UNIVERSITY OF BASQUE COUNTRY

MASTER IN ECONOMICS: Empirical Applications and Policies

Master thesis

A discriminatory auction for the day-ahead electricity market: its effect on windfall profits

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Due Date: 29 July, 2022

Abstract

The main goal of the present Master Thesis is to analyze the Spanish electricity day-ahead market from the design perspective, which like most European countries follows a uniform auction. Indeed, the price is set by the most expensive technology, which establishes the remuneration for the rest of the generators, leading to windfall profits for them. In this context, we analyze the changes that can be generated in the revenues of the generators if we switch from a uniform system to a discriminatory system, since in the latter system the generators will get the price of their bid instead of the marginal price. We also show the effect of a change in the bidding strategies. For this, we set different scenarios to show how the generated revenues would change after a change in the generators' bidding strategies. Our results show that we refuse the concept of revenue equivalence, since different revenues are generated depending on the scenario. Generally, the revenues obtained by the uniform system would be higher than the revenues generated by the discriminatory system. Hence, the discriminatory system would be more economical for consumers, since lower system costs would be generated. However, we observe differences by month and technology.

Keywords: bids, discriminatory system, revenues, system marginal price, uniform system.

1 Introduction

It is well known that we are living in a time of uncertainty caused by the effect of the pandemic and the change of regulations in some sectors, as is the case of electricity. In this way, one of the biggest challenges in the electricity system in recent decades has been the increase in costs. This effect is caused by the incorporation of new technologies, such as the case of renewable energies, which are constantly changing the rules of the market, since new regulations are required all the time. In this sense, in the beginning, renewable energies were promoted in some European countries (including Spain) through feed-in tariffs (FIT). Under this system, renewable producers had some advantages comparing with others, since producers might sell their entire output at a guaranteed price which was set above the wholesale market clearing price (Ciarreta et al., 2014).

This price allows the generators of some renewable sources of energy to cover the higher costs of this type of energy to (especially years ago when renewable were beginning to enter the market and were not yet amortized), stay in the market and increase incentives to carry on investing. Although, many European countries were successful in using this system, those design were inefficient, since overall electric cost rose due to the privileges obtained by the renewable energies, and at the same time reduced the economic competitiveness (Lesser, 2017).

However, as the criticism of this incentive scheme started to grow (subsidies to renewable) due to its financial burden, the Spanish government cancelled subsidies for any new electricity from renewable sources. Hence, another way to promote renewable energy was the creation of Tradable Green Certificate (TGC) markets, which created a demand for the renewable energy through the distributors obligation to meet a specified share of green energy and proved that electricity has been generated by a renewable (green) energy source. Anyway, TGC scheme may involve higher uncertainties than FIT scheme. For this reason, there are some proposals to combine both systems, as it could be in the case to finance solar technologies (Ciarreta et al., 2014). Therefore, it can be claimed that due to the incorporation of new technologies, the electrical system needs to change constantly, caused by the required change in the system.

Moreover, the metereological conditions also seem to affect the price of electricity -and its volatility-, due to the large installed wind and hydroelectric power in Spain and their large share of capacity in the total production (Casado et al., 2017). Indeed, it is worth mentioning that it has never been seen a price rise as big as the one of this last year (2022), due to the increase in natural gas prices. Hence, if electricity prices continue to rise, the Spanish economy will be affected by the different reasons that are described below.

First, it is an issue which affects society directly (consumers are the ones who are affected by price increases). This rise of price needs to be fixed and implied a special protection to the consumers, since use of electricity is provided with the main function of maintaining the welfare of society (Flores, et al.2015). In any case, the new reforms that were imposed in 2021, instead of benefiting the consumer, had the opposite result. According to the National Commission for Markets and Competition, the new tariff (2021) would impact residential consumers in different ways, depending on previous contracting conditions of the consumers. Indeed, those consumers, under old Time-of-Use tariffs are expected to face a significant increase in their electricity bill due to the changes in pricing periods. Since in 2021, instead of having two pricing period (peak and valley), the new regulation added another pricing period, flat period, which was the second more expensive pricing period after peak period. This situation becomes harder and more relevant for those consumers affected by energy poverty, which it refers to those who have lack of access to sustainable modern energy services and products. Especially considering this group needs to be in a regulated tariff to access social benefits (Canals et al., 2022).

Second, it must be mentioned that the electricity sector is one of the sectors with the greatest influence on the productive fabric of a country. Hence, a rise in the price of electricity can have relevant consequences in the stability of practically all products are produced in a whole country (Flores, et al.2015). Furthermore, imagine how the increase in electricity affects any type of business, such as a store, since if electricity price is higher, the costs would be higher, and they would be forced to raise the price of the products we consume.

