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MASTER´S FINAL WORK

DISSERTATION

THE IMPACT OF IMPERFECT STORABILITY ON PRICE DYNAMICS AND RISK PREMIUMS IN THE IBERIAN ELECTRICITY MARKET (MIBEL)

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Abstract

This dissertation explores the Iberian Electricity Market (MIBEL), which was established to integrate the energy markets of Portugal and Spain, aiming to enhance competition, efficiency, and transparency. The research focuses on the dynamics between spot and futures prices, examining the impact of electricity's non-storability on market behavior. Using theoretical models by Fama and French (1987) and Huisman and Kilic (2012), our analysis reveals that short-term futures contracts in MIBEL exhibit strong forecasting power, while longer-term contracts tend to have weaker predictive capabilities and display significant risk premiums. Through comparisons with other European energy markets like Nord Pool, this study identifies MIBEL's unique challenges and highlights areas for structural improvements. We conclude that advancing risk management practices and developing financial instruments tailored to non-storable energy assets are essential for MIBEL's continued growth and its role in building a more resilient and sustainable electricity market across the Iberian Peninsula.

Keywords: Electricity markets, storability, spot prices, future contracts.

Resumo

Esta dissertação explora o Mercado Ibérico de Eletricidade (MIBEL), que foi criado para integrar os mercados de energia de Portugal e Espanha, com o objetivo de aumentar a concorrência, a eficiência e a transparência. A investigação centra-se na dinâmica entre os preços spot e futuros, examinando o impacto da não armazenabilidade da eletricidade no comportamento do mercado. Utilizando modelos teóricos de Fama e French (1987) e Huisman e Kilic (2012), a nossa análise revela que os contratos de futuros de curto prazo no MIBEL apresentam um forte poder de previsão, enquanto os contratos de longo prazo tendem a ter capacidades preditivas mais fracas e apresentam prémios de risco significativos. Através de comparações com outros mercados europeus de energia, como o Nord Pool, este estudo identifica os desafios únicos do MIBEL e destaca áreas para melhorias estruturais. Concluímos que o avanço das práticas de gestão de risco e o desenvolvimento de instrumentos financeiros adaptados a ativos energéticos não armazenáveis são essenciais para o crescimento contínuo do MIBEL e para o seu papel na construção de um mercado de eletricidade mais resiliente e sustentável na Península Ibérica.

Palavras-chave: Mercados de eletricidade, armazenabilidade, preços spot, contratos futuros.

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Abbreviation List

Abbreviation	**Definition**
CNMC	Comisión Nacional de los Mercados y la Competencia
EDP	Energias de Portugal
EEX	European Energy Exchange
ERSE	Entidade Reguladora dos Serviços Energéticos
GARCH	Generalized Autoregressive Conditional Heteroskedasticity
MIBEL	Iberian Electricity Market
MIBGAS	Iberian Gas Market
MIT	Massachussets Intistitute of Technology
MW	Megawatt
NYMEX	New York Mercantile Exchange
OLS	Ordinary Least Squares
OMEL	Operador del Mercado Ibérico de Energía - Polo Español, S.A. (Before 2007)
OMIE	Operador del Mercado Ibérico de Energía - Polo Español, S.A. (After 2007)
OMIP	Operador do Mercado Ibérico - Portugal
PJM	Pennsylvania - New Jersey - Maryland
REE	Red Elétrica de España
REN	Redes Energéticas Nacionais

1. Introduction

The integration of energy markets has become an essential component of fostering economic growth and sustainability in interconnected regions. In this regard, the creation of the Iberian power Market (MIBEL) in 2007 marked a turning point for Portugal and Spain by uniting two previously separated power markets under a single, unified structure. MIBEL's primary goal was to encourage cross-border trade in electricity between the two nations while enhancing market efficiency, competitiveness, and pricing system transparency. This project was designed to address the wider objectives of the European Union's energy strategy, which aims to liberalize and integrate energy markets among its member states, in addition to improving the efficiency of the energy sector.

The electrical markets in Portugal and Spain, before the MIBEL, faced different challenges. EDP (*Energias de Portugal*), a state-owned utility company, dominated the production and distribution of energy in Portugal. Due to the lack of competition brought about by this almost monopolistic arrangement, inefficiencies including outmoded infrastructure and inefficient resource allocation occurred. Then, in the 1990s, Spain established the OMEL wholesale electricity market, which was home to several significant energy firms, including Endesa and Iberdrola. But even with competition, energy rates in Spain were still regulated, and the market faced difficulties related to regulations, especially those pertaining to the liberalization process (MIBEL, 2022).

The necessity to integrate these two disparate systems and remove obstacles to international energy trade was the impetus behind the establishment of MIBEL. This was necessary to maximize resource allocation and maintain supply and demand equilibrium throughout the Iberian Peninsula. MIBEL sought to lower energy costs, enhance infrastructure investment, and boost market liquidity by merging the Portuguese and Spanish electricity markets. It also aimed to improve consumer protection and transparency through improved regulatory oversight, working together to assure market efficiency and compliance between the Portuguese Energy Services Regulatory Authority (ERSE) and the Spanish National Commission on Markets and Competition (CNMC).

The Spot Market and the Forward Market are the two primary markets used by MIBEL. Daily and intraday trades take place in the Spot Market, which is run by OMIE (*Operador* *del Mercado Ibérico de Energía – Polo Español*). This allows for price discovery based on supply and demand that is current. The Forward Market, overseen by OMIP (*Operador do Mercado Ibérico de Energia – Polo Português*), allows market players to protect themselves against price volatility by facilitating the exchange of future contracts. Because of its dual structure, MIBEL can adapt to both long-term risk management plans and short-term market swings.

The idea of storability is one of the most important topics in the study of power markets. Unlike other commodities, electricity cannot be readily stored, so supply must always keep up with demand in real time. When compared to storable energy assets like natural gas, which can be stored and used to cushion demand variations, this feature poses special pricing issues for electricity. Because electricity cannot be stored, price volatility increases, which emphasizes the importance of futures markets for market players as a hedging strategy. The comparison of the natural gas market, MIBGAS, and the electricity market, MIBEL, offers insightful information about how storability affects market behavior and energy pricing, which may be used to further investigate this dynamic.

The remainder of this work is structured as follows. A thorough history of the MIBEL is given in Section 2, emphasizing its formation, the structure of the market, and the contributions of important parties including OMIE, OMIP, and regulatory agencies. With an emphasis on the impact of asset storability and the existence of risk premiums in futures contracts, Section 3 discusses the approach used to evaluate the link between spot and future prices in the MIBEL. The data sources for the analysis are listed in Section 4, which also includes an explanation of the time period and important variables. These sources include the spot and futures prices from OMIE, OMIP, and ERSE. Regression models are used in Section 5's empirical research to ascertain if time-varying risk premiums exist and how predictive futures contracts are. The study is finally ended in Section 6, which summarizes the results and discusses their implications for future research as well as for market participants and policymakers.

2. LITERATURE REVIEW

2.1 STORY OF THE MIBEL

The energy market on the Iberian Peninsula is, since 2007, called the MIBEL which integrates the electricity markets of Portugal and Spain. This market was established with the goal of facilitating the trade of electricity across the territory, promoting competition, efficiency and transparency in electricity pricing. Working alongside the MIBEL, MIBGAS is the Natural Gas market of the Iberian Peninsula, which allows cross-border gas trading between Portugal and Spain and was created with the same objectives as the MIBEL. The main difference between these two markets is the storability of the goods traded and their pricing, as Natural Gas is a perfectly storable energy asset, and Electricity is a non-storable energy asset. Therefore, the MIBGAS will be used as a term of comparison to our study of the MIBEL, regarding spot prices of energy assets with different storability.

