  | 2017        | King Canute muses in the South Seas: Why aren't Pacific Islands transitioning to low carbon sea transport futures?                    | Marine Policy                          | Article     |
| 74 | Gulagi, A., Bogdanov, D., Fasihi, M. & Breyer, C.                              | 2017        | Can Australia Power the Energy-Hungry Asia with Renewable Energy?                                                                     | Sustainability (Switzerland)           | Article     |
| 75 | Ha, S., Tae, S. & Kim, R.                                                      | 2019        | Energy Demand Forecast Models for Commercial Buildings in South Korea                                                                 | Energies                               | Article     |
| 76 | Haas, J., Cebulla, F., Nowak, W., Rahmann, C. & Palma-Behnke, R.               | 2018        | A multi-service approach for planning the optimal mix of energy storage technologies in a fully-renewable power supply                | Energy Conversion and Management       | Article     |
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| 79 | Hanak, D., Jenkins, B., Kruger, T. & Manovic, V.                  | 2017        | High-efficiency negative-carbon emission power generation from integrated solid-oxide fuel cell and calciner                                     | Applied Energy                                         | Article     |
| 80 | Hanak, D., Michalski, S. & Manovic, V.                            | 2018        | From post-combustion carbon capture to sorption-enhanced hydrogen production: A state-of-the-art review of carbonate looping process feasibility | Energy Conversion and Management                       | Article     |
| 81 | Handayani, K., Krozer, Y. & Filatova, T.                          | 2017        | Trade-offs between electrification and climate change mitigation: An analysis of the Java-Bali power system in Indonesia                         | Applied Energy                                         | Article     |
| 82 | Hayashi, A., Sano, F., Nakagami, Y. & Akimoto, K.                 | 2018        | Changes in terrestrial water stress and contributions of major factors under temperature rise constraint scenarios                               | Mitigation and Adaptation Strategies for Global Change | Article     |
| 83 | Hill, G., Heidrich, O., & Creutzig, F.                            | 2019        | The role of electric vehicles in near-term mitigation pathways and achieving the UK's carbon budget                                              | Applied Energy                                         | Article     |
| 84 | Hoeltl, A., Brandtweiner, R., Berger, T. & Bates, R.              | 2018        | Urban growth and energy supply in African cities: The case of Ethiopia                                                                           | WIT Transactions on the Built Environment              | Conference  |
| 85 | Hooftman, N., Messagie, M., Segard, J., Coosemans, T. & Joint, F. | 2018        | In-Life Range Modularity for Electric Vehicles: The Environmental Impact of a Range-Extender Trailer System                                      | Applied Sciences                                       | Article     |

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| 87 | Hu, X., Chen, Y. & Ding, Z.                                                                                                                                                                   | 2019 | Vehicle Optimal Control Design to Meet the 1.5 degrees C Target: A Control Design Framework for Vehicle Subsystems | Energies                                                                                       | Article      |
| 88 | Huang, C. & Shen, H.                                                                                                                                                                          | 2019 | Maximum hydrogen production by using a gasifier based on the adaptive control design                               | International Journal of Hydrogen Energy                                                       | Article      |
| 89 | Iyer, G., McJeon, H., Edmonds, J., Williams, J., Ledna, C., Clarke, L. & Kyle, P.                                                                                                             | 2017 | Measuring progress from nationally determined contributions to mid-century strategies                              | Nature Climate Change                                                                          | Article      |
| 90 | Izquierdo, M. & Río, P.                                                                                                                                                                       | 2018 | Do the costs of renewable energy promotion outweigh its benefits? An analysis of the European case                 | Innovation in Energy Law and Technology: Dynamic Solutions for Energy Transitions<br>pp. 1-457 | Book Chapter |
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| 92 | Jacob, D., Kotova, L., Teichmann, C., Sobolowski, S., Vautard, R., Donnelly, C., Koutroulis, A., Grillakis, M., Tsanis, I., Damm, A., Sakalli, A., Vliet, M., Centre, B., Ipsl, L. & Uvsq, C. | 2018 | Climate Impacts in Europe Under+1.5 degrees C Global Warming                                                       | Earth's Future                                                                                 | Article      |

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| 94 | Jäger-Waldau, A.                                                                                                                                                                                                                                                                                                                                                    | 2017 | Snapshot of Photovoltaics-March 2017                                                                                          | Sustainability<br>(Switzerland)                                                                                                                          | Article    |
| 95 | Jäger-Waldau, A., Huld, T., Bódis, K. &<br>Szabo, S.                                                                                                                                                                                                                                                                                                                | 2018 | Photovoltaics in Europe after the Paris Agreement                                                                             | IEEE 7th World<br>Conference on<br>Photovoltaic Energy<br>Conversion (WCPEC) (A<br>Joint Conference of 45th<br>IEEE PVSC, 28th PVSEC<br>& 34th EU PVSEC) | Conference |
| 96 | Jewell, J. & Cherp, A.                                                                                                                                                                                                                                                                                                                                              | 2019 | On the political feasibility of climate change mitigation<br>pathways: Is it too late to keep warming below 1.5 degrees<br>C? | Wiley Interdisciplinary<br>Reviews-climate Change                                                                                                        | Article    |
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| 98  | Jiang, J., Ye, B. & Liu, J.                                                                            | 2019 | Peak of CO2 emissions in various sectors and provinces of China: Recent progress and avenues for further research                                   | Renewable & Sustainable Energy Reviews                                                | Article    |
| 99  | Jiang, K., He, C., Dai, H., Liu, J. & Xu, X.                                                           | 2018 | Emission scenario analysis for China under the global 1.5 degrees C target                                                                          | Carbon Management                                                                     | Article    |
| 100 | Jungmeier, G., Lettmayer, G., Bird, N. & Schwarzsinger, S.                                             | 2017 | The paris-lifestyle - Analysis and assessment of biomass use for low carbon lifestyles to reach the climate targets 2050                            | European Biomass Conference and Exhibition Proceedings 2017(25thEUBCE), pp. 1537-1539 | Conference |
| 101 | Kabins, S., Bjørn, A., Jensen, C., Schmidt, J., Birkved, M., Nygaard, S., Kalbar, P. & Hauschild, M.   | 2018 | Pursuing necessary reductions in embedded GHG emissions of developed nations: Will efficiency improvements and changes in consumption get us there? | Global Environmental Change                                                           | Article    |
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| 103 | Kang, S., Selosse, S. & Maïzi, N.                                                                      | 2018 | Contribution of global GHG reduction pledges to bioenergy expansion                                                                                 | Biomass and Bioenergy                                                                 | Article    |
| 104 | Karim, M., Munir, A., Karim, M., Muhammad-Sukki, F., Abu-Bakar, S., Sellami, N., Bani, N. & Hassan, M. | 2018 | Energy Revolution for Our Common Future: An Evaluation of the Emerging International Renewable Energy Law                                           | Energies                                                                              | Article    |
| 105 | Karstensen, J. & Peters, G.                                                                            | 2018 | Distributions of carbon pricing on extraction, combustion and consumption of fossil fuels in the global supply-chain                                | Environmental Research Letters                                                        | Article    |

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| 106 | Khalili, S., Rantanen, E., Bogdanov, D. & Breyer, C.                                                                   | 2019 | Global Transportation Demand Development with Impacts on the Energy Demand and Greenhouse Gas Emissions in a Climate-Constrained World              | Energies                                                                                           | Article |
| 107 | Khatiwada, D., Purohit, P. & Ackom, E.                                                                                 | 2019 | Mapping Bioenergy Supply and Demand in Selected Least Developed Countries (LDCs): Exploratory Assessment of Modern Bioenergy's Contribution to SDG7 | Sustainability (Switzerland)                                                                       | Article |
| 108 | Kim, C. & Park, H.                                                                                                     | 2017 | An Investigation Into the Impact of Limiting Carbon Emissions on the Korean Power System and the Electricity Market                                 | Journal of Electrical Engineering and Technology                                                   | Article |
| 109 | Kim H. & Kakinaka, M.                                                                                                  | 2019 | Renewable energy consumption, carbon emissions, and development stages: Some evidence from panel cointegration analysis                             | Renewable Energy                                                                                   | Article |
| 110 | Kim, N., Shim, M. & Won, D.                                                                                            | 2018 | Building Energy Management Strategy Using an HVAC System and Energy Storage System                                                                  | Energies                                                                                           | Article |
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| 112 | Kriegler, E., Luderer, G., Bauer, N., Baumstark, L., Fujimori, S., Popp, A., Rogelj, J., Strefler, J. & van Vuuren, D. | 2018 | Pathways limiting warming to 1.5 degrees C: a tale of turning around in no time?                                                                    | Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences | Article |
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| 114 | Lacal Arantegui, R. & Jäger-Waldau, A.                  | 2018 | Photovoltaics and wind status in the European Union after the Paris Agreement                                                                               | Renewable and Sustainable Energy Reviews                                  | Article      |
| 115 | Leimbach, M., Roming, N., Schultes, A. & Schwerhoff, G. | 2018 | Long-Term Development Perspectives of Sub-Saharan Africa under Climate Policies                                                                             | Ecological Economics                                                      | Article      |
| 116 | Li, F. & Strachan, N.                                   | 2019 | Take me to your leader: Using socio-technical energy transitions (STET) modelling to explore the role of actors in decarbonisation pathways                 | Energy Research & Social Science                                          | Article      |
| 117 | Li, F. & Trutnevyte, E.                                 | 2017 | Investment appraisal of cost-optimal and near-optimal pathways for the UK electricity sector transition to 2050                                             | Applied Energy                                                            | Article      |
| 118 | Li, H., Li, F. D. S., Yu, X. & Shen, J.                 | 2018 | Carbon Emission Intensity, Economic Development and Energy Factors in 19 G20 Countries: Empirical Analysis Based on a Heterogeneous Panel from 1990 to 2015 | Sustainability (Switzerland)                                              | Article      |
| 119 | Lindroos, T., Ryden, M. & Langorgen, O.                 | 2019 | Robust decision making analysis of BECCS (bio-CLC) in a district heating and cooling grid                                                                   | Sustainable Energy Technologies and Assessments                           | Article      |
| 120 | Lindström, A., Rosner, K. & Granit, J.                  | 2017 | Cooperation in the power sector to advance regionalisation processes and sustainable energy flows                                                           | Global Resource Scarcity: Catalyst for Conflict or Cooperation? pp. 39-55 | Book Chapter |
| 121 | Litjens, G., Worrell, E. & van Sark, W.                 | 2018 | Lowering greenhouse gas emissions in the built environment by combining ground source heat pumps, photovoltaics and battery storage                         | Energy and Buildings                                                      | Article      |

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| 122 | Lopion, P., Markewitz, P., Robinius, M. & Stolten, D.                                                     | 2018 | A review of current challenges and trends in energy systems modeling                                                               | Renewable and Sustainable Energy Reviews                                        | Article    |
| 123 | Lu, X., Cao, L. & Wang, H.                                                                                | 2019 | Gasification of coal and biomass as a net carbon-negative power source for environment-friendly electricity generation in China    | Proceedings of the National Academy of Sciences of the United States of America | Conference |
| 124 | Ma, J., Oppong, A., Acheampong, K. & Abruquah, L.                                                         | 2018 | Forecasting Renewable Energy Consumption under Zero Assumptions                                                                    | Sustainability (Switzerland)                                                    | Article    |
| 125 | Maki, S., Ashina, S., Yabe, N., Boer, R., & Fujii, M., Fujita, T., Ginting, G., Uchida, K. & Chandran, R. | 2018 | Employing electricity-consumption monitoring systems and integrative time-series analysis models: A case study in Bogor, Indonesia | Frontiers in Energy                                                             | Article    |
| 126 | Maor, M., Tosun, J. & Jordan, A.                                                                          | 2017 | Proportionate and disproportionate policy responses to climate change: core concepts and empirical applications                    | Journal of Environmental Policy & Planning                                      | Article    |
| 127 | Maraseni, T. & Reardon-Smith, K.                                                                          | 2019 | Meeting National Emissions Reduction Obligations: A Case Study of Australia                                                        | Energies                                                                        | Article    |
| 128 | Matthews, N. & McCartney, M.                                                                              | 2018 | Opportunities for Building Resilience and Lessons for Navigating Risks: Dams and the Water Energy Food Nexus                       | Environmental Progress & Sustainable Energy                                     | Article    |
| 129 | May, M.                                                                                                   | 2017 | Safety first: The future of nuclear energy outside the United States                                                               | Bulletin of the Atomic Scientists                                               | Article    |

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| 130 | Mendiara, T., de Diego, L., Abad, A., Gayán, P., García-Labiano, F., Izquierdo, M. & Adánez, J.                                  | 2018 | Negative CO2 emissions through the use of biofuels in chemical looping technology: A review                                    | Applied Energy                                                                                                                   | Article    |
| 131 | Mercure, J., Pollitt, H., Edwards, N., Holden, P., Chewpreecha, U., Salas, P. Lam, A., Knobloch, F. & Vinuales, J.               | 2018 | Environmental impact assessment for climate change policy with the simulation-based integrated assessment model E3ME-FTT-GENIE | Energy Strategy Reviews                                                                                                          | Article    |
| 132 | Mercure, J., Pollitt, H., Vinuales, J., Edwards, N., Holden, P., Chewpreecha, U., Salas, P., Sognaes, I., Lam, A. & Knobloch, F. | 2018 | Macroeconomic impact of stranded fossil fuel assets                                                                            | Nature Climate Change                                                                                                            | Article    |
| 133 | Michalski, S., Hanak, D. & Manovic, V.                                                                                           | 2019 | Techno-economic feasibility assessment of calcium looping combustion using commercial technology appraisal tools               | Journal of Cleaner Production                                                                                                    | Article    |
| 134 | Michi, L., Carlini, E., Biondi, S., Capurso, P. & Santoro, M.                                                                    | 2017 | European Resource Adequacy: Success and Challenges<br>The traditional market design of 1980s not fit for today's markets       | 2017 AEIT International Annual Conference: Infrastructures for Energy and ICT: Opportunities for Fostering Innovation, AEIT 2017 | Conference |
| 135 | Miranda, M.                                                                                                                      | 2018 | Liberalization at the Speed of Light: International Trade in Electricity and Interconnected Networks                           | Journal of International Economic Law                                                                                            | Article    |
| 136 | Momodu, A.S.                                                                                                                     | 2017 | Energy use: Electricity system in West Africa and climate change impact                                                        | International Journal of Sustainable Energy Planning and Management                                                              | Article    |

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| 138 | Mu, Y., Evans, S., Wang, C. & Cai, W.    | 2018 | How will sectoral coverage affect the efficiency of an emissions trading system? A CGE-based case study of China                  | Applied Energy                     | Article |
| 139 | Nagar, P., Sharma, M. & Gupta, S.        | 2019 | A framework for developing and projecting GHG emission inventory and preparing mitigation plan: A case study of Delhi City, India | Urban Climate                      | Article |
| 140 | Niamir, L., Kiesewetter, G. & Wagner, F. | 2019 | Assessing the macroeconomic impacts of individual behavioral changes on carbon emissions                                          | Climatic Change                    | Article |
| 141 | Nong, D. & Siriwardana, M.               | 2018 | Effects on the US economy of its proposed withdrawal from the Paris Agreement: A quantitative assessment                          | Energy                             | Article |
| 142 | Nong, D., Siriwardana, M., & Perera, S.  | 2019 | Growth of low emission-intensive energy production and energy impacts in Vietnam under the new regulation                         | Journal of Cleaner Production      | Article |
| 143 | Norton, M., Baldi, A. & Buda, V.         | 2019 | Serious mismatches continue between science and policy in forest bioenergy                                                        | Global Change Biology Bioenergy    | Article |
| 144 | Ntombela, S., Bohlmann, H. & Kalaba, M.  | 2019 | Greening the South Africa's Economy Could Benefit the Food Sector: Evidence from a Carbon Tax Policy Assessment                   | Environmental & Resource Economics |         |

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| 146 | Ole, N.                             | 2018 | The Paris Agreement 2015 as a primer for developing Nigerian off-grid solar electricity                   | African Journal of International and Comparative Law                                                                | Article    |
| 147 | Oliveira, T., Gurgel, A., Tonry, S. | 2019 | International market mechanisms under the Paris Agreement: A cooperation between Brazil and Europe        | Energy Policy                                                                                                       | Article    |
| 148 | Olson, C. & Lenzmann, F.            | 2016 | Bringing the social costs and benefits of electric energy from photovoltaics versus fossil fuels to light | Energy, Sustainability and Society                                                                                  | Article    |
| 149 | Olson, C. & Lenzmann, F.            | 2016 | The social and economic consequences of the fossil fuel supply chain                                      | Energy, Sustainability and Society                                                                                  | Article    |
| 150 | Oshiro, K., Kainuma, M. & Masui, T. | 2017 | Implications of Japan's 2030 target for long-term low emission pathways                                   | Energy Policy                                                                                                       | Article    |
| 151 | Osman, O. & Sgouridis, S.           | 2018 | Optimizing the production of ammonia as an energy carrier in the UAE                                      | 5th International Conference on Renewable Energy: Generation and Application, ICREGA 2018 2018-January, pp. 277-280 | Conference |

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## **Chapter 3: The impact of the 2030 Climate and Energy Framework Agreement on electricity prices in MIBEL: A mixed-methods approach**

### **Abstract**

European Union member countries signed the 2030 Climate and Energy Framework Agreement on October 24, 2014. This framework brings with it changes in the expectations of energy consumers and producers, which opens new avenues of research. This study examines and compares the behavior of spot electricity prices in the Iberian market, MIBEL, before and after the 2030 Agreement. This study adopts a mixed-methods approach that combines a more traditional GARCH model with the qualitative fsQCA. The GARCH accounts for the well-documented characteristics of electricity prices: seasonality, high volatility, and price peaks. This method generates evidence from the Spanish and Portuguese data of reduced volatility and higher stability in prices after the signing of the 2030 Agreement. The fsQCA supports these results by identifying a larger number of paths that lead to price stability for the sub period after the signing of the 2030 Agreement.