Finally, it is worth highlighting the main motivation of the analysis of this master thesis, which is related to the different systems that regulate the electricity market. Indeed, the technologies based on natural gas mostly set the price of electricity, since the Spanish electricity system follows a uniform price model. Hence, there is a belief that companies enjoy windfall profits, which are unexpected gains resulting from "lucky circumstances", by following this model. Anyway, as the concept is quite open, we will try to focus on the two different auctions systems that will be discussed throughout this master thesis.

On the one hand, as in most of the rest of the EU countries, in Spain the wholesale electricity market operates under a uniform regime, in which the existing demand is covered primarily by the supply of technologies whose production costs are lower. If this supply is insufficient to cover the totality of demand, other more expensive types of energy enter the market, until all the demand is met. However, by setting prices under a marginal auction (uniform auction), the last price that enters establishes the remuneration for the rest of the production. This is what is known as the "marginalist system". In this system, all generators receive the same price, corresponding to the matching price of supply and demand which is related to the marginal production costs of the technology most expensive. That is why the most benefited producers are those that generate electricity through lower cost and enjoy the greatest windfall profits.

On the other hand, under a pay-as-bid (discriminatory) system, windfall profits would be supposed to be lower than in the other system. Since, each generator that enters the market is remunerated according to their price bid, instead of the marginal price. Under this system, only the marginal technology gets the marginal price and the rest of the incumbents receive a lower payment.

In light of the current debate on the design of electricity systems, i.e. whether a uniform price system receives more revenues (or windfall profits) than a pay-as-bid (discriminatory) system, it becomes crucial to compare both models. Furthermore, many different questions could be raised, since this subject opens many different fields. Even so, our research questions read as follows:

Firstly, we wonder how the revenues increase/decrease if we switch from an uniform system to a discriminatory system and then, we compare them without assuming any change in the bidding behaviour (all the rest ceteris paribus). In this case, we expect the windfall profits or remunerations created under an uniform system to be higher than those created under a discriminatory system, since in the latter system generators receive the price of their bid. However, those generators under a uniform system with cheaper technologies will enjoy higher profits, as the price is set by the more expensive technologies.

Secondly, we will propose a rule change and wonder how both system´s windfall profits differ if we assume different bidding behaviours (supply strategies). Therefore, we will focus on generators' bidding strategies and how they behave according to different scenarios.

2 Literature Review

As we have mentioned before, the comparison of both systems is quite controversial since different authors rely on different preferences and defend their claims through results.

On the one hand, we will mention those authors who develop the differences between the auctions (uniform system and the discriminatory system) in which we can emphasize that most of the cases disagree the concept of revenue equivalence, which states that any mechanism that results in the same outcomes also has the same expected revenues. Hence, according to (Alonso Perez, 2007) it can be determined that the revenues from discriminatory and uniform auctions are different depending on the demand and the degree of competitiveness in the electricity market. On the one hand, if the demand is small, there is no difference in the revenue acquired by both systems, since the price is equivalent to the marginal cost in both. On the other hand, if demand is large and competition is small, one or both companies maximize their expected revenue by bidding the maximum bid allowed in the uniform system. Throughout an uniform system the price is set by the firm, since it has the certainty to enter to the market due to the large size of the demand. Hence, as the firm wants to maximize its revenues the market price will be the maximum price. One of the measures to solve the problem would be with the entry of more companies so that competition would increase, and, in this way, prices would go down with profit share increasing.

Furthermore, (Fabra, 2006) suggests that the uniform auction is always weakly outperformed by the discriminatory auction with respect to total revenues. Even so, it is not easy to say which model is better. Its analysis claim that if the regulator assigns positive weights to both productive efficiency and consumer surplus, the auction ranking will depend on the specific weights assigned to each. For example, those regulator who is concerned only with the minimization of prices (consumer surplus) should prefer the discriminatory format. Anyway, the ranking in terms of productive efficiency is ambiguous, since there are a lot of different results depending on the demand and other parameters (depending on the demand or parameters we are considering, the ranking will be different).

Additionally, (Baldick et al. , 2004) argues that total revenues obtained in both systems are not equivalent, since the total payment of consumers would be smaller under pay-as-bid pricing. The same is for (Ciarreta et al., 2009) who claim that the high concentration of supply and the inelasticity of demand have allowed generators to set prices which are around 20% higher than our benchmark competitive price.