Since the creation of energy markets electricity pricing became a critical area of study, mostly regarding the storability of the asset. This literature review will focus on MIBEL and compare its methodology of pricing with other examples of markets across Europe. In this study, the aim is to provide understanding of how perfectly storable energy assets, such as Natural Gas and Hydropower, and non-storable energy assets, like wind and solar power, can influence electricity pricing by analyzing their treatment and impact.

Before 2006, year of the creation of the MIBEL, Portugal and Spain each had their own way of operating an energy market. In Portugal, the main player of the market, EDP, was state-owned, having a major role in both generation and distribution. This lack of competition created various problems, among those, outdated infrastructure and suboptimal resource allocation. In Spain, in the 1990's, there was, already, a wholesale electricity market, known as OMEL, with smaller and bigger producers, such as Iberdrola, Endesa or Gas Natural Fenosa. However, even with the competition created by this new market, prices were still regulated and there were growing pains with liberalization, especially in regulation, with CNMC (National Commission on Markets and Competition) overseeing the market. The combination of problems in Portugal and Spain, added to the difficulties and missed opportunities of cross-border trading, lead both countries to act and try to harmonize their regulatory frameworks and create mechanisms for cross-border trading by doing bilateral agreements that led to market integration. The goal of MIBEL's creation was to address these issues by integrating the markets, promoting competition, and improving overall market efficiency and transparency. In 2000, Portugal and Spain began negotiations to create a unified electricity market in the peninsula, with the idea being formalized in 2001 with an agreement in Madrid to establish the Iberian Electricity Market. Between 2002 and 2004, the regulatory entities of each country agreed on legislative changes to facilitate the integration of their electricity markets, including harmonization of market rules and standards. OMIE and OMIP, market operators for the MIBEL, were created in 2005 with the goal of managing day-ahead and intraday markets, OMIE (Spain), and the forward market, OMIP (Portugal). Finally, the first cross-border trade between Spain and Portugal happened on the 1st of July 2006. From that date, the MIBEL has been in constant improvement, adapting new to new technologies and including renewable energies to its framework (Histórias EDP, 2022).

But how does MIBEL work? MIBEL has two different markets: Spot Market and Forward Market. In the Spot Market, managed by OMIE, there are two different types of trades and markets, the Daily Market, where the settlement day is the next day and the price of the asset is defined by supply and demand, and the Intraday Market, where players can deal with volatility and unexpected changes of price as they can balance their position with adjustments closer to real-time. In the Forward Market, managed by OMIP, future contracts are traded, with a fixed price and a future delivery of electricity, in order to provide coverage to players against price volatility. In terms of Regulation, CNMC (Spain) and ERSE (Portugal) work together to guarantee market competition, market efficiency, consumer protection and regulatory compliance. The pricing system differs from market to market. In the Day-Ahead Market Auction, participants bid on how much electricity they want to buy or sell, with various prices that are then aggregated to create a demand and supply curve, with an equilibrium price where demand meets supply. This equilibrium price will become uniform for every trade happening in each hour of the next day. In the Intraday Market Auctions, the process is similar but with multiple sessions throughout the day that allow for continuous adjustment, with bidding closer to real-time. To ensure the efficient allocation of resources, and as we have learned, the price at which the total quantity of electricity supplied equals the electricity demanded reflects the marginal cost of the last unit of electricity traded. (ERSE, 2024)

The creation of the MIBEL brought benefits to the electricity market in the Iberian Peninsula, such as competition, allowing lower prices for consumers as producers have an open market; efficiency, as reso urce allocation was improved and security of supply, as cross-border trading provides solutions to unexpected shortages of supply. However, these benefits came with a cost and new challenges, mainly in infrastructures capable to sustain market integration and renewable energy and in regulation, since Portugal and Spain had to align in this regard. In a consumer view, even though market volatility increased, trade is now more transparent and efficient. (ERSE, 2024)

Today, the MIBEL involves a lot of players with different roles: Market Operators, Regulatory Bodies, Electricity Producers, Electricity Suppliers and Distributors, Traders and Financial Institutions and, finally, consumers and prosumers (consumers who own some kind of production of renewable energy, such as solar panels). The biggest player in Portugal is EDP S.A. and in Spain it is Iberdrola. (ERSE, 2024)

To sum it up, the MIBEL was a major breakthrough for the Iberian Market that helped not only producers, but also consumers with its competition, transparency and efficiency. Despite its almost 18 years of existence, MIBEL is an ongoing project and every year there is progress towards a more sustainable and efficient market.

2.2. TECHNICAL CHARACTERISTICS

According to ERSE, the regulator entity of the MIBEL, after the liberalization process, the structure of the market in the Iberian Peninsula is like other electricity markets in Europe, following European Union directives. Transportation and distribution of electricity are under a monopoly, with REN in Portugal and REE in Spain, being subject to regulation from ERSE and CNMC, respectively. On the other hand, to guarantee greater efficiency and a better resource allocation, production and commercialization of electricity have an open market, where production is a wholesale market and commercialization a retail market. (ERSE, 2024)

The liberalization process brought new challenges for the regulators and for the players in the MIBEL. Agents monitoring the market need to pay close attention to two different types of markets, not only the spot and forward market, where electricity is traded daily, intradaily and forward, between two parties and offers instruments of risk management in the form of derivatives, but also the markets of other resources that can influence electricity pricing, such as coal, oil, natural gas or CO2 allowances. The sources utilized in MIBEL are the following: wind, water, nuclear, sun and thermal.

OMIP and OMIE, main operators of the MIBEL, offer daily bulletins with market information regarding every product traded and the volume of electricity traded each session, from 8 a.m to 18.30 p.m. Players have access to a diversity of products, from spots to swaps, going through futures, forwards and options. Price formation will consider all these trades, as well as the supply. In our object, most sales happen on the daily market, where agents submit bids and offers for a 24-hour period, knowing that the delivery date will be on the day ahead. Every day at noon, there is a fixation of a reference price for the next day. Electricity producers make bids based on the marginal cost of production (which includes fuel cost, emission cost, variable operating and maintenance cost, and taxes), in the case of MIBEL (and all European markets), under the marginal model. Next, a ranking of each of these offers is done in ascending order. Regarding the energy purchase bids from the providers, they are ordered in descending order according to the purchase price. For all producers, the point of interception between supply and demand, or the marginal cost of production of the last producer fulfilling demand during the bidding period, will determine the energy production price. Data from past years makes it clear that the most popular way of trading in this market is the daily trade, although it has a decreasing trend, in 2018 it still represented 57,5% of the Portuguese market and 33,6% of the Spanish market. (OMIP, 2022)

2.3. PREVIOUS STUDIES ON COMMODITY MARKETS

As mentioned before, the MIBEL deals with a non-storable type of energy, electricity. When dealing with energy assets, there are different theories for how pricing works and what influences the price of future contracts and the spot price. While researching, we came across different papers highlighting different components of the price of electricity and different theories. However, every approach had one main component highlighted that created the main discussion, storability. To assess the influence of storability in the price of electricity, we would need to compare the MIBEL with an energy market with a storable asset. In 2012, a similar approach was conducted by Ronald Huisman and Mehtap Kilic who developed a paper analyzing the determinants of the spot price of electricity and how future contracts' prices may have information to forecast spot prices, focusing on several types of energy goods, using perfectly storable and non-storable goods to assess its influence on the result. The authors analyzed the Dutch Market, where power is produced from fossil fuels and compared it with the Nord Pool market, the electricity market from the Netherlands. In the Iberian Peninsula, to compare with the MIBEL, we have the MIBGAS, a similar market, with the same operators but where the main asset is Natural Gas.

There are different ways to deconstruct the spot price of electricity, but there are two theories that provide more detailed results: The Theory of Storage and The Expectations Theory(Fama & French, 1987), both with the objective of explaining the difference between contemporaneous futures and spot prices. From these two theories, the influence of storability of the assets on the evolution of prices was the object of study for different papers, which focused on the advantages and drawbacks of each theory and how they can be applied for different markets.