**Keywords:** MIBEL, Electricity prices, GARCH, fsQCA.

### 3.1 Introduction

On October 24, 2014, all EU member countries signed in Paris the 2030 Climate and Energy Framework Agreement (European Council, 2014) that contemplates meeting three main objectives: a reduction target of 40% in greenhouse gas emissions relative to 1990 levels, a target to increase renewable energy to at least 27% of energy consumption, and improved energy efficiency through possible amendments to the energy efficiency directive. This study examines the behavior of electricity prices before and after the signing of the 2030 Agreement to assess its relevance.

The electricity market is one of the last to be standardized and organized in terms of financial trading. Besides national markets, multinational markets like Nord Pool exist. Nord Pool operates in Scandinavia and was the first multinational exchange for electric power to be created in the European Union (EU) (European Commission, 2016).<sup>1</sup> Portugal and Spain created MIBEL in 2007 with the purpose of serving the interests of the Iberian market. Thus, MIBEL is one of the few multinational energy markets in Europe.

Over the years, some research has addressed energy markets, mainly Germany and Scandinavia. Such financial studies mostly focus on futures contracts (Longstaff & Wang, 2004; and Ullrich, 2007). Since MIBEL is recent, information on its performance is scarce. This study examines the behavior of electricity prices in Iberia by considering this market's characteristics of seasonality, high volatility, and peaks in prices (Janczura & Weron, 2010), characteristics that can be harmful to consumers (Newbery, 1998). Because electricity derivatives are traded in MIBEL, this study also considers the behavior of spot prices. In electricity markets the spot price is a day-ahead price (i.e., the

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<sup>1</sup> Nord Pool operates in Denmark, Estonia, Finland, Latvia, Lithuania, Norway, and Sweden.

price is established on day  $t$  for delivery on day  $t+1$ ; Bierbauer, Truck, & Weron, 2004).<sup>2</sup> The study sheds light on MIBEL's operations and assesses the impact of the 2030 Climate and Energy Framework Agreement (hereafter 2030 Agreement) on price stability. This subject is particularly relevant because world leaders repeatedly express concerns regarding the link between energy and sustainability.

This chapter uses two methods and compares their results in terms of price increases and higher stability after the establishment of the 2030 Agreement. The first method is the GARCH model that uses time series data. This regression models the behavior of the electricity spot price (Shawky, Marathe, & Barrett, 2003; Hadsell & Shawky, 2007). The second method is the fuzzy-set Qualitative Comparative Analysis (fsQCA) that we use to analyze the necessary and sufficient conditions for the outcome of stability in electricity prices, as in Fiss (2007) and Ragin (2009). This method is applied to both the Portuguese and Spanish markets. With this application, we can analyze the configurations associated with the outcome before the 2030 Agreement and after its signing. For our empirical study, we collect daily data from OMIP/OMEL (The Iberian Energy Derivatives Exchange) for a four-year period — two years prior to the 2030 Agreement, and two years after.

The study extends the literature by analyzing the behavior of spot prices before and after the 2030 Agreement by using a mixed-methods approach. This approach uses the GARCH and fsQCA to extract more information about the behavior of electricity prices in MIBEL (Woodside, 2013). While the GARCH method describes the behavior

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<sup>2</sup> A “classical” spot market with immediate delivery of the acquired asset is not possible for electricity because the system operator needs advance notice to ensure feasibility for the desired schedule and transmission constraints are respected. The spot is an hourly (in some markets, a daily) contract with physical delivery (Bierbauer et al., 2004).

before and after the 2030 Agreement signing, the fsQCA methodology identifies the configurations that drive towards stability in electricity prices in Spain and Portugal.

Our findings on the impact of the 2030 Agreement disclose the intention and political will of world leaders to incrementally promote cleaner and more renewable energies, despite them being more expensive than other energies. According to Paraschiv, Erni, and Pietsch (2014) the imposition of renewable energies causes an increase in the final price consumers pay. For example, Portugal legally guarantees the consumption of electricity from renewable sources (up to a limit) although they are more expensive than fossil fuel. Our data provides evidence that the mean price increases after the signing of the 2030 Agreement.

The fact that EU members signed the 2030 Agreement might also lead one to expect a less volatile (or more predictable) energy market, as long as the agreement is credible. Our data shows that price stability increases after the agreement, with lower volatility in the time series of electricity prices in Portugal and Spain. The results from the fsQCA show that different core conditions exist for the periods before and after the 2030 Agreement — hence, the conditions that explain the outcome of stability in spot prices change. Before the agreement, only two configurations could justify the spot prices' stability in the Iberian markets. For the period after the signing of the agreement, a larger number of paths for stability became available in both countries.

The article is organized as follows: Section 2 has a literature review on the behavior of electricity prices. Section 3 contains the objectives of the study. In Section 4, we describe the sample and the results from using the GARCH. Section 5 contains the application of the fsQCA. In Section 6, we discuss the results; Section 7 is the conclusion.

### 3.2 Literature review: Behavior of electricity prices

MIBEL's creation in 2007 aimed to integrate and promote cooperation between the Portuguese and Spanish electrical systems. From 2007 onwards, it became possible to trade futures on electricity. This cooperation is based on the mechanism of market splitting that consists in the separation of markets when the supply is unable to satisfy the demand, which gives rise to price peaks.

With MIBEL's creation and the deregulation it brought to state-owned companies, investors adjusted their behavior to the new rules. The liberalization of the electricity market ended the guaranteed returns for state-owned and independent producers—producers were now competing with one another. According to Furió and Meneu (2010), competition forces state-owned companies to improve efficiency because of the market's complexity along with strong uncertainty and with significant volatility. Furió and Meneu also claim that new types of risk are an outcome of the liberalization process. For that reason, agents in the market identify a need to manage risks, in particular to hedge price risk. Hedging needs make the derivatives for the electricity market desirable to investors, consumers, and suppliers.

The three main features of electricity commodities are the impossibility of storage, seasonality, and the limited possibility of transmission (Bessembinder & Lemon, 2002; Lucia & Schwartz, 2002; Longstaff & Wang, 2004; Pirrong & Jermakyan, 2008; Pietz, 2009; Janczura, Truck, Weron & Wolff, 2013). According to Sapio and Spagnolo (2016) the difficulty in electricity transmission generates energy islands, that is, certain regions have insufficient access to energy compared to their needs. Others studies also consider the inelasticity of demand as a special feature of electricity markets (Bierbrauer et al., 2004; Janssen & Wobben, 2009; Möst & Genoese, 2009; Redl, Haas, & Böhm, 2009; Joo, Ahn, & Yoon, 2009). The impossibility to store electricity invalidates the principle

of storage cost; and thus, the arbitrage condition that would result from the time lapse is not possible (Bessembinder & Lemon, 2002; Lucia & Schwartz, 2002; Longstaff & Wang, 2004; Pirrong & Jermakyan, 2008; Pietz, 2009). Wilkens and Wimschulte (2007) find that energy loss occurs when the distance between production and consumption increases. Congestion of the electricity network is also possible due to limited transmission capacity. Electricity prices can be more volatile than other commodities' due to the impossibility of storage (Shawky et al., 2003) that forces immediate consumption. Cartea and Figueroa (2005) find that storing electricity is hard and expensive, which justifies electricity prices' sensitivity to unexpected changes in supply or demand (Janczura, Truck, Weron, & Wolff, 2013). The seasonality in electricity markets exists on daily, weekly, and annual bases (Cartea & Villaplana, 2008, Janczura et al., 2013) and should also be considered when discussing price levels.

The structure of the electricity network hampers arbitrage forces in different markets—the farther one is from the delivery point, the larger the difficulties of transmission and the subsequent energy losses (Bierbrauer et al., 2004; Marckhoff & Wimschulte, 2009).

Cartea and Villaplana (2008) propose a model that explains the wholesale electricity price with two variables: demand and production capacity. They find that forward prices are seasonal depending on the demand volatility. Pirrong and Jermakyan (2008) also present a two-variable model, demand and electricity price, and find results that support Bessembinder and Lemon (2002). With a different approach, Benth, Cartea, and Kiesel (2008) establish a relation between the forward premium and the risk preferences of market participants as well as a relation between sellers and buyers.

Ullrich (2007) and Lucia and Torró (2008) highlight the importance of water reserves for the dynamics of the premium. They find different results from Bessembinder

and Lemon (2002), who defend the existence of a relation between the forward risk premium and the volatility of the spot price after examining weekly contracts in the Scandinavian market. Geman and Vasicek (2001) find a positive asymmetry premium for daily forward contracts during the summer months in the PJM markets.<sup>3</sup> Longstaff and Wang (2004) examine the risk premium of the forwards that use prices per hour. They provide evidence of a significant forward risk premium that varies systematically throughout the day and is directly related to economic factors, such as unexpected changes in demand, spot prices, and total revenue. The substantial rise in the premium might be related to a limited transmission network for imports (Bowden, Hu, & Payne, 2009). Eydeland and Geman (1999) and Lucia and Schwartz (2002) find that prices have strong geographic and temporal dependence.

Currently, one of the main obstacles to the existence of a unique electricity market in Europe is the presence of energy islands (Sapio & Spagnolo, 2016). Veraart (2015) examines the region of Sicily and models the behavior of wind production with stationary Levy processes and its impact on the price of electricity in Europe. Paraschiv et al. (2014) expand the analysis to consider production from renewable energies, photovoltaic and wind, in the formation of prices in the German market. Ketterer (2014) and Cardella, Ewing, and Williams (2017) highlight the relevance of such studies given the increasing production of energy from renewable sources over the last decade. However, the imposition of the consumption of energy from renewable sources affects the prices to the final consumer (Ketterer, 2014).

The integration of the European electricity market is one of the main objectives of the 2030 Agreement. The EU has made improvements to the electricity network, as in

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<sup>3</sup> PJM stands for the Pennsylvania - New Jersey - Maryland Interconnection. It was founded in 1927 as a power pool of three utilities serving Pennsylvania and New Jersey, and in 1956 two Maryland utilities joined.

the case of electricity transmission between neighbor countries such as Morocco and the Iberian Peninsula (Cambini & Rubino, 2014); however, transmission is still limited in certain countries and regions in the EU—for example, between France and the Iberian Peninsula, between Ireland and the UK, and between Sicily and mainland Italy or Tunisia (Sapio & Spagnolo, 2016). In Central Europe, though, markets are more interconnected.

In sum, different studies provide evidence of high volatility, seasonality, no arbitrage opportunities, and a statistically significant risk premium in the market for electricity derivatives. Derivatives of different maturities and on differences between spot and futures prices exist, but there is no consensus as to which factors finally influence electricity prices.

This chapter contributes to this literature by examining the impact of the 2030 Agreement on electricity price stability, using regressions in a quantitative approach (e.g., Hadsell & Shawky, 2007), and applying the qualitative fsQCA method (e.g., Ragin, 2000; Ragin, 2005; Fiss, 2007; Ragin, 2008; Ragin, 2009; Schneider, Schulze-Bentrop & Paunescu, 2010; Fiss, 2011; Woodside and Zhang, 2013).

### 3.3 Objectives of the study

This study focuses on the Iberian market MIBEL. Electricity derivatives are traded in MIBEL, and the study analyzes the behavior of spot electricity prices. Because the transmission network between Portugal and Spain is limited, the possibility of market splitting makes examining spot electricity prices relevant.

This study has two main objectives: to model the behavior of spot prices in the two countries using a time series econometric model to test for the presence of seasonality and price peaks (a quantitative analysis); and to perform a qualitative analysis that identifies the paths that lead to price stability (a qualitative analysis).

The analysis of mixed methods requires splitting the sample into two sub periods: before and after the 2030 Agreement signing. This split allows for the assessment of the impact of the new economic framework on the behavior of electricity prices in Portugal and Spain.

### 3.4 Time series econometric method

In any economy, periods of high volatility are often followed by others in which volatility is reduced (Wooldridge, 2006). GARCH models better capture changes in the conditional volatility of electricity market prices (Hadsell & Shawky, 2007).

#### 3.4.1. *Sample description*

To analyze the behavior of the spot electricity prices in MIBEL, we collect data from the day after market (spot) for the period October 24, 2012, to October 24, 2016. Hereafter the term spot refers to the electricity price for next day delivery. The spot price data come from OMEL's site and are treated by using the econometric software E-Views.

The data are divided into two sub periods: (1) before October 24, 2014, and (2) after October 24, 2014. Therefore, the first subsample comprises 721 observations and the second subsample has 755 observations. The observations with prices equal to or inferior to €1.00 are considered outliers and are excluded from the sample. The unit of measure in the spot price contracts is euros for a megawatt per hour (€/Mwh). Each contract guarantees the supply of one Mwh of electricity. Table 3.1 presents the summary statistics for the data.