The theory of Storage explains the difference between contemporaneous futures and spot prices in terms of interest changes, warehousing costs and convenience yields (Fama & French, 1987). The conclusions drawn from this paper were the starting point for new authors to conduct new studies with different geographies and types of commodities. Fama and French found that more powerful statistical tests make the response of future prices to storage-cost variables easier to detect than evidence that futures prices contain premiums or power to forecast spot prices (Fama & French, 1987). Using 21 different commodities, such as metals and agricultural commodities, the authors defined the basis as the difference between futures prices and spot prices and regressed it against nominal interest rates and monthly seasonal dummies. They concluded that, as expected, the relation between basis variability and the forecast power of futures prices is existent in the Theory of Storage.

When dealing with storable assets, the pricing evolution can be more inelastic due to its storability as in moments of unexpected supply investors can hold inventories to meet moments of unexpected demand, which produces a negative relation between convenience yields and inventories (Fama & French, 1987). Furthermore, storage costs will play a major role in how spot prices vary seasonally, for goods with high storage costs, like agricultural goods in this paper. On the contrary, metals have low storage costs, and this component will not be so important in this case. On the other hand, non-storable commodities do not contemplate this component in the price, therefore, the basis will not be influenced by storability, leading to a bigger elasticity in price. In this case, the futures price will reflect the expected changes in the spot price more accurately, with demand and supply expectations replacing storability.

One of the main challenges was the lack of precise spot prices at the time, something that is well documented for our object, in monthly reports from OMIP and OMIE.

Along the process of market liberalization in various geographies, Lucia and Schwartz wrote a paper regarding the importance of the regular patterns in the behaviour of electricity prices, and its implication for the purposes of derivative pricing (Lucia & Schwartz, 2002). The new era of market liberalization brought new challenges, such as the limited storability and transportability of electricity, which made the authors question older theories of price of commodities, like the Theory of Storage from French and Fama. This lack of explanation for prices in a new type of market led Lucia and Schwartz to formulate a new theory for pricing of imperfectly storable energy assets because, as we have seen before, one of the components of the Theory of Storage is the warehousing costs, not applicable to electricity markets. Before this approach, Schwarz and Smith had already conducted a study on commodity pricing, using a two-factor model which combines short-term mean reversion and long-term uncertainty in equilibrium prices, focused on the financial market (Schwartz & Smith, 2000). Lucia and Schwartz considered electricity as a flow commodity, due to its characteristics, like limited storability and transportability. Therefore, the impossibility of storage makes it impossible for market players to use inventories to hedge against shocks on the spot price, bringing a greater importance to futures and forwards as hedging instruments. This paper focused its research in one of the old oldest spot and futures electricity markets in the world, the Nordic Power Exchange, Nord Pool ASA (Lucia & Schwartz, 2002), using historical electricity prices and derivative contract prices. Then, to explore price patterns, volatility, and the hedging effects of derivatives, the methodology uses statistical and econometric analysis, such as regression models and time series analysis. Another challenge Lucia and Schwartz came across was the volatility created by the seasonal component, since demand varies a lot between summer and winter and supply is very inelastic in the short run, making prices increase a lot with an increase of demand.

With price forecast in mind, Lucia and Schwartz and Fama and French came up with two different ways to reach the same goal for an electricity market. The indirect use of the Theory of Storage allows the possibility to price electricity through the pricing of the fuels used for power generation, as the expectations theory will use derivatives. The common ground between these two theories is the fact that both papers highlight the complexities of predicting future prices and assume that there are factors responsible for deviations from theoretical expectations. Unlike Fama and French, Lucia and Schwartz did not use the expectations theory as they suggest non-storability could be a factor that would influence the alignment between expectations and forward prices in the electricity market.

More recently, with a better access to data, one of the greatest setbacks of older works, Ronald Huisman and Mehtap Kilic developed a study on the Nord Pool to examine the existence of forecasting power of spot prices in electricity futures prices. Using Fama and French's Theory of Storage, Huisman and Kilic concluded that if electricity comes from renewable energies, futures prices contain information about expected changes in the spot price of electricity, shown with data from NordPool (Huisman & Kilic, 2012). Furthermore, if electricity comes from fossil fuels, which are perfectly storable, futures prices contain information about both expected spot price changes and time-varying risk premium. In 2008, Douglas and Popova developed a model to assess the influence of natural gas storage inventories on the electricity forward premium (Douglas & Popova, 2008). Using PJM data, they found that a negative effect was present on the forward premium when the demand for electricity was high and demand for gas was low. A comment to this paper was made by Bloys van Treslong and Huisman in 2010, who examined the robustness of the results with success, using a different specification of the forward risk premium (Bloys van Treslong & Huisman, 2010). With these conclusions being present in several papers, it would be right to assume that the MIBEL should verify these conditions too. In other European Markets, like the EEX, studied by Wilkens and Wimschulte, (2007), or the German EEX, studied by Kolos and Ronn (2008), the forward risk premium was found to be highly volatile and positive for future contracts with times to maturity up to six months (Huisman & Kilic, 2012).

Moreover, Huisman and Kilic also found that when the main source of electricity is renewable energies, with imperfect storability, futures prices will depend heavily on price expectations, whereas, when the source has perfect indirect storability, for example, when the source is Natural Gas (perfectly storable), the futures price will include time-varying risk premiums, as we should observe in the MIBGAS. Regarding data, Huisman and Kilic's data set consists of the futures and forward contract prices that involve the delivery of base load power in calendar months, distinguishing contracts from 1 month to 6 months, for both NordPool and Dutch gas market. For the spot price, they used the day-ahead prices as a proxy, calculated as an arithmetic average of the 24-hourly market prices, similarly to the MIBEL and the MIBGAS. To conclude, this paper's findings show us that depending on the storability of the source of electricity production, there may or not be present risk premiums in electricity futures, implying great challenges for market participants when assessing the best hedging strategies and opportunities in the electricity market.

In the first years of the MIBEL, Capitán Herráiz and Monroy (2009) analysed market efficiency of the Iberian Power Futures Market, comparing it to other European Power Markets. The first attempt to study the efficiency of an energy market was done by W. David Walls in 1999, who found that in power markets, the players learn faster than in other commodity markets, making it easier to increase the efficiency over time (Walls, 1999). The main differences discovered by Capitán Herráiz and Monroy were created by the new regulations that came up with the liberalization of the market. After testing different hypotheses about the evolution of volatility with maturity and the evolution of Forward risk premiums, they found that in the early stages, the MIBEL efficiency was limited due to its immaturity when compared with other markets (Capitán Herráiz & Rodríguez Monroy, 2009). However, they concluded that there was a presence of a positive risk premium in electricity future contracts. This conclusion was also found in the paper from Bessembinder and Lemmon (2002), who affirm that when demand is very high or has a high variance, the equilibrium forward premium in electricity contracts increases. The authors used a different model to reach this conclusion, with a different assumption that prices are determined by industrial market players rather than speculative players, where companies will change their demand based on the variance and the mean of their profits (Bessembinder & Lemmon, 2002). Moreover, while analysing the PJM power market, Longstaff and Wang (2004)were able to identify similar results, with a data set identical to the one we can use to analyse the MIBEL, an hourly data set of spot and day-ahead forward prices. Other study conducted regarding the PJM, was the work from Cartea and Villaplana (2008), who found backwardation, where the spot price is higher than the prices of future contracts, in the PJM and two other markets, using the model from Bessembinder and Lemmon (2002). Then, in 2006, Ullrich extended the model proposed by Bessembinder and Lemmon (2002) and found that by incorporating constrained capacity, price spikes would be replicated and be closer to the reality of a market with a non-storable asset that does not provide means to smooth supply or demand shocks (Ullrich, 2007). The model proposed by Ullrich shows that whether the level of the expected spot price is greater or lesser than the fixed retail electricity price will influence the behavior of the forward premium, which is defined by the difference between the forward price and the expected wholesale spot price (Ullrich, 2007). We can find similarities to Herráiz and Monroy's work in other papers regarding market integration, such as Armstrong and Galli's work and Zachmann's work, both in European markets. The first one approaches European wholesale spot power prices and the latter the Dutch and German wholesale power prices. Their work brought similar conclusions, as it discovered price convergence between the price differences (Armstrong et al., 2004; Zachmann, 2008).