**Table 3.1:** Summary statistics - Time series

| <b>SPEL before 10/24/2014</b> |           | <b>PTEL before 10/24/2014</b> |           |
|-------------------------------|-----------|-------------------------------|-----------|
| Mean                          | 43.16     | Mean                          | 42.74     |
| Standard Error                | 0.60      | Standard Error                | 0.60      |
| Median                        | 45.99     | Median                        | 45.67     |
| Mode                          | 45.23     | Mode                          | 41.34     |
| Standard Deviation            | 16.01     | Standard Deviation            | 16.15     |
| Sample Variance               | 256.18    | Sample Variance               | 260.68    |
| Kurtosis                      | 0.78      | Kurtosis                      | 0.66      |
| Skewness                      | -0.46     | Skewness                      | -0.45     |
| Range                         | 92.01     | Range                         | 92.09     |
| Minimum                       | 1.10      | Minimum                       | 1.02      |
| Maximum                       | 93.11     | Maximum                       | 93.11     |
| Sum                           | 31,121.12 | Sum                           | 30,817.79 |
| Count                         | 721       | Count                         | 721       |
| <b>SPEL after 10/24/2014</b>  |           | <b>PTEL after 10/24/2014</b>  |           |
| Mean                          | 44.40     | Mean                          | 44.37     |
| Standard Error                | 0.45      | Standard Error                | 0.45      |
| Median                        | 45.49     | Median                        | 45.50     |
| Mode                          | 48.55     | Mode                          | 48.55     |
| Standard Deviation            | 12.38     | Standard Deviation            | 12.46     |
| Sample Variance               | 153.20    | Sample Variance               | 155.31    |
| Kurtosis                      | 0.15      | Kurtosis                      | 0.10      |
| Skewness                      | -0.62     | Skewness                      | -0.61     |
| Range                         | 65.60     | Range                         | 65.60     |
| Minimum                       | 5.46      | Minimum                       | 5.46      |
| Maximum                       | 71.06     | Maximum                       | 71.06     |
| Sum                           | 33,518.84 | Sum                           | 33,495.84 |
| Count                         | 755       | Count                         | 755       |

### 3.4.2. Results for the time series econometric method

The summary statistics show that in the Spanish market before the 2030 Agreement, spot prices had an average value of 43.16€/Mwh with a standard deviation of 16.00€/Mwh. Further, the prices varied from 93.11€/Mwh on December 8, 2013, to 1.1€/Mwh on February 8, 2014. For the same period, the average price in Portugal was

42.74€/Mwh with a standard deviation of 16.15€/Mwh. These prices varied from 93.11€/Mwh to 1.02€/Mwh. The summary statistics also show that prices in both markets increased after the signing of the 2030 Agreement.

Based on the correlogram of the time series, the seasonality of both markets and both sub periods, is of order seven, that is, every seven days prices oscillate. For Portugal and Spain, this seventh day is Sunday.

For the Portuguese market before October 24, 2014, the GARCH(1,1) model better describes the volatility where the mean behaves according to AR(1), SAR(7), MA(1), and SMA(7). For Spain, the GARCH(1,1) model also explains the errors, and the mean behaves according to AR(1), SAR(7), MA(1), and SMA(7).

When the analysis is repeated for the sub period after October 24, 2014, the best model for Portugal is again the GARCH(1,1) for explaining the errors and with the mean following AR(1), AR(2), SAR(7), MA(1), and SMA(7). For Spain, the same applies except the mean only follows AR(1), SAR(7), and MA(1).

As evidence of high volatility, we observe that prices vary between 1.02€/Mwh (Portugal) and 1.1€/Mwh (Spain) and go up to 93.11€/Mwh. The annual volatility in MIBEL is around 500%. A consequence of high volatility is the existence of price peaks, which, according to Bierbrauer et al. (2004), happen when the price variation with respect to the mean is 30% higher. This phenomenon is present in the data set.<sup>4</sup>

### 3.5 Qualitative comparative analysis method

Following Woodside and Zhang (2013), this study uses the fsQCA to test several conditional arguments that lead to the spot price's stability by examining the Portuguese

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<sup>4</sup> We do not tabulate the results from the GARCH models here but they are available from the authors on request.

and Spanish markets. To assess the influence of the 2030 Agreement, the analysis is repeated for the sub periods before and after the signing of the agreement.

The fsQCA requires that the cases be scaled into meaningful groups that reflect the degree of price stability. The degree ranges from one (price stability) to zero (absence of price stability). A score of 0.5 refers to the crossover point (Ragin, 2008). Following the rationale of Bierbrauer et al. (2004), stability in electricity prices is assumed to correspond to situations in which prices are within a 30% variation of the mean for the observed period. For the crossover point, an area of 30% is divided into two bands of 15% (one above and one below the central band of stability). The remaining area corresponds to the values of instability, that is, the two bands farther away from the mean, 20% each. Table 3.2 summarizes the statistics and calibration values of the outcomes and antecedent conditions.

**Table 3.2:** Statistics and calibration values for the outcomes and antecedent conditions

| Outcomes and Conditions | Statistics |         |         |         | Calibration                |                                   |                      |
|-------------------------|------------|---------|---------|---------|----------------------------|-----------------------------------|----------------------|
|                         | Mean       | Std dev | Max     | Min     | Stability                  | Ambiguity                         | Absence of stability |
| Spot PT before          | 44.24      | 15.65   | 91.89   | 1.17    | ]37.60 ; 50.87[            | ]30.96 , 37.23[ U ]50.87 , 57.51[ | < 30.96 U > 57.51    |
| Spot SP before          | 45.13      | 15.36   | 91.89   | 1.66    | ]38.07 ; 51.51[            | ]31.35 , 38.07[ U ]51.51 , 58.23[ | < 31.35 U > 58.23    |
| Spot PT after           | 46.36      | 11.43   | 67.12   | 15.76   | ]39.41 ; 53.31[            | ]32.45 , 39.10[ U ]53.31 , 60.26[ | < 32.45 U > 60.26    |
| Spot SP after           | 46.49      | 11.23   | 66.41   | 14.18   | ]39.52 ; 53.46[            | ]32.54 , 39.52[ U ]53.46 , 60.44[ | < 32.54 U > 60.44    |
| oil before              | 77.68      | 2.18    | 82.71   | 74.22   | (81.5;77;75)*              |                                   |                      |
| oil after               | 43.31      | 12.11   | 74.22   | 3.8     | (62;41.6;28.06)*           |                                   |                      |
| gas before              | 3.00       | 0.47    | 5.84    | 2.33    | (3.8;2.9;2.5)*             |                                   |                      |
| gas after               | 2.32       | 0.44    | 3.52    | 1.35    | (2.92;2.41;1.56)*          |                                   |                      |
| eex before              | 24.59      | 3.48    | 29.06   | 15.44   | (27.8;26.3;17.4)*          |                                   |                      |
| eex after               | 17.56      | 3.85    | 24.73   | 11.24   | (23;18.28;12.1)*           |                                   |                      |
| nordpool before         | 35.51      | 6.75    | 66.86   | 21.91   | (50;35;26)*                |                                   |                      |
| nordpool after          | 24.38      | 7.31    | 81.67   | 6.31    | (33.8;25;10.53)*           |                                   |                      |
| dax before              | 741,024    | 61,888  | 847,848 | 603,154 | (825,000;741,000;640,000)* |                                   |                      |

|            |         |        |           |         |                            |
|------------|---------|--------|-----------|---------|----------------------------|
| dax after  | 858,359 | 59,846 | 1,012,013 | 726,737 | (970,000;850,000;768,000)* |
| sre before | 19.16   | 11.30  | 40.23     | 3.23    | (68;60;52.8)*              |
| sre after  | 51.76   | 12.92  | 76.16     | 25.46   | (73.5;51.8;30.5)*          |

\*Cuts: 95%; 50% and 5%

Label: Max=maximum; Min = minimum; Std dev = standard deviation; (oil) average price of oil barrel in euros, (gas) natural gas price - per Million British Thermal Units, (eex) electricity price in the German market/Megawatt Hour, (nordpool) average price of electricity in the Scandinavian market, (dax) daily DAX index, (sre) renewable energies index - Total Market Renewable Energy Equipment

The advantages of the fsQCA analysis relative to more traditional methods – such as multifinality, equifinality, and conjunctural causation – allow a better understanding of the circumstances under which electricity price stability can be achieved, in a similar way to what has already been done in applications to other contexts (e.g., Wu, Yeh, Huan & Woodside, 2014). In the presence of complex causal structures (Ragin, 2008), fsQCA has the advantage of analyzing the effects of sets of several variables, instead of focusing on the average effect of single variables, and is able to address relationships in which multicollinearity would affect the traditional correlation-based approaches. Although fsQCA was initially developed with small samples in mind (for which traditional methods could not be implemented), it is theoretically suitable also for larger samples when the links suspected in the data are complex and configurational (Greckhamer, Misangyi & Fiss, 2013). More recent literature has successfully applied fsQCA to medium and large samples (e.g., Schulze-Bentrop, 2013; Ordanini, Parasuraman & Rubera, 2014; Wu et al., 2014; Silva & Gonçalves, 2016). We follow this trend in a new application with financial data.

### 3.5.1. Sample description (fsQCA)

To analyze the behavior of electricity spot prices in MIBEL, data is collected for the period from October 24, 2012, to October 24, 2016. To study the impact of the 2030 Agreement, the sample is split into two sub periods—before and after October 24, 2014. The sample of the first sub period comprises 518 observations, and the second sub period includes 521 observations, for a total of 1,039 observations for the Spanish and Portuguese markets.

**Table 3.3: Summary Statistics - fsQCA**

| <b>PTEL before 10/24/2014</b> |           | <b>SPEL before 10/24/2014</b> |           |
|-------------------------------|-----------|-------------------------------|-----------|
| Mean                          | 44.58     | Mean                          | 45.13     |
| Standard Error                | 0.69      | Standard Error                | 0.67      |
| Median                        | 47.65     | Median                        | 48.12     |
| Mode                          | 51.36     | Mode                          | 49.02     |
| Standard Deviation            | 15.65     | Standard Deviation            | 15.36     |
| Sample Variance               | 244.96    | Sample Variance               | 235.89    |
| Kurtosis                      | 0.95      | Kurtosis                      | 1.19      |
| Skewness                      | -0.58     | Skewness                      | -0.59     |
| Range                         | 90.72     | Range                         | 90.23     |
| Minimum                       | 1.17      | Minimum                       | 1.66      |
| Maximum                       | 91.89     | Maximum                       | 91.89     |
| Sum                           | 23,091.81 | Sum                           | 23,374.81 |
| Count                         | 518       | Count                         | 518       |
| <b>PTEL after 10/24/2014</b>  |           | <b>SPEL after 10/24/2014</b>  |           |
| Mean                          | 46.36     | Mean                          | 46.49     |
| Standard Error                | 0.50      | Standard Error                | 0.49      |
| Median                        | 46.70     | Median                        | 46.77     |
| Mode                          | 47.24     | Mode                          | 47.24     |
| Standard Deviation            | 11.43     | Standard Deviation            | 11.23     |
| Sample Variance               | 130.67    | Sample Variance               | 126.15    |
| Kurtosis                      | -0.44     | Kurtosis                      | -0.42     |
| Skewness                      | -0.47     | Skewness                      | -0.46     |
| Range                         | 51.36     | Range                         | 52.23     |
| Minimum                       | 15.76     | Minimum                       | 14.18     |
| Maximum                       | 67.12     | Maximum                       | 66.41     |
| Sum                           | 24,156.07 | Sum                           | 24,223.23 |
| Count                         | 521       | Count                         | 521       |

The data on electricity prices were collected from OMIP/OMEL's site. The remaining variables are daily quotations obtained from Datastream. To implement the

fsQCA, we select a set of conditions that are relevant to the electricity prices' behavior in Europe, hence in Iberia. Since oil and gas are two of the most important energy sources for the production of electricity (Shawky et al., 2003; Pietz, 2009; Paraschiv et al., 2014), we consider the price of a barrel of oil in euros (variable oil), and the price of natural gas per million BTUs (variable gas). We also consider the renewable energies index—Total Market Renewable Energy Equipment (variable sre). Because the Scandinavian market is the largest multinational European electricity market (Lucia & Schwartz, 2002; European Commission, 2016) and the German-based EEX is the largest European single-country market in terms of electricity consumption (Redl et al., 2009; Paraschiv et al., 2014), we include the average price of electricity in the Scandinavian market (variable nordpool) and the electricity price in the German market per Mwh (variable eex). Finally, we also include the daily DAX index (variable dax), a leading European stock market index, which reflects the relation between energy prices and other types of investments (Orbendorfer, 2009). To homogenize the sample, we only consider those days in which there are price negotiations for all variables.

### *3.5.2. Analysis of the necessary conditions*

We test the markets of Portugal (ptel) and Spain (spel) and the variables oil, gas, sre, nordpool, eex, and dax to assess if necessary conditions exist for the outcome in the sub periods before and after the 2030 Agreement. Usually, a condition or a combination of conditions is necessary or almost always necessary if the consistency score surpasses 0.8 (Ragin, 2000; Schneider, Schulze-Bentrop & Paunescu, 2010). There are no necessary conditions to report in both periods and electricity markets.

### 3.5.3. *Analysis of the sufficient conditions sets*

This subsection presents an analysis of the sufficient conditions to determine the causal configurations that lead to the presence of the outcome in both countries. These conditions are our core conditions. Solutions respect the recommended consistency limits (solution consistency) ( $> 0.8$ ) and solution coverage limits ( $> 0.25$ ) (Ragin, 2008, Woodside & Zhang, 2013), since it is desirable to have consistency to describe the behavior of electricity prices.

For the tables of truth, the causal combinations of conditions that exceed 0.8 are categorized as sufficient, and the outcome is assigned a value of one in the truth table. On the other hand, causal combinations with a consistency level below or at the cut-off value are not considered as sufficient, and the outcome is assigned a value of zero (Schneider et al., 2010). This study applies the cut-off values of 0.8 for both markets: ptel and spel.

Following the recommendations of Ragin (2000; 2008), Schneider and Wagemann (2010), Fiss (2011), and Mas-Verdú, Ribeiro-Soriano, and Roig-Tierno (2015), the results for the intermediate solutions of ptel and spel for the two sub periods are presented in Tables 4 and 5, respectively.

The coverage indices have empirical importance, and the consistency scores comply with the 0.8 threshold point (Ragin, 2008). According to Ragin (2005), high consistency scores confirm that the particular configuration of antecedents is sufficient for explaining the outcome condition.

**Table 3.4:** Results of the intermediate solutions before the 2030 Agreement (outcome: ptel and sptel)

|                              | Intermediate solution<br>for Portugal before 10/24/2014                                                     |      | Intermediate solution<br>for Spain before 10/24/2014                                                          |      |
|------------------------------|-------------------------------------------------------------------------------------------------------------|------|---------------------------------------------------------------------------------------------------------------|------|
|                              | Model: 2014ptel = f(oil_<br>before, gas_before, eex_<br>before, nordpool_before,<br>dax_before, sre_before) |      | Model: 2014sptel =<br>f(oil_before, gas_before,<br>eex_before,<br>nordpool_before,<br>dax_before, sre_before) |      |
| Causal configurations        | 1                                                                                                           | 2    | 1                                                                                                             | 2    |
| oil_before                   | ●                                                                                                           | ●    | ●                                                                                                             | ●    |
| gas_before                   | O                                                                                                           | O    | O                                                                                                             | O    |
| eex_before                   | O                                                                                                           | O    | O                                                                                                             | O    |
| nordpool_before              | O                                                                                                           | O    | O                                                                                                             | O    |
| dax_before                   | o                                                                                                           | ●    | o                                                                                                             | ●    |
| sre_before                   | o                                                                                                           | ●    | o                                                                                                             | ●    |
| Consistency                  | 0.80                                                                                                        | 0.82 | 0.81                                                                                                          | 0.83 |
| Raw coverage                 | 0.18                                                                                                        | 0.21 | 0.18                                                                                                          | 0.20 |
| Unique coverage              | 0.06                                                                                                        | 0.08 | 0.06                                                                                                          | 0.08 |
| Overall solution consistency | 0.82                                                                                                        |      | 0.83                                                                                                          |      |
| Overall solution coverage    | 0.27                                                                                                        |      | 0.26                                                                                                          |      |

Label: (oil) average price of oil barrel in euros, (gas) natural gas price per million British thermal units, (eex) electricity price in the German market per megawatt hour, (nordpool) average price of electricity in the Scandinavian market, (dax) daily DAX index, (sre) renewable energies index—total market renewable energy equipment. The full black circles (●) indicate the presence of a condition, and center white circles (◐) indicate its absence. Large circles indicate core conditions; small ones indicate peripheral conditions. Blank spaces indicate “does not contribute to configuration.”

When comparing the intermediate and parsimonious solutions, the conditions present in both solutions are the core conditions (Fiss, 2011). The results in Table 3.4 for the sufficiency analysis show that there are two causal configurations that lead to stability before the 2030 Agreement for both electricity markets (ptel and spel). The results in Table 3.5 for the second sub period show seven configurations that lead to stability in the Portuguese market and ten configurations for the Spanish market that lead to stability.

**Table 3.5:** Results of the intermediate solutions after the 2030 Agreement (outcome: ptel and sptel)

| Intermediate solution<br>for Portugal after 10/24/2014                                      |      |      |      |      |      |      |      |
|---------------------------------------------------------------------------------------------|------|------|------|------|------|------|------|
| Model: ptel2014 = f(oil_after, gas_after, eex- after, nordpool_after, dax_after, sre_after) |      |      |      |      |      |      |      |
| Causal configurations                                                                       | 1    | 2    | 3    | 4    | 5    | 6    | 7    |
| oil_after                                                                                   |      | O    |      |      |      | O    | •    |
| gas_after                                                                                   | O    | •    | •    | O    |      | O    | O    |
| eex_after                                                                                   | •    | O    | O    | •    | •    | •    |      |
| nordpool_after                                                                              | •    |      |      | •    | •    |      | •    |
| dax_after                                                                                   |      |      | o    | •    | •    | o    | •    |
| sre_after                                                                                   | O    | •    | •    |      | O    | O    | •    |
| Consistency                                                                                 | 0.85 | 0.84 | 0.85 | 0.85 | 0.84 | 0.81 | 0.82 |
| Raw coverage                                                                                | 0.25 | 0.30 | 0.28 | 0.24 | 0.29 | 0.19 | 0.22 |
| Unique coverage                                                                             | 0.01 | 0.02 | 0.02 | 0.00 | 0.06 | 0.02 | 0.01 |
| Overall solution consistency                                                                | 0.84 |      |      |      |      |      |      |
| Overall solution coverage                                                                   | 0.53 |      |      |      |      |      |      |
| Intermediate solution<br>for Spain after 10/24/2014                                         |      |      |      |      |      |      |      |

| Model: spel2014 = f(oil_after, gas_after, eex_after, nordpool_after, dax_after, sre_after) |      |      |      |      |      |      |      |      |      |      |
|--------------------------------------------------------------------------------------------|------|------|------|------|------|------|------|------|------|------|
| Causal Configurations                                                                      | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   |
| oil_after                                                                                  | O    |      | •    |      | O    | •    | O    | •    |      |      |
| Gas_after                                                                                  | •    | •    | O    |      |      |      | O    | O    | O    | O    |
| Eex_after                                                                                  | O    | O    | •    | •    | •    | O    | •    |      | •    | •    |
| Nordpool_after                                                                             |      |      |      | •    | o    | o    |      | •    |      | •    |
| dax_after                                                                                  |      | O    |      | •    | O    | O    | •    | •    | O    |      |
| sre_after                                                                                  | •    | •    | o    | o    | o    | •    | •    | •    | o    | o    |
| Consistency                                                                                | 0.85 | 0.86 | 0.83 | 0.84 | 0.81 | 0.82 | 0.81 | 0.83 | 0.81 | 0.85 |
| Raw coverage                                                                               | 0.30 | 0.28 | 0.31 | 0.28 | 0.18 | 0.24 | 0.19 | 0.22 | 0.22 | 0.25 |
| Unique coverage                                                                            | 0.02 | 0.01 | 0.02 | 0.05 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| Overall solution consistency                                                               | 0.82 |      |      |      |      |      |      |      |      |      |
| Overall solution coverage                                                                  | 0.56 |      |      |      |      |      |      |      |      |      |

Label: (oil) average price of oil barrel in euros, (gas) natural gas price per million British thermal units, (eex) electricity price in the German market per megawatt hour, (nordpool) average price of electricity in the Scandinavian market, (dax) daily DAX index, (sre) renewable energies index—total market renewable energy equipment. The full black circles (•) indicate the presence of a condition, and center white circles (◦) indicate its absence. Large circles indicate core conditions; small ones indicate peripheral conditions. Blank spaces indicate “does not contribute to configuration.”

The results for both markets indicate change in the causal conditions sets that contribute to stability in electricity prices.

### 3.6 Discussion of the results

The time series results show seasonality (order 7) in both markets before and after the climate framework was signed. The existence of price peaks is also confirmed, which agrees with recent studies (Janzcura et al., 2013; Paraschiv et al., 2014; Veraart, 2015; and Sapio & Spagnolo, 2016). The data also show a reduction in the standard deviation of electricity prices after the 2030 Agreement. This reduction indicates lower volatility in electricity markets, and is associated with a rise in the mean price. The evolution indicates more price stability in Spain and Portugal after October 24, 2014.

The qualitative analysis finds that the 2030 Agreement has resulted in a larger number of configurations that lead to price stability. For the sub period before the agreement, two causal combinations provide stability in electricity prices in Portugal and Spain. After the 2030 Agreement, seven combinations provide price stability in Portugal, and ten combinations for the Spanish market. The increasing number of configurations that lead to electricity price stability after October 24, 2014, means more stable prices in MIBEL.

### 3.7 Conclusions

This study explores two different methodological approaches to examine the impact of the introduction of the EU's 2030 Agreement on the stability of electricity prices in the Iberian Peninsula. We have modeled the behavior of spot prices in Portugal and Spain by using time series econometric models that identify the presence of

seasonality and price peaks. In the qualitative analysis, we have identified paths that lead to price stability.

Both methods produce results that indicate the same direction: the 2030 Climate and Energy Framework Agreement has generated more price stability, which is consistent with the idea that setting a clearer framework regarding energy policy reduces uncertainty for producers and consumers. We also show an increase in the mean price of electricity after the 2030 Agreement was signed, which agrees with the historical record of higher costs being associated with renewable energies (Paraschiv et al., 2014).

The GARCH method models the behavior of prices over time and depicts more stability after 2014. The fsQCA identifies the combinations of variables that are conducive to price stability. We find that, for both countries, there are a larger number of configurations that lead to price stability after the 2030 Agreement. Before the 2030 Agreement, we identify two configurations that lead to price stability in MIBEL, whereas after the agreement, the number of paths to price stability is larger. We interpret the increasing number of configurations after the agreement as a sign of a more propitious environment for stability that complements the time series analysis.

Moreover, before the 2030 Agreement the only two configurations that lead to stability identify oil prices as the core condition, while after the agreement this is no longer so, with several different combinations of other variables becoming sufficient for price stability. This result from the qualitative analysis is in accordance with the idea that the new energy framework has an impact on promoting alternative energy sources.

In terms of related future research opportunities, it would be interesting to examine the impact of the framework on other markets besides Iberia, and to extend the analysis to a longer time frame in order to assess the long-term effects. The current study shows that the signing of the 2030 Agreement had an impact on the behavior of electricity

prices and markets, which is evidence of market participants trusting its political credibility. Since the 2016 US Presidential election and, in particular, since US President Trump recently withdrew the US from the 2030 Agreement, it is possible that its credibility has been affected. With practical consequences for energy portfolios and the behavior of electricity prices, the US withdrawal is another interesting issue to include in a future research agenda.

This study highlights the advantages of implementing a mixed-methods approach. The fsQCA complements the results from the more traditional quantitative method and sheds more light on the conditions for price stability in the electricity market under the 2030 Climate and Energy Framework.

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## **Chapter 4: An analysis of the impact of the 2030 Agreement on R&D intensity in the energy sector**

### **Abstract**

European Union countries signed the 2030 Climate and Energy Framework Agreement on October 24, 2014. This framework brings with it changes in the expectations of energy consumers and producers that has opened new avenues of research.

Because the 2030 Agreement imposed targets to be achieved by 2030, energy companies could increase their R&D expenditures as they search for increased efficiency through a reduction of carbon dioxide emissions and stronger base in renewable sources that promotes innovation. In addition, the risks that arise from climate change can compromise the successful achievement of the targets, such as 27% renewable energy consumption, reduction in emissions of carbon dioxide by at least 40% and to improve energy efficiency. In this study, I conduct an evaluation of the behavior of R&D intensity in this sector. It analyze the behavior of companies related to the electricity sector in two different moments, before and after the 2030 Agreement, by using panel data and comparing the listed companies with headquarters in European Union countries with companies headquartered elsewhere in Europe.

The results show that the 2030 Agreement had no effect on R&D intensity in companies in the electricity sector in the countries of the European Union.

**Keywords:** R&D intensity, Electricity sector, 2030 Agreement

## 4.1 Introduction

The 2030 Climate and Energy Framework Agreement was signed in 2014 by European Union (EU) countries. The Agreement has three main objectives to achieve by 2030: to reduce greenhouse gas emissions by at least 40% from the levels of 1990; to consume at least 27% of renewable energy; and to improve energy efficiency through possible amendments to the energy efficiency directive (European Council, 2014). To achieve these goals, new technologies and/or improvement in energetic efficiency of existing technologies must be developed. In both cases, implementation will only be possible, in all likelihood, through an increase in research and development (R&D) expenditures. For example, an excerpt of a statement made by the largest Portuguese operator, EDP (2018, p. 35) states the following: “The path of decarbonization implicates a deep change to the economic model based on fossil fuels, a strong bet in energy efficiency, electrification based in renewables and the promotion of innovation”.

According to Kahouli (2018), “the energy sector has an important role in the new challenges both economic, geopolitical, technological and environmental”. This is reinforced by the 2015 report by the Intergovernmental Panel on Climate Change (IPCC) which mentions that key economic sectors such as energy, water, transport, human health, human security and poverty will experience effects from climate change. How to lead with innovation and the climate change is one of the most prominent topics regarding sustainability (Calabrese, Castaldi, Forte, & Levialdi, 2018).

As Franzen, Rodgers, and Simin (2007) and Lee and Lee (2013) show, the expense of R&D has been increasing over the last 20 years, because companies want to be competitive and so need to modernize and innovate in order to gain competitive

advantages against the opponents. One-way companies can obtain competitive advantages is through the development of new technologies or by increasing the efficiency of existing technologies. Therefore, companies need to invest more in R&D (Peteraf, 1993). This is in line with the research that shows that a positive relationship exists for companies in terms of R&D and the investment made in the previous period (Su & Moaniba, 2020).

According to Lin and Chen (2019), the innovation of renewable energy technologies is positively associated with R&D expenditures and economic growth. In addition, sustainable economies depend on the reduction of greenhouse gas emissions that should only be possible through technology and energy consumption with a minor environmental impact (Fernández Fernández, Fernández López, & Olmedillas Blanco, 2018).

Nowadays, as the world population continues to grow, a significant part of the developed world is placing a strong emphasis on future generations, especially in developing countries. In these countries, the energy sector has an important role in the new economic, geopolitical, technological, and environmental challenges (Kahouli, 2018). According to Toledano et al., (2020), the utility sector was responsible for 41% of global emissions in 2017, and of those emissions electricity and heat generation were the worst. For that reason, the alignment of electricity utilities with the United Nation's Sustainable Development Goals (SDGs), mainly through SDG 7 (renewable energies) and SDG 13 (climate changes), is important. Electricity companies are subject to risks arising from climate change. According to Wei et al., (2016), these risks can be operational (risks of extreme weather events that can occur may compromise facilities, manufacturing, supplies, and the workforce), input risks due to a reduction of natural resources, market

risks through a change in the demand for electricity services or products; financial risks due to possible financial losses, reputational risks because the various stakeholders can be disappointed given their expectations about the companies, and last but not least, regulatory risk due to the increasingly stringent climate policies and the potential result of rising prices of high carbon sources of energy.

The purpose of this study is to analyze the impact that the 2030 Agreement had on the companies in the energy and utilities sectors in Europe. The Agreement takes effect in 2015, with the window of analysis being pre-signature (up to the signing in 2014) and 2015 onwards is period of the impact of the Agreement, which corresponds to the implementation period. According to the United Nations, (2015), line 5 in article 10 of the Agreement states its mission: “Accelerating, encouraging and enabling innovation is critical for an effective, long-term response to climate change and promoting economic growth and sustainable development.”

Therefore, the Agreement could lead to an increase in R&D expenses due to the need for competitive advantages over their direct competitors. The Agreement could affect the intensity of R&D through its imposition of limits on carbon dioxide emissions and its expansion renewable energy consumption. According to Wei et al. (2016), there should be 3.9 trillion dollars invested in renewable energy by 2030. This level might enable companies to achieve the objectives proposed by the Agreement.

However, the Agreement could reduce R&D expenses because this investment has a medium-term impact, and these expenses have significant weights in the budgets of the companies. Additionally, companies may reduce R&D expenses due to uncertainty before a change scenario. According to Mudambi & Swift (2011), the external turbulence

from the change in regulation can create reactions in the levels of R&D expenditures, as companies wait for a clearer set of rules.

Based on these conjectures, two research question (RQ) emerge that this study aims to address:

RQ1: Is there a change in the R&D intensity of energy companies after the 2030 Agreement?

RQ2: Is there asymmetric change in the R&D intensity of energy companies between EU28 and non-EU28 energy companies after the 2030 Agreement?

Subsequently, this study tests the hypothesis that companies in the EU28 have different R&D intensities than the companies in non-EU28 countries. We also test the hypothesis of a change in the R&D intensity after the Agreement in the energy companies in non-EU28 countries as they did not sign the 2030 Agreement. To answer these research questions, we use a panel data method.

The present study is organized as follows: the first section is dedicated to the literature review on factors that can condition R&D expenditures in the electricity industry, followed by a presentation of the method and a description of the sample selection. The empirical results and their implications are discussed afterwards. The last section presents the conclusions, contribution, and limitations of the study.

## 4.2 Literature review

Greenhouse gas emissions have followed the trend of increasing energy consumption. Yet, energy efficiency improvements through technological development

and innovations introduced in the energy sector companies could invert that trend (Costa-Campi, García-Quevedo, & Trujillo-Baute, 2015). So, R&D expenses on low-carbon technology could facilitate the reduction of CO<sub>2</sub> emissions and consequently transform into energy savings (Gu & Wang, 2018). Brandão & Ehrl, (2019, p. 432) reinforce this idea and claim that “R&D investments contribute to a reduction of CO<sub>2</sub> emissions through the development and implementation of environmentally friendly technologies”. In the same way, Alam, Atif, Chien-Chi, & Soytaş, (2019) demonstrate that in countries such as the G-6, the impact of R&D investment is negative for energy consumption and also for the intensities of carbon emissions.

Another way of reducing CO<sub>2</sub> emissions is by increasing the use of renewable resources (Sim, 2018). The governments’ policy aims can influence the speed of development of these resources (Kim, Lee, & Park, 2014). However, in countries where the petroleum refining sector has a large presence, governmental policies for R&D investment in renewable energy have a negative relationship with government budgets for energy R&D. Nevertheless, there is a positive relationship between fossil fuels and R&D investment that is reflected in the search for new forms of extraction of fossil fuels (Sun & Kim, 2017).

Based on the IEA 2017 report, just 18% of world primary energy supply was non fossil in 2015. The growth in the demand for fossil fuels around the world in this century was accompanied by rising CO<sub>2</sub> emissions of which fossil fuels were the main culprit (Zhao & Luo, 2017).

There are several factors that can condition R&D expenditures in a company, such as its strategy, financing, budget (Heidenberger, Schillinger, & Stummer, 2003), profitability (Lin & Wang, 2016), market growth (Brown, Martinsson, & Petersen, 2016),

its previous investment in R&D (Alam et al. 2019), location (Engel, Rothgang, & Eckel (2016), institutional environment (Alam, Uddin, & Yazdifar, 2019), and pressure for sustainable economies. According to Kahouli, (2018), an energy sector with greater economic sustainability is the most intelligent approach to future global efforts to save energy.

One of the main factors that influences R&D is the location of companies' head offices because companies normally carry out their R&D activities at their headquarters (Engel, Rothgang, & Eckl, 2016). Further, this dependence also exists because of the previous investment that was made in R&D (Alam et al.2019), since R&D are medium term investments with uncertain returns.