While Bessembinder and Lemmon assumed that speculation was not present in the price formation of energy markets, in 2014, Matteo Manera, Marcella Nicolini and Ilaria Vignati assessed the role of speculation in the price formation of energy markets. In this paper, a different model is used to prove the negative effect from speculation, GARCH model, which is used in financial markets to evaluate the role of speculation in the modelling of volatility of commodity futures prices (Manera et al., 2016) . However, this paper did not contemplate non-storable energy assets in its array of commodities studied. Before them, in 2001, Petter Skantze from the MIT, wrote a thesis which approached the theme of speculation more extensively, relating it to increased liquidity, increased short-term volatility, due to the quick reaction from speculators and market distortions (Petter Skantze & Smith, 2001).

From this literature review we can conclude that most of the studies written in this regard use the Nord Pool as their object, since it is the oldest and most developed electricity market in Europe, created in 1993. As the MIBEL is one of the most recent markets in Europe, some relevant conclusions and characteristics of the market can be found.

2.4 RESULTS FROM PREVIOUS STUDIES

Results from Fama and French showed that a positive estimate β_f, which means that the basis contains reliable information about future changes in the spot price, appears in assets with high storage costs, whereas in assets with low storage costs the forecast power of forward prices is not present, as β_f is not significantly different from zero.

However, Fama and French's work did not contemplate non-storable energy assets, as their commodities were broilers, eggs, hogs, cattle and pork bellies, animal products that have high storage costs due to their perishability, and oats, soybeans and soy meal, which have high storage costs relative to value (Huisman & Kilic, 2012).

Huisman and Kilic's work is the most relevant in our analysis, as we will use the same framework but with data applied to the MIBEL and we will compare our results with theirs, in order to come up with conclusions that can put the MIBEL alongside the biggest electricity market in Europe, the NordPool. They used 6 different contracts with different maturities, from 1 month maturity (M1) to 6 month maturity (M6).

Huisman and Kilic dealt with non-storable assets and their findings were different. They found that β_f estimates and β_p estimates had opposite results, when considering the NordPool market. The first one ranged between 0.83 for M3 and 0.94 for M2 with all the contracts showing a result significantly different from zero and not significantly different from one. The latter showed the opposite, for every contract, β_p is not significantly different from zero, ranging between 0.06 and 0.17. This means that forward prices contain information and forecasting power without evidence for time-varying risk premiums. When analyzing the Dutch market, the β_f estimates were close to the ones in the NordPool. However, the estimates for β_p showed that for M1, M2 and M3, β_p is significantly different from zero, which confirms that, in the dutch market, forward prices have both forecasting power and time-varying risk premiums. Fama and French also found this to be true for orange juice and plywood. To conclude, time-varying risk premiums cease to exist in futures prices when the maturity is furthest.

Capitán Herráiz and Monroy (2009) found that monthly future contracts in the MIBEL showed a positive average risk premium, decreasing as maturity increased. Using Bessembinder's and Lemon's testable hypothesis, they found that the variation of the risk premium was relatively low compared to the variation of the spot. They supported the idea that the creation of the MIBGAS would be favorable for the improvement of efficiency of the MIBEL.

Our aim is to get a more detailed view of the history of MIBEL and the events that influenced the price formation in the Iberian Peninsula. Therefore, we prepared different graphs, for Portugal and Spain, which allow us to identify each event and its effects on the price of every derivative traded in the MIBEL. Moreover, we will see how the correlation between the variables behaves for every contract, and the story it tells, to provide a more complete picture of the market. Although we will use the regressions conducted by Fama and French and improved by Huisman and Kilic, we will also compare our results with other different papers, such as the work from Capitán Herráiz and Monroy (2009), who dealt with an underdeveloped MIBEL and have some limitations due to the immaturity of the market.

3. METHODOLOGY

3.1 INTRODUCTION TO METHODOLOGY

As done in past studies, our objective is to find evidence of predictive power of spot prices in electricity future contracts or if they contain expected risk premiums and how storability influences the results.

Based on the approach proposed by Fama and French (1987), and further improved by Huisman in 2007 (Huisman et al., 2007), then in 2010 and finally, Huisman and Kilic (2012), which use the underlying energy source to distinguish between markets. Therefore, our goal is to determine whether storability plays a major role in the existence of time-varying risk premiums or in the predictive power of future contracts.

To study these relationships, we gathered data for spot price and electricity future contracts price for the MIBEL in 2 different geographies: Portugal and Spain.

3.2 METHODOLOGICAL FRAMEWORK

In this dissertation we follow the approach proposed by Fama and French (1987). Let $F_{t,T}$ denote the price per megawatt (MW) of a futures contract at time t, for delivery of 1 MW of electricity during each hour of delivery period T (with $t < T$). The day-ahead price per megawatt-hour (MWh), S_t, is quoted on day t for the delivery of 1 MW of electricity in each hour of the day, $t + 1$. The expected future spot price, $E_t(S_T)$, reflects the anticipated average day-ahead price for electricity during delivery period T, based on the information available at time t. The term $P_{t,T}$ represents the expected risk premium per MWh at time t, applied for the delivery of electricity in period T. The expectations theory states that an asset's future price equals expected spot price plus an expected risk premium (Huisman & Kilic, 2012):

$$F_{t,T} = E_t(S_T) + P_{t,T} \tag{1}$$

From the subtraction of the current spot price in both sides of (1), as Fama and French did, we get:

$$F_{t,T} - S_t = E_t(S_T) - S_t + P_{t,T} \tag{2}$$

From (2), we conclude that $F_{t,T} - S_t$holds information of the expected difference between spot price in t and T and about the risk premium.

The following regression equations are proposed by Fama and French (1987) to be estimated, assuming traders make rational forecasts (i.e., forecast errors are random with zero mean):

$$S_T - S_t = \alpha_f + \beta_f(F_{t,T} - S_t) + \sigma_f\epsilon_{f,t} \tag{3}$$

and

$$F_{t,T} - S_T = \alpha_p + \beta_p(F_{t,T} - S_t) + \sigma_p \epsilon_{p,t} \quad (4)$$

In equation (3), the left-hand-side represents the difference between spot prices in time t and time T, whereas in (4) it is the realised risk premium, and, under the assumption of rational forecast, it proxies for the expected risk premium $P_{t,T}$ which comes from equation (1). Since these two equations were derived from (2), we know that α and β will add up to 0 and 1, respectively. From the economic nature of the Fama and French model and the interpretation made by Huisman, we know that β_f is the component that shows the presence and the magnitude of the forecasting power, i.e., how the futures price have the possibility to predict changes in the future spot price and β_p is the component that contains evidence for the existence of a Risk Premium, i.e., compensation for the risk of holding a future contract. Therefore, the explanation for the need of their sum to be 1 is to guarantee that no information is lost and every variation in the forward basis is explained by the expected price changes or risk premium.

We aim to find statistical evidence of the presence of predictive power in the future contract price or a risk premium associated to it. To find this evidence, we'll have to do two regressions, one for each equation, for every contract available in the MIBEL and asses the values from β_f and β_p, using a robustness test to confirm that $\beta_f + \beta_p$ is equal to 1 and the sum of the constants is 0. To run these tests, we will use the statistical program STATA, with the data available, provided by ERSE and OMIE/OMIP, MIBEL's market operators.