Before carrying out R&D expenditures, a company must first secure funding. For Coad & Rao, (2010), the financing of R&D expenditures has several difficulties: first, the return on the funds invested in R&D is unknown both in terms of profitability and of the payout period. Second, due to the intangible nature of R&D investment, R&D projects have no guarantee of success (Bakker, 2013). Third, asymmetric information problems can arise if the investor has difficulty distinguishing good projects from bad ones or even if the company is wary of releasing detailed information about its R&D project (Guiso, 1998). Information asymmetries (of the “adverse selection” type) can be especially severe in the case of high-tech companies (Guiso, 1998). Fourth, moral hazard problems can be amplified by the uncertainty inherent in R&D projects (Bakker, 2013). Fifth, the possibility of technological by-products and imitation by rivals may discourage investment in R&D (Mudambi & Swift, 2014).

According to Bhagat & Welch, (1995), managers in the presence of low operational cash flow in companies could use the cash flow available to invest in R&D,

with the expectation of future returns on the operational cash flows and avoiding the costs of external capital. However, the investment into innovative outputs is less efficient when the free cash flow is positive (Podolski, 2016). On the other hand, there are studies that point to the fact that companies with larger cash flows have the propensity to invest more in R&D (Alam et al., 2019) to avoid the costs of external capital markets (Bhagat & Welch, 1995).

In order to have a high operational cash flow, small innovation companies traditionally have higher capital costs for external financing due to asymmetric information. But those costs can be mitigated by the existence of venture capital (Hall & Lerner, 2009). Whether capital costs are high for large R&D companies is not clear. However, large companies typically prefer using internal capital for R&D investment to guarantee the financing and to reduce the adverse selection problem. Following Alam et al. (2019), the cash flows usually have a positive relation with R&D. The rationality behind this relation is the fact that companies that have more cash flow have a greater propensity to spend more money on R&D expenditures. Therefore, a positive relation should exist between cash flow and R&D intensity.

On the other hand, bank loans are the most traditional form of financing the R&D investment. According to Ogawa (2007), in cases of firms which already have outstanding debt, new issues can bring pressure and a negative impact on investment due to paying a finance premium that discourages new investments; outstanding debt and new debt increase the probability of bankruptcy, or at least financial distress, which managers tend to avoid. Laborda, Salas-Fumás, & Suárez, (2020) add that companies need to control cash flows to avoid financial constraints in order to increase leverage and optimize debt costs. Moreover, countries with higher levels of common trust have more R&D

expenditure to promote innovation, and this trust could diminish information asymmetries, inferior monitoring, and transaction costs that increases investors' risk-taking (Meng, Wang, Zhang, & Zheng, 2020). Consequently, the cost of debt reduces and allows companies to access more external financing. But in the face of economic and political instability, the capital costs can increase considerably (Xu, 2020). Therefore, a negative relation should exist between the debt ratio and R&D intensity.

The financial constraints on firms' R&D intensity are seen as a discontinuity or a suspension of R&D projects (Li, 2011). These actions can affect the R&D intensity of companies that leads them to be the target of more acquisition proposals and, as a result, creates greater risk for them as well as being financially constrained (Lin & Wang, 2016). This discontinuity or suspension of projects can mean a reduction in the value of the company given the probability that the company will be unable to finish its R&D project before its competitors. Thus, there is a strong relationship between financial constraints and the expected return on investment in R&D (Li, 2011).

Contrary to expectations, profit growth has little relation to R&D investment (Morbey, 1989; Lee, 2018). However, R&D investment is related to sales and employment. A different view was presented by Klette & Griliches (2000) who claim that the growth of the company depends on R&D and innovation spending. On the other hand, Kumar & Li (2016) argue that technologically mature industries make capital investments for the purpose of growing assets that presents a negative relation between the investment in capital and short-term yields. However, in many industries with huge potential for innovation, companies make capital investments to develop innovative capabilities to generate and commercialize potential future innovations, such as buying and selling patents that can help business growth (Mudambi & Swift, 2014). Companies in industries

that focus on innovation proactively use capital investment to facilitate the generation of new growth options by building innovative capacity (Pike, Ross, & Marr, 2005). Lee & Lee (2013) show that the number of energy patents, mainly in ocean and geothermal technologies, has increased in the last 20 years. In addition, investment in innovation capacity increases the expected revenue, allowing the company to make sales based on the quality of the innovations, conditioned to its creation and development (Mudambi & Swift, 2014); Coombs (1996) finds that intangible assets are one of the main drivers of innovation and organizational value. If a company has a certain revenue stream, it will put some of it into R&D in the next period (Coad & Rao, 2010).

Jiang (2016) finds a positive relationship between the future performance of firms and their spending on R&D, which Jiang calls the effects of externalities on R&D investments. Moreover, companies have higher returns. Another aspect to bear in mind is that the market reacts not only to the companies' R&D investments but also to their peers (Jiang, 2016). The investments carried out by competitors compel the market to be surprised by the positive performance of these companies. There are also positive externalities of R&D investments that can be explained by the expansion of the market due to technological advances (Brown et al., 2016).

In addition to the above, other factors also affect the R&D intensity such as the strategy of a company and its dimension. Larger firms have a tendency to be more differentiated, more technologically complex, and more cognizant of technological opportunities (Hagedoorn & Schakenraad, 1994). Looking at tangible assets, the size of the companies, usually measured by a proxy of total assets, has a positive relation with R&D investments (Aschhoff, 2009). Szücs (2020) finds that companies with higher R&D intensity have a propensity to increase their R&D when they participate in subsidized

projects. Therefore, a positive relation is expected between total assets and R&D intensity.

Innovation and productivity growth are due to investment in R&D, but financing difficulties make this investment smaller than the optimal social level (González & Pazó, 2008), particularly for companies with higher technological intensity (Brown et al., 2016). Several countries have tried to solve this problem through tax incentives and other policy initiatives to solve the problem of underinvestment in R&D (Hung, 2016).

The rules of financial markets that improve accounting standards consider a positive relationship between R&D investment and higher technology companies, as well as in countries where there is greater protection of property rights (Brown et al., 2016). On the opposite side are credit rights and R&D tax credits that contribute to a negative relation with R&D investment in companies with a higher technological level, according to the same authors. Therefore, one can conclude that direct policies related to financial problems and property rights should be more effective than traditional subsidies to promote R&D investments that facilitate economic growth (Brown et al., 2016). González & Pazó (2008) they add that subsidies have no effect on R&D expenditure, that is, the subsidies obtained did not influence R&D expenditures of the companies because they would have invested the same without the subsidies. However, in the case of companies where there is no R&D activity, subsidies are an incentive to start these activities. In some industries, the environmental regulations and R&D subsidies are enhancers of green innovation efficiency (Yi, Wang, Yan, Fu, & Zhang, 2020).

Another aspect to pay attention to is that energy R&D influences the supply of energy; but energy consumption, of course, determines the demand for energy which in turn affects the growth of GDP (gross domestic product) in the economy (Wong, Chang,

& Chia, 2013). Kocsis & Kiss (2014) support the positive relation between GDP and high levels of R&D expenditures through renewable energy consumption. The GDP and the cumulative knowledge induced by public R&D expenditures allows “each billion EUR of GDP leading to an additional knowledge of 3.1 mil EUR” (Bointner, 2014). A stronger incentive to R&D investment is the growth in GDP (Wang, 2010).

The R&D in companies can be influenced by intrinsic factors such as sales, cash flows, and assets; and extrinsic factors such as political stability, government effectiveness, regulatory quality, and control of corruption (Krammer, 2015). Alam et al. (2019) is a pioneer study that, for the first time, focused on emerging markets with a combination of several extrinsic factors. Other studies had focused only on one extrinsic determinant to explain the R&D investment. This study intends to apply the same idea of intrinsic and extrinsic factors can influence the energy market in European companies.

The innovation activities in companies can be influenced by institutions through laws, regulations, and policies (Wang et al., 2015). The R&D investment may be encouraged by effective institutions through the reduction of the agency problem with investors (Choi, Yoshikawa, Zahra, & Han, 2014). The knowledge accumulation and its spillover can expand in a country with stronger institutional settings and help short-term R&D investment (Yi, Wang, & Kafouros, 2013).

The political situation of any country has an important influence on corporate investment. Political stability is a means to achieve a favorable investment environment, as stability guarantees continuation of economic policies and reduction of future uncertainty. R&D investment is also influenced by political conditions (Karadayi & Ekinici, 2019). R&D investment is medium to long term and risky in nature. Therefore, the presence of instability in the political situation will affect R&D more than other forms

of company investments (Masino, 2015). The same author shows that due to the volatility and the uncertainty in the economy, companies tend to reduce the level of R&D investment. This uncertainty makes the value of the option to wait before making investments increase (Atanassov, Julio, & Leng, 2016). Political decisions to stimulate investment in the short term influence government policy and condition future political and regulatory decisions in the long term (Julio & Yook, 2012).

Pearce, Xin, Xu, & Rao (2011) state that government effectiveness can influence corporate performance based on the effects of managerial assumptions and actions which allows for a reduction in agency costs. In the presence of lower agency costs, the efficiency of the investment is likely to increase. Entrepreneurial activities can be promoted through fiscal policies by governments as a way for companies to invest more in R&D (Jiao, Koo, & Cui, 2015). Effective government can inspire and incentivize private and public companies to be involved in R&D investment and stimulate entrepreneurial activities. In emerging markets, the role of government has a greater contribution to improving innovation performance in companies by offering grants for innovation activities (Szczygielski, Grabowski, Pamukcu, & Tandogan, 2017). As pointed out by Hong, Wang, & Kafouros, (2015), the role of the government gains greater prominence in these markets.

Hillier, Pindado, Queiroz, & Torre, (2011) was one of the first studies to look at R&D through the prism of external factors and how these can affect R&D. They found that the relationship between R&D and law enforcement had little sensitivity to changes. The quality of the rule of law (law enforcement) is higher in the countries with less asymmetric information and in turn leads to lower capital costs. Pindado et al. (2015) reinforce the idea that strong legal systems, where for example the question of protection

of minority shareholders or protection of creditors' rights is ensured, provides investors with a greater propensity to invest in R&D. Law enforcement mitigates opaque information. Seitz & Watzinger (2017) find a positive relationship between R&D intensity and contract enforcement. The R&D intensity in an industry increases with the quality of the judicial system. With a better judicial system, companies have more confidence to invest in R&D.

According to Blind, Petersen, & Riillo (2017), the market environment can influence the relation between innovations and regulations; they find evidence that in markets with low uncertainty, regulation has a positive impact; but in the case of markets with high uncertainty, regulation has a negative impact. Karadayi & Ekinici, (2019) add that good regulatory quality increases R&D efficiency. However, if the companies are in the presence of a good quality regulatory environment, investors are willing to invest and attract foreign investment; but the same is valid for foreign investment in weak government regulations were these investors are reluctant to put their money into R&D projects (Kirkpatrick, Parker, & Zhang, 2006). In the case of Mahendra, Zuhdi, & Muyanto (2015), they find evidence that innovation is positively influence by good regulatory quality and access to finance. The energy sector is a highly regulated market by nature that is going through a phase of deregulation. These factors have caused R&D to decrease rather than increase (U-inverted) (Marino, Parrotta, & Valletta, 2019).

## 4.3 Method and sample data

### 4.3.1 Method

The goal of this study is identifying how the 2030 Agreement has affected the R&D intensity of the energy sector of listed companies with headquarters in EU28

countries. For that reason, data were collected from the Thompson Reuters database for the period between 2010 and 2019. Therefore, its use the panel data methodology. Following Engel, Rothgang, & Eckl (2016), R&D activities are mainly concentrated in the headquarters of the companies; for that reason, the nationality of a company was identified according to its headquarters.

To control the level of R&D intensity, data were also collected from Thompson Reuters on the total assets, cash flows, and debt ratio of these companies.

Furthermore, its use several additional control variables. GDP per capita controls for economic development and economic conditions each year. To control for the economic development of the country and indicators of perception of governance such as political instability and rule of law are retrieved from the Worldwide Governance Indicators (WGI) of the World Bank.

Table 4.1 presents the variables, their definitions, and the studies they come from.

**Table 4.1:** List of variables and definitions

| Variable      | Description                                                                                                                                                           | Author(s)                                                                                                               |
|---------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| LnRDIntensity | Represents the natural logarithm of R&D intensity in period t.                                                                                                        | Alam, Uddin & Yazdifar (2019);<br>Chen, Chen, Liang & Wang (2013)<br>Makri, Hitt & Lane (2010);<br>Su & Moaniba (2020); |
| L.RDIntensity | Represents the R&D intensity in period t-1.                                                                                                                           | Alam, Uddin & Yazdifar (2019);<br>Inglesi-Lotz (2017)                                                                   |
| after2014     | A binary variable equal to one from 2015 onward, and zero otherwise.                                                                                                  | Sapio & Spanolo (2016)                                                                                                  |
| EU28          | A binary variable equal to one if the headquarters of a company is in EU28, and zero otherwise.                                                                       | Spencer et al., (2017)                                                                                                  |
| LnTotalAssets | Represent the natural logarithm of total assets.                                                                                                                      | Alam, Uddin & Yazdifar (2019)<br>Meng, Wang, Zhang & Zheng (2020)<br>Wu, Wang, Hong, Piperopoulos & Zhuo (2019)         |
| Cash Flow     | The sum of net income after taxes minus preferred dividends and general partner distributions plus depreciation and amortization of intangibles for the fiscal period | Bhagat & Welch (1995)<br>Podolski (2016)<br>Xu (2020)                                                                   |

|                     |                                                                                                                                                                                                                                                                                            |                                                                                   |
|---------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| Debt ratio          | The ratio between total debt and total assets of a company in period t                                                                                                                                                                                                                     | Alam, Uddin & Yazdifar (2019); Meng, Wang, Zhang & Zheng (2020) Xu (2020);        |
| GDPpc               | Represents the GDP per capita of the countries in period t.                                                                                                                                                                                                                                | Alam, Uddin & Yazdifar (2019); Kahouli (2018) Marino, Parrotta & Valletta (2019); |
| Political Stability | Measures the perceptions of the likelihood of political instability and/or politically motivated violence like terrorism. Source: World Bank (WGI).                                                                                                                                        | Julio & Yook (2012) Karadayi & Ekinici (2019) Masino (2015)                       |
| Rule of law         | Reflects the perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts as well as the likelihood of crime and violence. Source: World Bank (WGI). | Hiller et al. (2011) Pindado et al. (2015) Seitz & Watzinger (2017)               |

Therefore, to answer the RQ 1 and 2, we propose the following three equations:

$$(1) \ln R\&D \text{ intensity} = \ln R\&D \text{ intensity}_{it-1} + \ln \text{Total Assets}_{it} + \text{Cash} - \text{Flow}_{it} + \text{debt ratio}_{it} + \text{GDP per capita}_{it} + \text{Political Stability}_{it} + \text{Rule of Law}_{it} + \varepsilon_{it} + \mu_{it}$$

$$(2) \ln R\&D \text{ intensity} = \ln R\&D \text{ intensity}_{it-1} + \text{after2014} * \text{EU28} + \ln \text{Total Assets}_{it} + \text{Cash} - \text{Flow}_{it} + \text{debt ratio}_{it} + \text{GDP per capita}_{it} + \text{Political Stability}_{it} + \text{Rule of Law}_{it} + \varepsilon_{it} + \mu_{it}$$

$$(3) \ln R\&D \text{ intensity} = \ln R\&D \text{ intensity}_{it-1} + \text{after2014} + \ln \text{Total Assets}_{it} + \text{Cash} - \text{Flow}_{it} + \text{debt ratio}_{it} + \text{GDP per capita}_{it} + \text{Political Stability}_{it} + \text{Rule of Law}_{it} + \varepsilon_{it} + \mu_{it}$$

The results presented consider two models, an OLS (Ordinary Least Squares) and a panel-data models. The latter is a FE (Fixed Effects), after testing against a RE (Random Effects) model, that controls for the firm's characteristics. It is common practice to present just two models, the OLS model and one of the two panel-data models (FE or RE) based on Hausman's test, which favoured the former. In this case the p-value of the Hausman test is 0.0000 that indicates the FE model better explains R&D intensity than the RE model. Therefore, its present the OLS and FE models to ensure the consistency of results.

#### 4.3.2 Data

The sample consists of 414 listed companies in the energy sector in Europe. Because the disclosure of this type of expenditure is not mandatory, there are companies in the database that do not release this information, which is the reason for the existence of missing values. The sample was organized by removing observations of companies that did not have data available for R&D expenditures (unbalanced sample), and the same procedure was used for the control variables. After removing the missing values and unrealistic figures (such as negative values of R&D expenditure) from the sample, 95 firms remained in the sample and represent 557 firm-years. Considering this number, we analyzed the weight that these companies had in the sector, and they represented about 69.96% of the revenues in the energy sector.

Tables 4.2, 4.3, and 4.4 present the descriptive statistics, the results of the VIF test, and the matrix of correlations between the variables. The main variable under study (R&D intensity) presents an average value of about 4%, which can be considered within the normal values for this type of ratio. It is worth noting the wide range between the

minimum and maximum. The other variable that deserves to be highlighted is the debt ratio with a wide range of values.

**Table 4.2:** Descriptive statistics

| Variable            | Obs | Mean     | Std.Dev. | Min       | Max       |
|---------------------|-----|----------|----------|-----------|-----------|
| RD intensity        | 557 | 0.042735 | 0.112585 | 0.000029  | 1.166203  |
| after2014           | 557 | 0.585278 | 0.493116 | 0         | 1         |
| EU28                | 557 | 0.590664 | 0.492153 | 0         | 1         |
| after2014*EU28      | 557 | 0.357271 | 0.479626 | 0         | 1         |
| Total Assets        | 557 | 2.12e+10 | 5.48e+10 | 1476855   | 3.150e+11 |
| Cash Flow           | 557 | 2.10e+09 | 5.67e+09 | -2.30e+09 | 4.01e+10  |
| Debt ratio          | 557 | 0.212443 | 0.218758 | 0         | 1.259726  |
| GDP pc              | 557 | 41963.25 | 15714.50 | 11237.07  | 86781.39  |
| Political Stability | 557 | 0.236839 | 0.804639 | -2.020833 | 1.418336  |
| Rule of Law         | 557 | 1.152871 | 1.015182 | -0.818469 | 2.096355  |

**Source:** author elaboration

The Pearson correlation matrix shows the results of analyzing the relationship between R&D intensity and the other variables. R&D intensity presents a negative correlation with the period after the Agreement (after 2014), and a positive correlation with EU28 companies. The correlations that show statistically significant values are evidence that there may be a relationship between the variables. In case there are relationships between the variables, it may lead to multicollinearity problems. In order to avoid this kind of problem, it was performed a VIF test that had results lower than 10 (Table 4.3) as suggested by (Meng, Jing, & Mander, 2017). In view of the above, there are guarantees that the relationships are stable and can be analyzed through linear regression in panel data given the stability of the correlations.

**Table 4.3:** Results of VIF test

| Variable            | VIF  | 1/VIF    |
|---------------------|------|----------|
| GDP_pc              | 5.04 | 0.198583 |
| Political Stability | 4.6  | 0.217557 |
| ln Total Assets     | 2.12 | 0.471283 |
| Rule of Law         | 1.96 | 0.509413 |

|                   |             |                 |
|-------------------|-------------|-----------------|
| CashFlow          | 1.68        | 0.596515        |
| l.ln RD intensity | 1.52        | 0.656557        |
| <u>Debt ratio</u> | <u>1.13</u> | <u>0.888655</u> |
| Mean VIF          | 2.58        |                 |

**Table 4.4:** Pearson correlation matrix

| Variable            | 1         | 2        | 3          | 4         | 5         | 6         | 7        | 8        | 9        | 10 |
|---------------------|-----------|----------|------------|-----------|-----------|-----------|----------|----------|----------|----|
| RD intensity        | 1         |          |            |           |           |           |          |          |          |    |
| after2014           | -0.0699*  | 1        |            |           |           |           |          |          |          |    |
| EU28                | 0.120***  | 0.0511   | 1          |           |           |           |          |          |          |    |
| after2014*EU28      | 0.0183    | 0.662*** | 0.575***   | 1         |           |           |          |          |          |    |
| Total Assets        | -0.103*** | 0.0187   | -0.0992*** | -0.0470   | 1         |           |          |          |          |    |
| Cash Flow           | -0.100*** | -0.0316  | -0.163***  | -0.111*** | 0.933***  | 1         |          |          |          |    |
| Debt ratio          | -0.133*** | 0.0663*  | -0.147***  | -0.0294   | -0.00300  | -0.0314   | 1        |          |          |    |
| GDP pc              | 0.113***  | 0.0836** | 0.239***   | 0.210***  | -0.101*** | -0.138*** | 0.172*** |          |          |    |
| Political Stability | 0.117***  | -0.0612  | 0.347***   | 0.149***  | -0.144*** | -0.176*** | 0.112*** | 0.881*** | 1        |    |
| Rule of Law         | 0.167***  | -0.0005  | 0.385***   | 0.202***  | -0.221*** | -0.282*** | 0.0744*  | 0.646*** | 0.649*** | 1  |

Note: This table presents the Pearson correlations of the variables used in the study.  $p < 0.1^*$ ,  $p < 0.05^{**}$ ,  $p < 0.01^{***}$

The sample in terms of geographical distribution shows 19 European countries of which 14 are from the EU28 (the other countries have no observations available) and 5 are from countries outside of the EU28 (Norway, Republic of Serbia, Russia, Switzerland, and Ukraine) (see Table 4.5). The remaining countries of Europe were not possible to include in the sample because of the missing values for R&D expenditures of the companies.

**Table 4.5:** Statistical frequency of observations by headquarters

| Country of Headquarters   | Freq. | Percent | Cum.  |
|---------------------------|-------|---------|-------|
| Austria                   | 18    | 3.230   | 3.230 |
| Cyprus                    | 4     | 0.720   | 3.950 |
| Denmark                   | 9     | 1.620   | 5.570 |
| Finland                   | 3     | 0.540   | 6.100 |
| France                    | 42    | 7.540   | 13.64 |
| Germany                   | 25    | 4.490   | 18.13 |
| Greece                    | 9     | 1.620   | 19.75 |
| Ireland, Republic         | 25    | 4.490   | 24.24 |
| <b>Norway</b>             | 82    | 14.72   | 38.96 |
| Poland                    | 4     | 0.720   | 39.68 |
| <b>Republic of Serbia</b> | 9     | 1.620   | 41.29 |
| Romania                   | 27    | 4.850   | 46.14 |
| <b>Russia</b>             | 94    | 16.88   | 63.02 |
| Spain                     | 116   | 2.510   | 65.53 |
| Sweden                    | 5     | 0.900   | 66.43 |
| <b>Switzerland</b>        | 4     | 0.720   | 67.15 |
| Turkey                    | 35    | 6.280   | 73.43 |
| <b>Ukraine</b>            | 4     | 0.720   | 74.15 |
| United Kingdom            | 144   | 25.85   | 100   |
| Total                     | 557   | 100     |       |

**Source:** author elaboration

Table 4.6 presents the panel unit root tests based on Augmented Dickey-Fuller (ADF). The ADF was chosen as it permits unbalanced panel data. The null hypothesis of a Fisher-type test is that panels hold unit roots (i.e., the variables are non-stationary).

Based on Alam et al. (2019), the results show that R&D intensity, lag R&D intensity, Total Assets, Cash Flows, Political Stability, and Rule of Law are stationary; while after first-order differencing, *GDP* per capita and debt ratio stay stationary. The results confirm that the variables in our model are stationary which means that the regressions are not spurious.

**Table 4.6:** Panel unit root test

|                     | level       | First difference |
|---------------------|-------------|------------------|
| RD intensity        | 559.5046*** |                  |
| Ln RD intensity     | 257.4701*** |                  |
| Ln Total Assets     | 289.4041*** |                  |
| Cash Flow           | 382.9208*** |                  |
| Debt ratio          | 157.7169    | 195.8894***      |
| GDP per capita      | 157.1252    | 188.5008**       |
| Political Stability | 462.0521*** |                  |
| Rule of Law         | 310.0322*** |                  |

Notes: All panel unit root tests were performed without intercept, drift, and trend for all variables.  
Level of significant: \* <0.10, \*\* <0.05, \*\*\* <0.01.

## 4.4 Results

Table 4.7 shows the results of the regressions that use the data with no restrictions to identify the determinants of R&D intensity in the energy sector. As in Alam et al. (2019), R&D intensity is positively related to that in the previous period for the OLS model. According to Wooldridge, (2013) when the value of the coefficient is higher than 0.1, an adjustment should be made for the interpretation to obtain the exact value. This model presents a persistence rate of 105% [ $\exp(0.722) - 1$ ] that indicates firms follow a stable R&D policy in the energy sector. Nerveless, in the FE models this relation is not significant.

The total assets show a negative impact on R&D intensity in both models. In the OLS model, when the total assets increase by 1%, the R&D intensity decreases by 7.5%, *ceteris paribus*. For the FE models, the effect is larger at 43% [ $\exp(-0.565) - 1$ ], *ceteris paribus*. These results go against the hypothesis of a positive relation between total assets and R&D intensity, which can be interpreted as less willingness by listed energy companies to take on R&D risks.

In the case of cash flows, we find a positive impact on R&D intensity in one model. The OLS model shows a positive impact that is significant at the 5% level. In both cases (OLS and FE) the value is very close to zero. Therefore, the results of OLS model do support the hypothesis of a positive relation between cash flow and R&D intensity. This support could mean that energy companies with bigger cash flow have the propensity to invest more in R&D (Alam et al., 2019) and to avoid the costs of external capital markets (Bhagat & Welch, 1995).

The regressions also present a statistically significant and negative relation with the debt ratio in both models. This relation can perhaps be explained by the fact that these companies are the largest in this sector, so typically they have lower levels of debt due to the confidence they convey to funders (Meng et al., 2020). For the OLS model, a 1% increase in the debt ratio leads to a 38% increase in the R&D intensity, *ceteris paribus*. Meanwhile, the values presented in the models are statistically significant at the 10% level for OLS model and at the 5% level for the FE model. Therefore, we predict that a negative relation will exist between the debt ratio and R&D intensity, following the expectations of the literature. Ogawa (2007) states that for the firms which already have outstanding debt, new issues can bring pressure and a negative impact on investment due to a finance premium that increases the probability of bankruptcy and discourages new investments.

The GDP per capita of the country in which the company is headquartered is also positively related with R&D intensity, but for FE model the impact is not significant. For the OLS model, a 1% increase in GDP per capita leads to a 0.00173% increase in the R&D intensity, *ceteris paribus*. This result means that if the economy of a country is growing, the energy companies of that country have a higher propensity to increase their R&D expenses (Kahouli, 2018).

Further, in the same table, it's found that the rule of law has a positive relation with R&D intensity, but only in the OLS model. This relation is significant at the 10% level and a 1% increase in the rule of law leads to an 8.9% increase in the R&D intensity, *ceteris paribus*. This relation means the agents have confidence in and abide by the rules of society. In the case of Political Stability, it is negatively related to R&D intensity and is significant at the 10% level. This relation means that if the political instability decreases, then the R&D intensity of energy companies will increase, but only for the FE model.

**Table 4.7:** Ln R&D intensity, full sample.

| Variables           | (1)<br>OLS          | (2)<br>FE            |
|---------------------|---------------------|----------------------|
| L.In RD intensity   | 0.722***<br>(0.053) | 0.120<br>(0.084)     |
| lnTotal Assets      | -0.075**<br>(0.030) | -0.565***<br>(0.169) |
| Cash Flow           | 0**<br>(0)          | -0<br>(0)            |
| Debt ratio          | -0.490*<br>(0.252)  | -1.069**<br>(0.513)  |
| GDP_pc              | 0.000**<br>(0.000)  | 0.000<br>(0.000)     |
| Political Stability | -0.127<br>(0.153)   | -0.505*<br>(0.274)   |
| Rule of Law         | 0.089*<br>(0.050)   | 0.817<br>(0.909)     |
| Timme Dummies       | Yes                 | Yes                  |
| Constant            | -0.360<br>(0.686)   | 6.139<br>(4.142)     |
| Observations        | 557                 | 557                  |
| R-squared           | 0.676               | 0.248                |

Robust t-statistics are in parentheses.  $p < 0.1^*$ ,  $p < 0.05^{**}$ ,  $p < 0.01^{***}$ . In columns 2 and 3, the outcome variable is logarithmic function of R&D intensity.  $\text{LnRDintensity}$  is the logarithmic function of R&D intensity in period  $t-1$ .  $\text{LnTotal Assets}$  represent the logarithmic function of the sum of total assets; long-term receivables; investment in unconsolidated subsidiaries; other investments; and net property, plant, and equipment and other assets. Cash Flow is the sum of net income after taxes minus preferred dividends and general partner distributions plus depreciation and amortization of intangibles for the fiscal period  $t$ . Debt ratio is the ratio between total debt and total assets of companies in period  $t$ .  $\text{GDPpc}$  represents the GDP per capita of the countries in period  $t$ . Political Stability measures perceptions of the likelihood of political instability and/or politically motivated violence, including terrorism. Rule of law reflects perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence.

In an increasingly globalized world in which political and other measures have consequences, even for those who are not necessarily covered by these constraints, an attempt was made to analyze whether all European countries, including those that are not part of the EU28, were affected by the 2030 Agreement that therefore addresses RQ1. According to Table 4.8, the variable dummy ( $\text{after2014}$ ) is considered for the period after the 2030 Agreement.

The results show that after 2014, although the results are not statistically significant at the 10% level for the variable  $\text{after2014}$ , the sign of the variable is negative in both models (OLS and FE), although the results are not statistically significant at the 10% level. The effect of  $\text{after2014}$ , on average, decreases the lag of the logarithm of R&D intensity for all companies in the sample; however, these differences are not significant in the OLS and FE models. The  $\text{LnRDintensity}$  has a positive and significant relation with  $\text{LnRDintensity}$  in both models.

All the independent variables do not present statistically significant results at the 10% level for either the OLS and FE models that means the 2030 Agreement has no effect on the variables.

**Table 4.8:** Ln R&D intensity, controlling for the 2030 Agreement.

| VARIABLES                     | (1)<br>OLS             | (2)<br>FE              |
|-------------------------------|------------------------|------------------------|
| after2014                     | -0.365<br>(1.295)      | -1.064<br>(1.573)      |
| L.ln RD intensity             | 0.794***<br>(0.045)    | 0.151*<br>(0.086)      |
| L.lnRDintensity*after2014     | -0.141<br>(0.087)      | -0.050<br>(0.0555)     |
| Ln Total Assets               | -0.045<br>(0.031)      | -0.567***<br>(0.165)   |
| lnTotal Assets*after2014      | -0.048<br>(0.052)      | -0.003<br>(0.047)      |
| Cash Flow                     | 0<br>(0)               | -0<br>(0)              |
| Cash Flow*after2014           | 0<br>(0)               | 0<br>(0)               |
| Debt ratio                    | -0.355<br>(0.397)      | -0.539<br>(0.613)      |
| Debt ratio*after2014          | -0.194<br>(0.495)      | -0.817<br>(0.574)      |
| GDP per capita                | 9.11e-06<br>(1.12e-05) | 1.48e-05<br>(3.69e-05) |
| GDP_pc*after2014              | 1.30e-05<br>(1.52e-05) | 1.61e-05<br>(2.42e-05) |
| Political Stability           | -0.023<br>(0.205)      | -0.443<br>(0.424)      |
| Political Stability*after2014 | -0.172<br>(0.287)      | -0.201<br>(0.410)      |
| Rule of Law                   | 0.112<br>(0.072)       | 0.846<br>(1.072)       |
| Rule of Law*after2014         | -0.042<br>(0.102)      | -0.047<br>(0.149)      |
| Time Dummies                  | Yes                    | Yes                    |
| Constant                      | -0.401<br>(0.812)      | 6.750*<br>(3.928)      |
| Observations                  | 557                    | 557                    |
| R-squared                     | 0.680                  | 0.255                  |
| Number of company_id          |                        | 95                     |

Robust t-statistics are in parentheses.  $p < 0.1^*$ ,  $p < 0.05$ ,  $** p < 0.01$ \*\*\*. In columns 2 and 3, the outcome variable is logarithmic function of R&D intensity. LlnRDintensity is the logarithmic function of R&D intensity in period t-1. LnTotal Assets represent the logarithmic function of sum of total assets; long-term receivables; investment in unconsolidated subsidiaries; other investments; and net property, plant, and equipment and other assets. Cash Flow is the sum of net income after taxes minus preferred dividends and general partner distributions plus depreciation and amortization of intangibles for the fiscal period t. Debt ratio is the ratio between total debt and total assets of companies in period t. GDP\_pc represents the GDP per capita of the countries in period t. Political Stability measures perceptions of the likelihood of political instability and/or politically motivated violence, including terrorism. Rule of law reflects perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of

contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence.