To regress these equations, we will conduct two Ordinary Least Square regressions, to estimate the relationship between $S_T - S_t$ and $F_{t,T} - S_t$ in equation (3) and $F_{t,T} - S_T$ and $F_{t,T} - S_t$ in equation (4), looking for forecasting information and evidence for the risk premium, respectively. From these regressions, we will analyse the coefficient significance to evaluate the significance of the relationships in the equations studied, as well as the R-squared that contains information about the level of variance explained by the independent variables. If the independent variables are meaningful, we expect the estimated coefficients to be significantly different from zero, using a $p - value < 0.1$ in this case.

From STATA, we can extract the regressions of every variable, with β_f and β_p as the main concern and we can do both T-statistics to determine the information contained in each price.

However, in the case of one of the coefficients not having statistical significance, we must assure the credibility of the regressions, conducting a robustness test that allows us to guarantee the assumptions of the regression are not violated, such as heteroscedasticity, autocorrelation or multicollinearity. In this joint significance test, the $F - test$, we make sure that the sum between β_f and β_p is equal to 1, if the results allow us to reject the null hypothesis.

From the regressions, we will also get the confidence interval, which gives us a range of values where β_f and β_p can be found and quantifies the significance of the coefficients. In our case, this will help assess the reliability of the forecast power and risk premium estimates.

Another helpful tool provided by these regressions is the level of correlation between the variables, as it will inform us about the strength and direction of the linear relationship between our variables. It is expected that for contracts closer to maturity, the correlation between our variables to indicate a higher forecasting power and a low or non-existent risk premium.

When dealing with future prices it is important to describe their relationship with spot prices in terms of demand, supply and trading strategies. Two popular terms to describe this relation are backwardation and contango, which are observable in graph 4 and graph 5 containing the futures price curve and the spot price curve. When the spot price is higher than the future price, we have backwardation, and when the opposite happens, we will be in the presence of contango.

4. DATA

The data used in this study was obtained from OMIP, OMIE and ERSE, MIBEL's market operators. Our dataset includes futures contract prices that have different maturities, that can be distinguished by the way we refer to them. For example, the 1M contract's delivery date is in the next month, whereas the 2M contract's is in the month thereafter and so on until the 6M contract, and every contract has a Base Load of 1 MWh.

Most MIBEL future contracts are settled financially, where the difference between the contract price and the actual spot at the time of maturity is settled in cash. However, between spot market operators, there can be physical settlements which are not so common.

The sample period for the MIBEL and other electricity markets is from January 2017 through March 2023, making it 74 monthly futures price observations. The prices we will be using are all taken from the first trading session of each month, assuming the futures contracts will mature in the first trading session of the delivery month. The spot price of electricity will be calculated as an arithmetic average of the 24-hourly market prices present both in Portugal and Spain, from January 1998 to February 2024, making it possible to identify different historical events, with 9555 daily observations.

The spread between Portugal and Spain is created by the influence of the relative weight of hydroelectric generation, with Portugal being more dependent on it, making prices fluctuate in an indirect way towards the water reserves in Portugal.

We will use as a reference of comparison, the results from the Huisman and Kilic paper, regarding the Nord Pool and the Dutch market; the results from Fama and French regarding different commodities; and Chris Brooks' work on the NYMEX (New York Mercantile Exchange). In Huisman's paper, the contracts used also range from 1 month to 6 months to maturity and the proxy used for the spot price is also the day-ahead price in each market, making it the ideal comparison to our results.

5. *EMPIRICAL ANALYSIS*

In this section, we can find the OLS estimation, in Table 1, for the equations mentioned in the Methodology section, (3) and (4), for the Portuguese and the Spanish trading sessions in the MIBEL. In our analysis, the values for Portugal and Spain were not the same during the time range we used, converging towards the end, meaning a uniformity of the market in the Iberian Peninsula. With 74 monthly observations, from January 2017 throughout August 2023, the results for these estimations were similar, with slight differences we shall analyze and understand.

Table 1. Estimates for the parameters in Eqs. (3) and (4)

1M	βf	βp	$\beta f + \beta p$	R_f^2	R_p^2	t_s	P>|t|	t_{rp}	P>|t|	n
Portugal	1.32	-0.32	1	0.3619	0.0324	6.43	0	-1.56	0.122	75
Espanha	1.11	-0.11	1	0.2969	0.0044	5.55	0	-0.57	0.571	75
2M										
Portugal	0.75	0.25	1	0.1915	0.0268	4.16	0	1.42	0.161	75
Espanha	0.66	0.34	1	0.258	0.086	5.04	0	2.62	0.011	75
3M										
Portugal	0.7	0.3	1	0.1381	0.1441	3.42	0.001	1.48	0.144	75
Espanha	0.72	0.28	1	0.1427	0.0243	3.49	0.001	1.35	0.182	75
4M										
Portugal	0.34	0.66	1	0.0421	0.1436	1.79	0.078	3.5	0.001	75
Espanha	0.29	0.71	1	0.0291	0.1499	1.48	0.143	3.59	0.001	75
5M										
Portugal	0.27	0.73	1	0.0225	0.1473	1.3	0.199	3.55	0.001	75
Espanha	0.19	0.81	1	0.0101	0.1617	0.86	3.75	0.391	0	75
6M										
Portugal	0.22	0.78	1	0.0194	0.1936	1.2	0.234	4.19	0	75
Espanha	0.18	0.82	1	0.0114	0.2046	0.92	0.361	4.33	0	75

Firstly, in Portugal, the estimates for β_f range between 0.22 for 6M and 1.32 for 1M, being significantly different from zero for 1M until 4M and not significantly different from zero for 5M and 6M. The estimates for β_p range between -0.32 and 0.78, being significantly different from zero on the contracts with the furthest maturity, 4M, 5M and 6M and not significantly different from zero on the first three. Therefore, we can conclude that, in Portugal, the contracts with maturity up to 4 months contain a good forecasting power and no evidence of a risk premium. However, in the 5M and 6M contracts, there is no forecasting power, and we can find a time-varying risk premium. Particularly, the 4M contract has evidence for both characteristics, with a significant forecasting power and a presence of a time-varying risk premium.

In Spain, the estimates for β_f and β_p gave different conclusions with mixed results between the contracts, with discrepancy with Portugal in the first three contracts. In the 1M and 3M contracts, β_f is 1.11 and 0.72, respectively, both being significantly different from zero and representing significant forecasting power. However, in the 2M contract, we find both forecasting power and evidence for a risk premium with β_f and β_p significantly different from zero. In the last three contracts, 4M, 5M and 6M, we have evidence for a risk premium and no forecast power, with β_f ranging from 0.18 to 0.29 and β_p ranging from 0.71 to 0.82, with β_p significantly different from zero on all occasions.

This estimation is not enough to confirm the results obtained, as we may come across a scenario where one of the coefficients is not significant and we must assure that the sum between β_f and β_p is equal to 1. As we have said before, we conducted this robustness test and, by rejecting the null hypothesis, we have concluded that every data used respects these conditions and supports our results. We can observe in column Prob > F that every value is bigger than the p-value used in this case, meaning that they are significantly different from zero, rejecting the null hypothesis.

Table 2. Robustness Test and Correlation

1M	F	Prob > F	Correlation (3)	Correlation (4)
Portugal	0.14	0.7089	0.6015	-0.18
Espanha	0.1	0.7576	0.5449	-0.0665
2M				
Portugal	0.01	0.9109	0.4376	0.1637
Espanha	0.18	0.6688	0.5079	0.2933
3M				
Portugal	0.05	0.8207	0.3716	0.1703
Espanha	0.02	0.9023	0.3778	0.1559
4M				
Portugal	0.31	0.5789	0.2051	0.3789
Espanha	0.25	0.6196	0.1707	0.3871
5M				
Portugal	0.41	0.522	0.1499	0.3838
Espanha	0.36	0.55	0.1006	0.4022
6M				
Portugal	0.61	0.4381	0.1391	0.44
Espanha	0.53	0.4702	0.107	0.4523

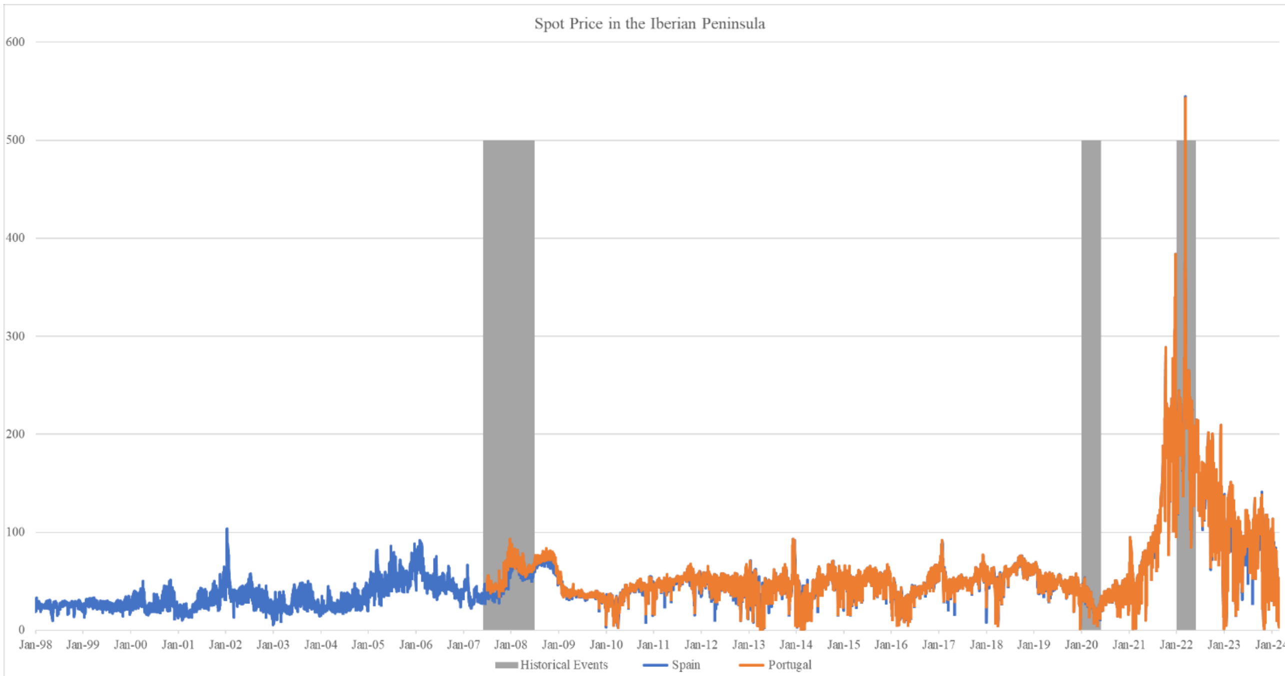
.

Besides the results for the estimations of β_f and β_p, we can also observe some more results and take different conclusions from our data. The correlation between variables in equation (3) and (4) supports our analysis as it presents a decreasing trend in the first one (β_f), ranging from 0.6015 (1M) to 0.107 (6M), which means that the forecasting power decreases as we get further from maturity. In the case of equation (4), we can observe the opposite, as risk premium evidence gets stronger as maturity gets further. There is one exception, in the 2-month futures contract, as we observed in the second paragraph, it contains information for both forecasting power and risk premium, making it an isolated case.

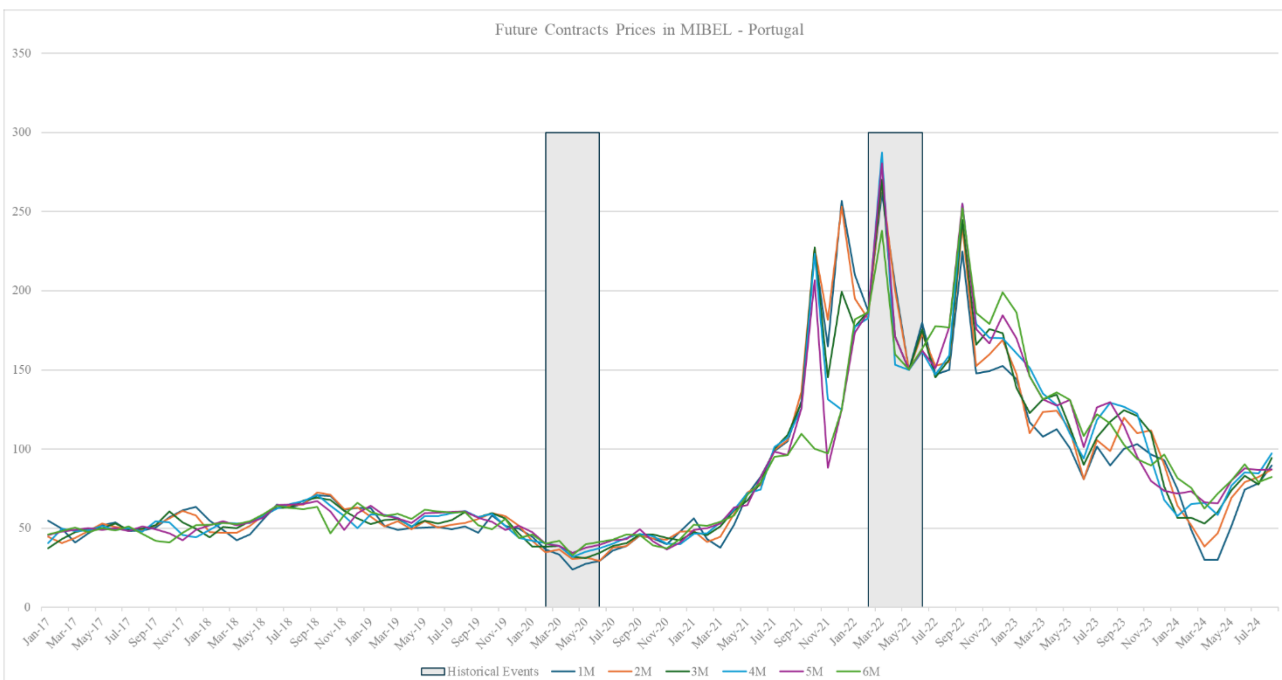
Comparing with the papers already analyzed, we can see similarities between with Huisman and Kilic's results, where the authors found evidence of forecasting power in the contracts of up to 3 months and no evidence for a risk premium. However, in the MIBEL, we found that after the 4M contract, we could no longer justify the presence of forecasting power, whereas, in the Nord Pool, it could be justified for every contract analyzed. In the Fama and French's work, these results were observed in assets with high storage costs, mostly animal products which perish very quickly, and in assets which are very cheap and, therefore, any expense with storage will be high, mostly agricultural assets. On the other side of the Atlantic, Chris Brooks found that, in the NYMEX, dealing with different types of assets, the forecasting power of future contracts prices with maturity of 2 months and 6 months was very strong and present for assets like Heating Oil, Natural Gas and Gasoline, with little to no evidence of a Risk Premium, in assets with perfect storability, contrary to what we found in our 6 month sample, where the risk premium had very strong presence, one of the effects of dealing with imperfectly storable assets(Brooks et al., 2013). Regarding the risk premium presence, also Huisman and Kilic's conclusions had some divergences to what we found to happen in the MIBEL, particularly in contracts with higher maturity, where we conclude that electricity futures show great evidence for a time-varying risk premium while Huisman states that, in the Nord Pool, there was no evidence for a risk premium. However, in their comparison with the Netherlands market, their results were very similar with our results from the Portuguese side of the MIBEL, with the evidence of a risk premium increasing with time to maturity, while the forecasting power decreases, becoming not significant in Portugal for the last two contracts.