In order to address RQ2, a dummy variable of interaction,  $\text{after2014*EU28}$ , was created that equals one for companies headquartered in the EU28 and after the signature of the Agreement (in 2014), and zero otherwise.

The results are presented in Table 4.9. Although the results are not statistically significant at the 10% level, the sign of the variable is negative in both models (OLS and FE). This result can be interpreted as that the 2030 Agreement signed by EU28 countries is associated with a slight decrease in the R&D intensity of their companies in the energy sector.

Further, the logarithmic function of R&D intensity in the previous period is statistically significant at the 1% level in the OLS model. When analyzing the effect that the Agreement had on firms based in EU28 countries after 2014, the relation is no longer significant. However, the sign of the coefficient for  $\text{Ln RD intensity*after2014*EU28}$  is positive which means the R&D intensity increases in EU28 headquartered companies relative to the previous period.

Based on the results of the regressions, the variable  $\text{Ln Total Assets}$  is a significantly negative at the 5% significance level in the OLS model with  $\text{Ln R\&D intensity}$  and at the 1% significance level in the FE model. However, the effect of the Agreement on companies headquartered in the EU28 is not significant in the OLS and FE models. The same happens for the variable  $\text{Cash Flows}$ . In the OLS model, the variable  $\text{Cash Flow}$  is positive at the 5% level of significance, but in FE model it is negative and non-significant at the 10% level of significance.

In the FE model, the debt ratio has a negative and significant relation with R&D intensity that is significant at the 5% level. In another words, if energy companies have high values of R&D intensity, then the debt ratio of these companies is lower.

**Table 4.9:** Ln R&D intensity, controlling for the 2030 Agreement and the EU28 headquarters firms

| VARIABLES                          | (1)<br>ols           | (2)<br>fe               |
|------------------------------------|----------------------|-------------------------|
| after2014*EU28                     | -1.467<br>(1.616)    | -1.976<br>(2.122)       |
| L.lnRD intensity                   | 0.709***<br>(0.057)  | 0.108<br>(0.079)        |
| L.ln RD intensity*after2014*EU28   | 0.0225<br>(0.068)    | 0.003<br>(0.052)        |
| Ln Total Assets                    | -0.0939**<br>(0.036) | -0.582***<br>(0.177)    |
| Ln Total Assets*after2014*EU28     | 0.064<br>(0.059)     | 0.0305<br>(0.0711)      |
| Cash Flow                          | 0**<br>(0)           | -0<br>(0)               |
| Cash Flow*after2014*EU28           | -0<br>(0)            | -0<br>(0)               |
| Deb tratio                         | -0.332<br>(0.303)    | -0.456<br>(0.481)       |
| Debt ratio*after2014*EU28          | -0.599<br>(0.551)    | -1.415**<br>(0.698)     |
| GDP per capita                     | 0.000<br>(0.000)     | -5.62e-05<br>(5.45e-05) |
| GDPpc*after2014*EU28               | -0.000<br>(0.000)    | 6.48e-05<br>(4.89e-05)  |
| Political Stability                | -0.092<br>(0.220)    | -0.338<br>(0.302)       |
| Political Stability*after2014*EU28 | -0.385<br>(0.542)    | 0.0341<br>(0.659)       |
| Rule of Law                        | 0.058<br>(0.047)     | 1.462<br>(1.242)        |
| RL*after2014*EU28                  | 0.297<br>(0.322)     | -0.720<br>(0.674)       |
| Time Dummies                       | Yes                  | Yes                     |
| Constant                           | -0.049<br>(0.790)    | 8.957**<br>(4.134)      |
| Observations                       | 557                  | 557                     |
| R-squared                          | 0.679                | 0.262                   |
| Number of company_id               |                      | 95                      |

Robust t-statistics are in parentheses.  $p < 0.1^*$ ,  $p < 0.05^{**}$ ,  $p < 0.01^{***}$ . In columns 2 and 3, the outcome variable is logarithmic function of R&D intensity. L.lnRDintensity is the logarithmic function of R&D intensity in period  $t-1$ . LnTotal Assets represent the logarithmic function of sum of total assets; long term receivables; investment in unconsolidated subsidiaries; other investments; and net property, plant, and equipment and other assets. Cash Flow is the sum of net income after taxes minus preferred dividends and general partner distributions plus depreciation and amortization of intangibles for fiscal period  $t$ . Debt ratio is the ratio between total debt and total assets of companies in period  $t$ . GDPpc represents the GDP per capita of the countries in period  $t$ . Political Stability measures perceptions of the likelihood of political instability and/or politically motivated violence, including terrorism. Rule of law reflects perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of

contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence.

#### 4.5 Discussion

The questions that are related to climate change hotly debate matters such as innovation and how to rescue the planet (Calabrese et al., 2018). The energy sector, being one of the most pollutants, has made an effort to improve its polluting status through new energies and by increasing the efficiencies of traditional energies through investment in R&D (Toledano et al., 2020). There is more and more encouragement for green production and green innovation. According to Huang, Liao, & Li, (2019), the relation among companies, banks, and governments is becoming increasingly greater as governments guide the behavior of companies through effective interventions such as subsidies requiring green innovations, in which banks contribute through financing these innovation activities. In this study, we find that R&D intensity is positively associated to the previous period such as in (Alam et al., 2019; Su & Moaniba, 2020). This association means that R&D intensity depends very much on what happened in the previous period and not on external constraints. Also was found a positive relation between GDP and R&D intensity. This results corroborate those of Kocsis & Kiss, (2014), in the case of renewables energies.

Another finding that emerges from this study is the negative relation between R&D intensity and firms' size (Total Assets) that indicates that in energy sector, the largest companies have a lower propensity to pursue R&D due to its dominant position in the market that is an entry barrier for competitors. This finding corroborates the study of (Jiao et al., 2015). Nevertheless, analyzing the relation with R&D after 2014, we find a positive but non-significant relation for EU28 companies that overall, is still negative.

The rationale behind this result is that the largest companies, being dominant in the market, have a preference to buy R&D instead of developing it in-house, because the returns are uncertain in the future.

Although not statistically significant, a difference in cash flows exists between companies headquartered in EU28 countries and the rest of Europe after 2014. In the EU28, the relation between cash flows and R&D intensity turns negative. However, in a model without controlling for location, this sample presents a significant and positive relation with R&D intensity that supports hypothesis 2 and the literature associated with this hypothesis.

We also find a negative relation between R&D intensity and the debt ratio, which is in line with what the literature has previously shown. For example, Ogawa (2007) emphasizes that high debt can lead to the risk of bankruptcy for companies and, as such, argues that if debt is high it has a negative impact on R&D. Meng, Wang, Zhang, & Zheng, (2020) add the issue of access to credit that is conditioned to low levels of debt, and as such, the financing entities offer companies lower costs of debt compared to companies with higher levels of debt.

The results also highlight the questions related to political (in)stability in the energy companies. In particular, a lower instability could lead to increase R&D intensity. This increase means that the political environment can disturb the R&D intensity by affecting the uncertainty and costs related to R&D (Alam et al., 2019). The results obtained also raise questions about the perceptions of credibility of the government's commitment to such policies. The government's commitment may be a possible check as a change in the behavior of a country in which the environment of trust on the quality of formulation and implementation of policies and the credibility of the government's

commitment to such policies decrease can be the reason why companies headquartered there decrease their R&D intensity also decrease. The rule of law has a positive relation with R&D intensity that gives investors' confidence and, in turn, less asymmetric information that lowers the costs of capital. Pindado et al. (2015) argue that strong legal systems that ensure minority shareholder protection or the protection of creditor rights provide investors with an environment where investing in R&D is more conducive.

Taking in consideration the effect of R&D intensity before and after 2014 signing of the 2030 Agreement, we find a decrease of R&D intensity, although not significant, after 2014. Based on the sign, the results of the study of Marino, Parrotta, & Valletta (2019) match our findings. They also find evidence that the relation between regulation and innovation has an inverted U-shaped form. In our case, it can be interpreted that this regulatory measure associated with a decrease in R&D intensity. This sector is extremely regulated and a new legal imposition, even though in 2030, had a negative effect on R&D intensity, in the period under review. This form might mean that the effect of regulation on R&D intensity depends on the strength of the regulatory process. The research of Bassanini & Ernst, (2002) draws attention to the fact that there is a negative relation between the intensity of product regulation and the intensity of R&D expenditures.

## 4.6 Conclusions and contribution

### 4.6.1 Main findings

In this study, we provide a conceptual framework for the determinants of R&D intensity in the context of a policy change due to the 2030 Agreement. Consequently, the objective was empirically analyze the impact of the 2030 Agreement on R&D intensity on companies in the energy sector that were headquartered in the EU28. In a general way,

the results diverge from the initial expectation because the Agreement did not bring an increase in R&D intensity to those companies. However, the same condition exists in the other European countries. Although we do not find a statistically significant change in the behavior of the R&D intensity, in the sample and based on the sign of the effect after 2014, this study supports the results of Marino, Parrotta & Valletta (2019) who argue that regulation shocks, instead of increasing innovation, decrease it (U-inverted).

Another fact that should be highlighted is the effect of the previous R&D intensity on the present period. In all models, the relation is statistically significant which means that R&D is sticky in terms of lags. This stickiness can be explained by the high costs in the energy sector with no guarantee of a safe return, as well as the fact that they are multi-year investment plans that do not fluctuate much from year to year. Therefore, the largest companies become immune to external legal changes. Unsurprisingly, we find a statistically significant and positive influence of R&D intensity in the previous year on the current year such as in Su & Moaniba, (2020).

Also, we find that R&D intensity relates to the size (Total Assets) of the companies. This relation is negative that indicates the largest companies have a lower propensity to pursue R&D. This lack is due to their dominant position in the market that becomes an entry barrier to competitors (Jiao et al., 2015). However, after 2014 in Europe the relation changes to positive that signals the commitment by EU28 companies to the Agreement and an alignment with the SDGs. But overall, this commitment is not enough to increase R&D in the energy sector.

The results also call the attention to the questions of perceptions of governance. The 2030 Agreement brought more political instability and a greater perception of the

rule of law to the European countries that increased agency costs and decreased R&D investment, such as Wang et al., (2015).

Following the rationale of Makri, Hitt, & Lane (2010), large companies prefer to buy technology already developed by start-ups that thus accelerates their adoption of new technology. Therefore, this decrease could be explained by the fact that companies may have redirected their investment to purchase assets, such as solar panels or wind turbines, in order to comply with the 2030 Agreement, thus divesting them of developing new technologies or improving their energy efficiency. Another aspect that could justify these results is the possibility of national governments or the EU giving subsidies to the companies for research projects and that those funds are classified as a different accounting item. Another hypothesis is that R&D expenses are associated with very high fixed costs and, therefore, the changes in the behavior of these agents are not immediate. Based on these high fixed costs, these expenses have significant weights in the budgets of the companies, but R&D investment has a medium-term impact, so those decisions at a reporting level are not instantaneous.

Finally, the differences between companies based in EU28 or non-EU28 countries are marginal. The main difference occurs for Total Assets in companies headquartered in EU28 countries; Total Assets has a non-significant positive relation with R&D intensity as compared to a non-significant negative relation in non-EU28 countries. This relation means that companies with bigger Total Assets in the EU28 are more likely to invest more in R&D than companies in non-EU28.

#### 4.6.2 Policy implications

The contribution of this study is to understand the strategy adopted by companies in the energy sector with regard to R&D intensity by taking into account the effect of the 2030 Agreement on the EU28 countries. Bearing in mind that not investing in R&D can question the future of companies, it should create concern for shareholders. The results of this study may reflect a highly regulated sector where entry costs are high and where competition is not so high. So, governments need to lower the barriers to entry in the market to increase competition.

The implementation of this Agreement caused a decrease in R&D intensity in our sample, although the difference is not statistically significant. Therefore, governments need to create more incentives for companies to increase R&D intensity faster in order to achieve the targets of the 2030 Agreement and a sustainable economy. This goal should be possible through technology and energy consumption with a minor environmental impact with innovation a key factor (Fernandez Fernandez et al. 2018). The goals of the 2030 Agreement can be achieved by increasing the percentage of renewable energy consumption by increasing innovation (Sim, 2018), and reduce carbon dioxide emissions (Fernández Fernández et al., 2018). Since this sector is one of the most polluting, they should take the initiative to help mitigate climate change, if only because of the pressure of public opinion.

The results also highlight the questions related to political (in)stability. In this case, the change of regulation brought a disturbance to the political environment and the consequence was the decrease in R&D intensity because of uncertainty and the costs related to R&D (Alam et al., 2019). Further, in EU28 companies after 2014, although not

significant, there has been a growth in the perception of the rule of law, although not significant.

In sum, to achieve the goals of the 2030 Agreement, companies and governments need to improve the R&D investment to increase renewable energy consumption, improve energy efficiency, and reduce greenhouse gases in order to contribute to an alignment with the SDGs of the Agreement. This increase can be done in three ways: through incentives to companies (may be through subsidies or grants) or by creating penalizing measures for those who do not have acceptable levels of energy efficiency or low CO<sub>2</sub> emissions. The second way is to decrease the entry barriers and increase the competition in this highly regulated sector. The last way is to create an atmosphere of political stability and rule of law (contract enforcement) with strong incentives.

#### 4.6.3 Main limitations

Like any research, this study also has limitations. One limitation is the fact that the study focuses on companies in the energy sector in Europe, and the data on R&D spending is not available for all the listed companies of this sector. Therefore, we cannot generalize the results. In accounting terms, R&D can be classified in two ways: first as an asset from which the company expects to obtain future benefits and second as expenditures from which there is no certainty of obtaining future benefits. For these motives, it is not possible to make a generalization of the results, because they are based on expenditure information.

Due to the lack of data available, it is not possible to generalize the results because that not all EU28 countries are represented in the sample. The same happens with non-EU28 companies.

Hence, this investigation can only be generalized for companies in the stock market, as the features of those companies can diverge from non-traded companies. Therefore, further research is needed on the companies outside of this sample, like SMEs.

#### 4.6.4 Further research

Future studies need to collect data on companies of non-renewable energies because these companies must rethink their business because of the further agreements that will emerge regarding climate change. Due to the objectives of the 2030 Agreement, it will also be interesting to analyze the sector of oil companies which will have the greatest direct effect not only in terms of R&D but also in terms of performance.

One possible explanation for our results is the fact that no distinction has been made in the type of company linked to the energy sector, and perhaps different behaviors in renewable energy companies exist compared to non-renewable energy companies in terms of R&D expenditures. Thus, this suggests the need for such a study.

For the energy sector it would be interesting to analyze the business strategy that these companies have as well as the type of management by observing factors such as the composition of the board or ownership structure.

Further, analyzing the behavior of R&D intensity in other markets such as China, India, or the US, since they are a major contributor to the pollution of the planet, could be of interest.

At last, since the energy sector has an important role in the economy, geopolitically, technologically, and environmentally, it is important to find out the

reasons for the decrease in R&D spending in the European countries, especially in the EU28 countries, since the 2030 Agreement focuses on them.

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## Chapter 5: Conclusions and Contributions

### 5.1 Conclusions

Electricity research comprises various fields, such as Environmental Science, Engineering, Social Sciences, Economics, Econometric, and Finance. It is a field of multidisciplinary study that brings together many viewpoints (Haunschild et al., 2016). Consequently, the main objective of this study was to examine a growing electricity segment from different perspectives– the 2030 Paris Agreement. Was chosen this setting as it combines research strategies with both qualitative and quantitative approaches across countries, and over time.

This thesis contains three studies that encompass the multidisciplinary nature of the energy sector due to the nature of the issues involved (Foley et al., 2017), and it provides a deep overview of the industry: by academia, the markets, companies, and policymakers. The first study is entitled “*Toward the Paris Agreement implementation impact on electricity sector: The emerging reality*”. This study examines the state of the art related to the electricity sector and verifies the effect of the Paris Agreement that attests to the importance of these type of agreements to fight against the climate changes in the planet through journals, universities, and funding agencies. Was used a sample of 210 publications for the period from 2016 to 2019 to identify an increasing trend in the research that is related to the Paris Agreement that show the importance of this Agreement on the context of electricity.

This study contributes to the literature in several ways. First, it has identified the prevalence of studies based on forecasting models that would lead to the achievement of the goals established in the Agreement regarding the reduction of greenhouse gas emissions such as Baek, Jung, & Kang (2019) and Bataille et al. (2018) and increase the

consumption of renewable energy such as Lacal Arantegui & Jäger-Waldau (2018) and Washburn & Pablo-Romero (2019). After that, the investigation recognized the cross-cultural dimension of the Paris Agreement by showing that in the electricity sector, research is being conducted across 57 different countries from all continents and participating in research participated through various avenues such as journals, books, and conference proceedings. Furthermore, the number of publications has been growing year after year and has tripled in 2017 in terms of articles.

Additionally, reflecting that climate change is an international phenomenon is the fact that around a third of the articles published in journals were in partnership with researchers from other countries. The systematic literature review has a limited association with the systematization procedure and the range of the research. The a priori definition of a research equation, and other insertion and elimination criteria, can inadvertently leave out some essential articles. However, this limitation is part of the systematization procedure and is enormously helpful in delimiting the research in accordance with our goals.

The second study is entitled “*The impact of the 2030 Climate and Energy Framework Agreement on electricity prices in MIBEL: A mixed-methods approach*”. It brings an insight into the markets by analyzing the impact of the 2030 Agreement on derivatives of electricity, in particular the spot prices in Portuguese and Spanish markets. Qualitative and quantitative methods (mixed-methods) were applied and were complementary that enriched the research. The sample is composed of four years of daily spot prices between 2012 and 2016 which generated 1,476 observations from the Iberian markets in order to check for seasonality, peak prices, and volatility. The results show that these markets are very volatile with a seasonality of order 7, that is, on Sunday spot

prices are lower. Also, was found the existence of a peak price. Furthermore, when comparing the periods before and after the 2030 Agreement, the volatility of spot prices decreases in both markets. This finding led to the conclusion that the Agreement was a factor of greater price stability which is advantageous by limiting the price fluctuations for consumers and enabling producers to be able to better respond to their consumers' demand needs. This reduced the uncertainty for both sides. As for electricity pricing after the 2030 Agreement, the average price increased due to the cost of renewable energy production being higher than that of fossil fuels. This result can be interpreted as an effort to achieve the goals of the 2030 Agreement by increasing the consumption of renewable energy.

In terms of seasonality there were no changes and peak prices continued to exist in both periods. This is interpreted as a sign that the grid does not have sufficient capacity to meet the needs of consumers, so policymakers must ensure ways to increase grid capacity.

The qualitative analysis showed that the conditions which contribute to the stability of spot prices. Due to issues related to the standardization of the sample, the other variables only had values for five days of the week while the spot prices had data for seven days of the week. Thus, the sample was reduced to 1,039 observations. The results show that fsQCA supports the finding of a decrease in volatility by identifying a larger number of paths that lead to price stability for the subperiod after the signing of the 2030 Agreement. We interpret the increasing number of configurations after the Agreement as a sign of a more propitious environment for stable spot prices. Thus, further research is suggested to examine the impact of the 2030 Agreement on other markets besides the Iberian and to check for the conditions that lead to stability.

This study contributes to the current literature for several reasons. First, to the best of our knowledge, this study is the first work that combines the use of the quantitative methodology of a time series with the qualitative method of fsQCA that shows there are different ways of looking at the same problem and that the same conclusions can be reached (Roig-Tierno, Gonzalez-Cruz, & Llopis-Martinez, 2017). Traditionally, only the time series is used to check the seasonality, peak prices, and volatility (Pietz, 2009), but the conditions that contributed to the stability and non-stability of spot prices were never analyzed. Second, the implementation of measures to mitigate climate change, such as the 2030 Agreement, brings stability to prices in the derivatives markets. An increase in the stability of the spot price is good for consumers and producers because it reduces uncertainty. And finally, this study reinforces the literature about the specific characteristics of this commodity, such as the existence of weekly seasonality on Sundays as well as the existence of peak prices (Janczura & Weron, 2010), that are features that can be harmful to consumers (Newbery, 1998).

The third and last study complements this overview about the energy sector by looking at the company's point of view and prospects of this business. The title is "*Analysis of the impact of the 2030 Agreement on R&D intensity on energy sector*". Based on panel data, was conducted an analyze of R&D intensity on companies in the energy sector and check their behavior before and after the 2030 Agreement. We also analyze whether there is a difference between companies headquartered in the EU28 and those in the rest of Europe. The reason is the fact that the literature has verify that R&D investments contribute to a reduction of CO2 emissions (Gu & Wang, 2018) through the development and implementation of environmental friendly technologies and that improving the efficiency of existing technologies through R&D can transform it into energy savings (Costa-Campi et al., 2015) and increase the use of renewable energies (Lin

& Chen, 2019). In addition to looking at R&D intensity, financial indicators were also analyzed as well as the institutional issues involving companies in this sector such as in Alam, Uddin, & Yazdifar, (2019). From a sample of 95 companies in the energy sector with headquarters in Europe, was examine the level of R&D intensity before and after the 2030 Agreement to check if companies are committed to mitigating climate change.

The results show that the 2030 Agreement generated a decrease in R&D intensity in Europe that is based on the signal analysis, although no statistically significant change in the level of R&D intensity was found. The result matches the result obtained by Marino, Parrotta, & Valletta, (2019) who complain that since this is a highly regulated sector, at a certain point regulation instead of increasing R&D decreases it. However, the level of R&D intensity is closely related to the previous period (Su & Moaniba, 2020). In terms of the size of companies (total assets), the 2030 Agreement in EU28 brought a change. Traditionally, the largest companies were in dominant market positions and were not as likely to invest in R&D intensity (Jiao et al., 2015); however, after the 2030 Agreement they started to invest more in R&D, although it was not always statistically significant in the models.

The relation between R&D intensity and cash flows was positive but the effect of the 2030 Agreement brought a negative sign to the relation, although the effect was not statistically significant in the EU28 countries. This result is a reflection of the fact that companies with lower cash flow invest more in R&D in order to obtain more returns in the future, with the expectation of future returns to operational cash flows by avoiding the costs of external capital. (Bhagat & Welch, 1995).

In terms of the debt ratio, the relation with R&D intensity in the sample without restrictions is negative which means that, according to Ogawa, (2007), companies give

attention to the level of debt and they reduce their R&D intensity if the level is high. In cases of companies which already have outstanding debt, new issues can bring pressure and a negative impact on investment due to a finance premium that discourages new investments - due to outstanding debt and new debt increasing the probability of bankruptcy or at least financial distress, which managers tend to avoid.

The energy sector by nature is highly regulated and, with some restrictions on the entry of new companies, the results also show that after the 2030 Agreement there was a perception of greater instability and less credibility in the government's commitment to such policies. These less positive perceptions cause agency costs to increase and as a result investors are less available to invest in R&D (Hong et al., 2015). In sum, the R&D intensity decreases after the 2030 Agreement but not in a statistically significant way. Therefore, there should be some indications from the EU28 countries that could lead to increased R&D intensity in the coming years and as soon as they can contribute to achieving the SDGs of the 2030 Agreement. Nevertheless, more research is advised on this topic to advance the theoretical foundation.

The question of the perception of the rule of law help to explain the R&D intensity because in this sample a significantly positive relation is established between these two variables, that is, when companies have a positive perception of the rule of law and feel more comfortable with strong legal systems where there is, for example, protection of minority interests or the protection of creditor rights, they provide investors with a higher propensity to invest in R&D (Pindado et al. 2015). Analyzing the effect of the 2030 Agreement on the EU28 countries did not show a significant change.

## 5.2 Contributions to Practice

Researchers are sometimes considered to be spokespersons for the financial system and as such they need to be protected against these risks as there is public resentment against the financial system in general. Therefore, there needs to be better explanations and documentation of the contributions of finance to society and not just for academia (Zingales, 2015). The contribution that this thesis makes has several levels: academic, policy, and managerial.

The practical contributions of this doctoral thesis are at the academic level and call attention to the emerging topic that relates electricity to the political measures that governments and companies have taken to mitigate climate change and thus contribute to a sustainable world. The research developed in chapter 2 shows that the growth in this topic is not only in terms of the increase in publications but also through partnerships between several countries. Although the study area with the greatest weight in terms of publications is the field of Energy, the interest is vast in different areas such as Engineering, Social Sciences, Economics, Econometric, Finance, or Mathematics and is therefore a multidisciplinary area.

Chapter 3's contribution is at the managerial level. Its research is based on the derivatives markets point of view. This view calls attention to the recent liberalization of the electricity market of Iberian countries. This market reflects the specificities of this types of commodities that include characteristics such as seasonality, high volatility, and peak prices. These indicators reflect an electric power network that is not sufficient to meet the needs of demand and supply, so it is necessary to take political measures to encourage an increase in the network. For consumers, the 2030 Agreement brings greater awareness of the need to pay better attention to climate change from which consumers are willing to pay more for the use of renewable energies.

Based on chapter 3, the results show a decrease in volatility but still has peak prices. For that reason, the policymakers should improve the grid to avoid periods where demand is greater than supply because of the limited capacity of the grid.

From the energy companies' point of view this thesis helps with understanding that the 2030 Agreement does not increase R&D intensity so it can compromise the fight against climate change in the future. However, studies have shown that R&D intensity is very dependent on previous R&D. Therefore, external effects have no impact on R&D intensity because of R&D's medium-term effect. Thus, after 2014, the 2030 Agreement has no effect on the variables in the models. This result means that companies do not condition their strategic choices on external factors. For energy companies there was a decrease in the credibility of government policies as well as the perception of political instability from their point of view. Based on these facts, policymakers should think about promoting R&D as a way to progress to a sustainable world.

At the policy level, the contribution of the research in chapter 4 is centered on the point of view of companies and policymakers. The results provide an important overview of the current situation in which there is a verifiable statistically nonsignificant decrease in R&D intensity verify after 2014. This decrease raises questions related to the possibility of companies losing competitive advantages while having more expenses with R&D. Thus, monitoring technological modifications now has a strategic meaning (Lee & Lee, 2013). From the point of view of managers, they need to understand the conditions for R&D in the energy sector in Europe. Then, they can take advantage of the opportunity from a slight reduction in R&D intensity and invest countercyclically to gain more competitive advantages.

For policymakers, this study provides insights into policies that allow the energy sector to contribute to the SDGs. To achieve the SDGs of the 2030 Agreement,

governments and companies need to promote measures that allow for an increase in R&D intensity. These measures could take the form of tax incentives or subsidies to achieve a sustainable economy. Policymakers from European markets should focus more on institutional factors, like political stability and government effectiveness, to formulate the right policies to increase R&D investment. Further, policymakers can create measures that promote increased competition in this sector and look for ways to remove some barriers to entry for new players. According to (Alam et al., 2019), if the perception of the institutional environment of a country is good, it can stimulate R&D investment by reducing bureaucracy, promote market entry, capture foreign investors, increase investors' confidence through protection, and speed up technological investment.

### 5.3 Limitations

The diverse stages of the research present some limitations that are linked to the intrinsic methodological choices and the samples.

From the beginning, the bibliometric analysis has a limitation that is associated with the systematization and the range of the study. The a priori definition of a research topic, and other inclusion and exclusion criteria, can involuntarily leave out some important articles. However, this limitation is part of the bibliometric process and is extremely helpful in delimiting the research in accordance with our goals.

The time series methodology based just on the spot price does not consider other types of electricity derivative contracts with other maturities such as hourly prices or annual, semester, or monthly contracts. These other types of contract can show another characteristic of electricity that may be hidden. The choice of the sample period might influence the results.

The choice of fsQCA is limited by the available data that exclude weekends from the working week. This exclusion does not allow for checking if the conditions are the same when data of the weekends is included. The recommendations are for the use of a maximum of five to six conditions in fsQCA. These conditions would be limited to those variables that were more relevant to explaining the stability of spot prices.

The panel data that was applied is limited to the data that are available on the R&D expenditures of the companies selected. By nature, the release of this information is not mandatory that raises questions whether that is a good governance practice. Also, variables for the type of ownership were not considered. Ownership might condition the company strategy for R&D investment as could the age and gender of managers.

## 5.4 Further Research

Taking stock of the evolution of this work, I had expected to understand how the markets and companies in the energy sector reacted to the 2030 Agreement, to which I got some answers. However, other questions came up that I would like to explore further in the future, in addition to the suggestions for future research that I have indicated in each study.

Since market results indicate that the Agreement brought greater price stability and less perceived legislative effectiveness, it is important to explore the factors that led to this apparent divergent behavior between markets and companies.

Another idea for future research that arises is related to the characteristic of the electricity commodity, which is the impossibility of storage in economic terms. There needs to be a better understanding of what is being done in terms of research and investment to make the storage of electricity possible. What are the main companies that

are developing technology to achieve this end? Are these companies related to energy production, energy transportation, or something else, such as renewable or fossil energy?

Another topic that needs more development is related to the policy question on the existence of a single European electricity market where prices are similar from country to country. What measures can be taken to create this single electricity market and to further harmonize prices? The question of a common electricity market raises questions related to the tax policy of the European Union which still does not exist and whose mechanisms such as feed-in tariffs, tax-reduction schemes, investment subsidies, and quota systems specifically target the generation of renewable energy resources have different applications according to each country. These issues can cause companies to move their facilities to where the tax situation is most beneficial. It will be interesting to explore if there are companies that exploit these types of opportunities that arise within the European Union.

The issue with subsidies and grants as a way of promoting the production and consumption of renewable energy is that there are countries that give more incentives than others despite being under the same regulation. Which incentives are most prevalent and why? The European Union countries are among the most developed countries; will these types of incentive mechanisms increase the gap between these and less developed countries?

Another topic in the energy sector that would be interesting to explore is related to R&D spending; how do managers not condition R&D expenditures on the remunerations or awards they give themselves? An analyzation of the composition of the boards of companies would be advisable. Answering the question on how the gender and

age of managers affects R&D investment might help. Does the composition of the board affect the strategy of companies?

The research done in this thesis looked only at listed companies, so it would be interesting to see if SMEs present similar or opposite results due to another strategy in relation to R&D.

The situation that the whole planet faced with covid-19 came to affect all businesses. The effect of lock downs probably impacted spot prices and in turn the performance of companies. Beyond the energy sector, one of the most affected were the airlines that saw many of their planes grounded. Due to this situation, they have not used fuel, and demand declined abruptly as it probably had an impact on the fuel price. It will be interesting to see the impact it has had on energy prices and on-air transport companies.

In addition to political and financial issues, there are also social issues that can be explored. It would also be interesting to understand how the social issue works, that is, how the issues of certain regions not yet having access to electricity are being addressed. What is being done to make this happen? Also, the average price of electricity has risen due to the incorporation of the cost of renewable energy that increases the financial difficulties of more families. Therefore, what is the role of the states as social agents?

I am far from fully understanding how the energy sector has reacted to the 2030 Agreement. Thus, my investigation in this field will continue to develop over the following years to help to understand this phenomenon and to generate relevant policy suggestions for those companies and countries that intend to improve their sustainable financial and economic development.

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