5.1 CHRONOLOGIC HISTORY OF THE ELECTRICITY MARKET IN THE IBERIAN PENINSULA

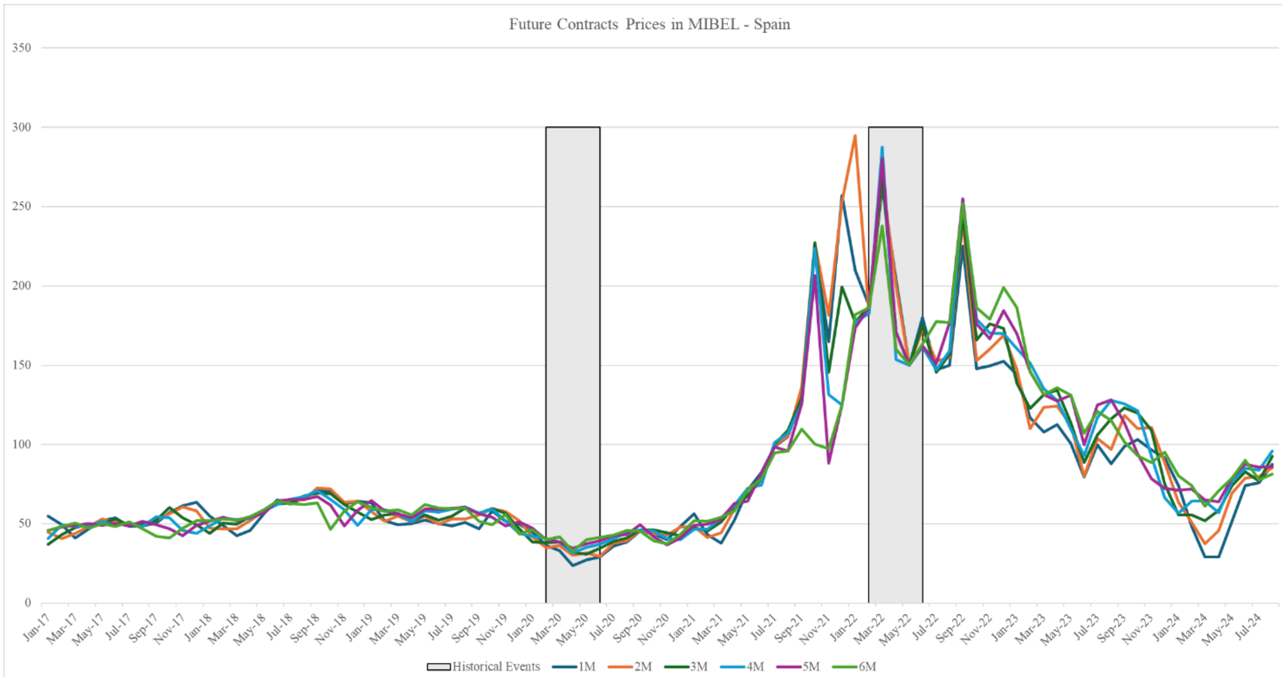
The data recovered from the electricity market in the Iberian Peninsula also tells another story, with historical events easily observed in graphs of spot price and future contracts. In the following graphs, we will have the evolution of the spot price in Spain from 1998 through March 2024, the evolution of the spot price in Portugal from 2007 through March 2024, as well as the evolution of the electricity future contracts prices, from January 2017 through March 2023, making it easy to identify different historical events and peaks. In the highlighted areas we can identify the Euro introduction, with a maximum at the time, in January 2002; the Subprime crisis, starting in July 2007, in the same year as the creation of the MIBEL, with a new maximum at the time, followed by a minimum, due to the falling interest rates; the beginning of the COVID and the first lockdown, which brought a new all-time minimum for futures and spot prices, and the second lockdown with a big decrease of volume traded; and, more recently, the beginning of the war in Ukraine, with several all-time highs registered in a very short period of time, in February 2022. We can observe these effects in the spot price and in futures prices also, as they follow the trend of the spot price, due to the forecasting power present.



Graph 2. Spot price in the Iberian Peninsula.



Graph 1. Evolution of Future Contracts prices in Portugal.



Graph 3. Evolution of Future Contracts prices in Spain.

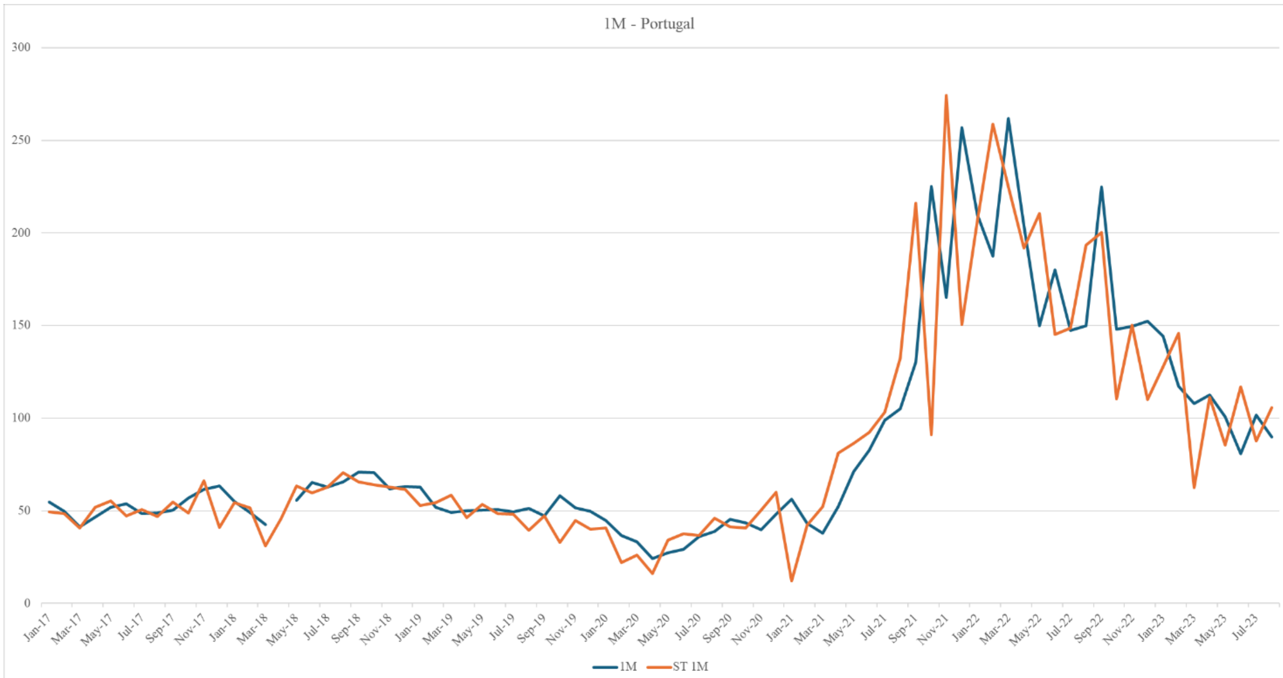
We can observe that the trends are similar in these graphs, Graph 1, 2 and 3, as maximums and minimums happen at the same time. For example, in Portugal and Spain, the maximum for each contract and spot price happened in March 2022, due to the beginning of the Ukraine war and the high inflation period created by the conflict, with exception of the 6-month contract, which happened in September 2022, as we can see in Table 3. Also, the minimums were similar in both countries, spreading through the months of lockdown after the discovery of the presence of COVID in European countries, as we can see in the table.

SPOT	Max	Date	Min	Date
Portugal	542.78	mar/22	17*	apr/20
Espanha	544.98	mar/22	17*	apr/20
1M				
Portugal	262	mar/22	24.07	apr/20
Espanha	262	mar/22	23.87	apr/20
2M				
Portugal	268.5	mar/22	29.46	jun/20
Espanha	295	jan/21	29.45	jun/20
3M				
Portugal	270.45	mar/22	31.05	may/20
Espanha	270.45	mar/22	31.04	may/20
4M				
Portugal	287.45	mar/22	31.83	apr/20
Espanha	287.45	mar/22	31.82	apr/20
5M				
Portugal	280.46	mar/22	34.62	apr/20
Espanha	280.46	mar/22	34.61	apr/20
6M				
Portugal	252.09	sep/22	32.87	apr/20
Espanha	252.09	sep/22	32.65	apr/20

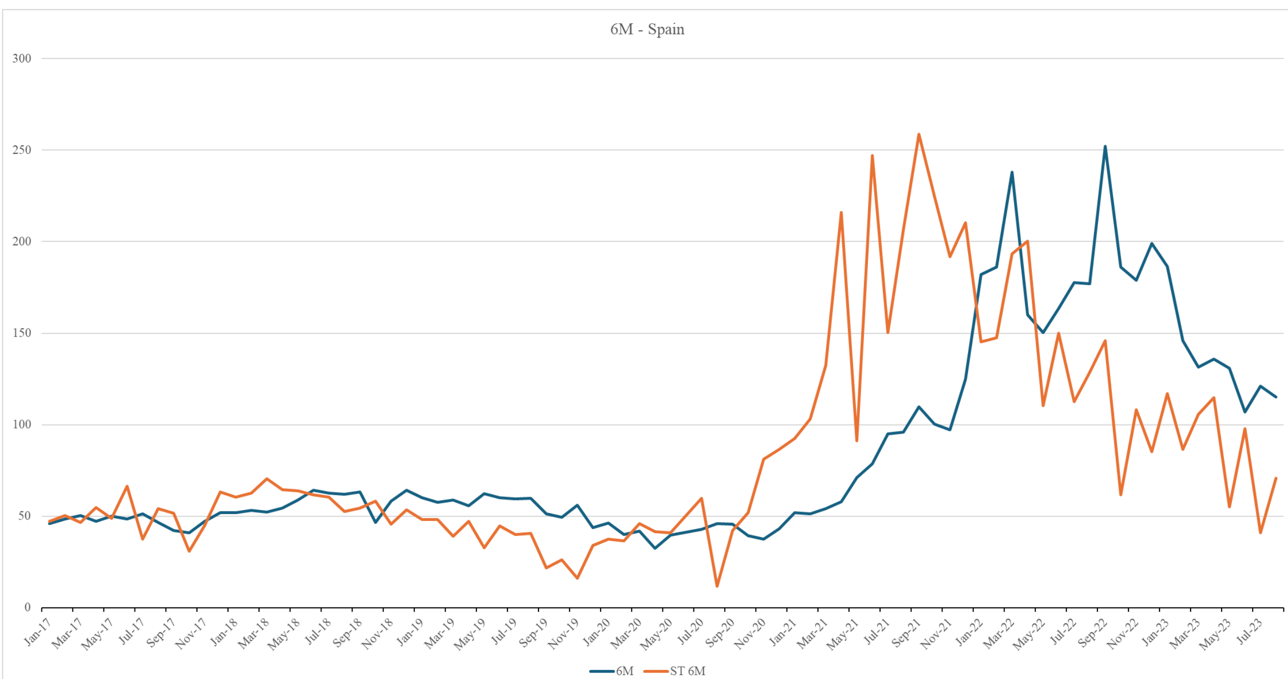
Table 3. Maximum and Minimum for Spot and Futures prices.

*Smallest monthly average price.

In the last paragraph of the Methodology, we mentioned trading strategies present in our market with the terms "Backwardation" and "Contango". With the analysis of the curves mentioned, we can observe that different historical events have different outcomes in this aspect, with the biggest difference observed between the COVID period and the start of the war. In the following graphs (1M Portugal & 6M Spain), we can observe a contango in March 2020 as futures were more expensive than the spot price, as we were reaching historical minimums. On the other hand, with the beginning of the war, the spot price never reached the value of the futures at that time, as the predictions were pointing to new historical maximums, in a situation of backwardation.



Graph 4. Comparison between Spot and Futures prices of the Portuguese 1M electricity future contract.



Graph 5. Comparison between Spot and Futures prices of the Spanish 6M electricity future contract.

6. CONCLUSION

The establishment of the Iberian power Market (MIBEL), which aims to promote competition, efficiency, and transparency in power pricing throughout the Iberian Peninsula, marked a turning point in the integration of the energy markets in Portugal and Spain. Understanding the financial and economic dynamics of MIBEL, assessing how storability affects market behavior and the existence of risk premiums, and investigating the relationship between spot pricing and futures contract prices were the main goals of this study.

Following the theoretical framework developed by Fama and French (1987) and later expanded by Huisman and Kilic (2012), our empirical analysis provided evidence of the predictive power of futures contracts in the MIBEL for shorter maturities, with limited to no presence of risk premiums. However, as the maturity of these contracts increases, we observed a decline in forecasting accuracy and a rise in the significance of time-varying risk premiums. This outcome reflects the unique characteristics of non-storable energy assets, such as electricity, which inherently leads to greater price variation and presents challenges in stabilizing market prices.

Then, while comparing with different markets, like the Nord Pool, the Dutch market and the multiple commodities analysed by Fama and French (1987), we were able to highlight key similarities and differences in how storability impacts market dynamics. While storable assets like natural gas allow for better price stability, the dependency of MIBEL on renewable energy sources, which cannot be stored, contributes to higher market volatility. This characteristic increases the reliance on futures markets as essential tools for hedging against price fluctuations.

After almost 18 years and despite the progress made in the integration of the Portuguese and Spanish electricity markets, the MIBEL still faces difficult challenges regarding infrastructure development, regulatory harmonization, and the broader incorporation of renewable energy. The market's reaction to major economic disruptions, such as the COVID-19 pandemic and the Ukraine conflict, further emphasized the need for continuous adaptation and improved strategies for risk management to enhance market resilience.

Despite its contributions to understanding price dynamics and risk premiums in the Iberian Electricity Market (MIBEL), this study has several limitations. The reliance on established models, such as Fama and French (1987) and Huisman and Kilic (2012), while effective, may not fully capture the unique characteristics of MIBEL, particularly regarding the influence of renewable energy sources and regulatory disparities between Portugal and Spain. Data limitations also pose constraints, with the scope restricted to 2017–2023 for futures prices and 1998–2024 for spot prices, potentially overlooking recent developments or long-term trends. Furthermore, the study assumes linear relationships in risk premium analysis and rational forecasting by market participants, which might not reflect real-world complexities such as non-linear behaviors or speculative actions. Finally, the geographic focus on MIBEL limits the generalizability of the findings to other markets with different structures, energy mixes, or regulatory environments. These limitations highlight opportunities for future research to expand and refine the understanding of electricity markets.

In summary, the MIBEL has proven to be a significant development in the liberalization and integration of the Iberian electricity market. However, its evolution is an ongoing process and requires the adoption of technological innovations, enhanced regulatory frameworks and greater focus on incorporating renewable energy sources. As it is in other European markets, further research could focus on exploring strategies to mitigate market volatility and on designing financial products that cater to the specific needs of non-storable energy markets. These efforts are essential for MIBEL to strengthen its role in the European energy market and support the development of a more resilient and sustainable electricity sector across the Iberian Peninsula.

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