There are more authors that argues in favour of uniform system, as it is the case of (Cramton, 2004), since according to him, bidding above marginal cost simulates and enhance investment. In the uniform price system, companies offer prices above marginal cost and therefore the revenues are sufficient to reward the entry of marginal capacity. As companies will have the advantage of being able to continue producing and selling above their marginal cost, in the end they will have the incentive to produce and invest more and more.

Following the dynamics of authors that prefer the uniform system, (Tierney, et al., 2008) argue that although there are some authors that say that through the pay-as-bid system prices decrease, it is shown that pay-as-bid is not likely to result in any immediate decrease in wholesale prices through eliminating suppliers' margins. Indeed, price increases are largely a consequence of market forces beyond the control of those who regulate the electricity system

On the other hand, there are authors who talk about the different strategies and behaviours that are followed in auctions, as it is the case of (Garcia-Díaz et al., 2003), who claims that the dominant firm will use hydro in a strategic manner equating its marginal cost across periods, even some authors suggest that Spanish hydro generators follow a Cournot model. In his simulation he assumes that all firms allocate hydro production in a peak-shaving manner.

Returning back to (Fabra, 2006), it is also mentioned how the bidding of the systems is carried out depending on the demand. If the demand is low, both systems follow competitive bidding with highest accepted offer c (cost marginal). However, if the demand is high, since all suppliers are paid a higher price than reserve price, a pure-strategy equilibrium exists in the uniform auction, with the highest accepted offer price equal to P, but not in the discriminatory auction. Apart from that, (Fabra, 2003) argues that under a discriminatory pricing rule, each firm would try to bid slightly below the market price, as long as the market price was higher than its marginal cost, in order to maximize its revenues by selling at full capacity. However, if all firms behaved in this way, the firm that was setting the market price would in turn have incentives to cut the market price. This rules out the existence of stable equilibrium and leads to the fact that in equilibrium firms choose prices randomly, i.e., "mixed strategy equilibrium".

Moreover, some Institutions as the case of (Maaz, 2017) also analyze the different scenarios that could be created if we change the producers' strategy. In the context of evaluating the impact of market designs on revenues of producers and the risks they face, they implement different behaviours for the producers, and show how the revenues change according to the strategies they are holding, such as the case of bidding fixed cost which result in higher revenues in comparison with Marginal Cost Bidding.

3 Theoretical background

It is clear that, as we mentioned above, some differences exist in both system (uniform system and pay-as-bid system) and depending on the system on which we are relied on, different conclusions and results will be generated. Hence, in an attempt to explain the findings obtained through this master thesis, the theoretical background will mainly focus on the paper of (Baldick et al. , 2004), who disagree with the concept of the "revenue equivalence theorem" by the following reasons that will be developed below:

On the one side, an example of a Game Theory was applied to analyze the market power problem under uniform and pay-as-bid pricing electricity auctions. Hence, in the paper a simple two-player game model is set up to differentiate how the generators behave in each case. According to this paper, the game has two players, the dominator, which would be the large company, and the dominated player, which would be the small one.

Unfortunately, in the case of Spain, it is worth mentioning the difficulties which will be found out to determine which company have the most market power and therefore which is the dominant, since there are a lot of different generators, which use different technologies. Moreover, by following this theoretical background we would not have any empirical finding to disagree the theory of "Revenue equivalence theorem" as many authors did in the past (as we have seen in the previous section "Literature Review"). Even so, it could be interesting if we present the game theory that comes out in the paper of (Baldick et al. , 2004) to see and clarify how the players would choose hypothetically their behaviours and how the behaviour of each player would affects the revenues (to see how it would work out in). Consequently, we would make an empirical study, choosing different strategies and see how the revenues are changing.

Hence, if there were two players (A, the dominator and B, the dominated), different behaviours and results would be determinated depending on the strategies the generators are following. The generator with market power would follow different strategies; "withholding" (generator with market power exercise extreme market power), "undercutting" (A believes that undercutting player B´bid is more profiTable for him) and "Timid" (represents the remaining range of prices that A can bid). Whereas player B would have two different strategies: "Safe" (choose the largest bid) and "Risky" (take the risk of being undercut). Once, the different strategies of each player have been determined, different scenarios will be exposed to observe the best responses and NE of each player (any player has an incentive to deviate from the strategy they have followed after considering their opponent's choices). Therefore, the results that are obtained by the paper, will be shown below:

Firstly, it can be shown how the players would react in an uniform system.

Table 1: Player A best response

Strategy (Player B)	Player A best response
Safe	Withholding
Risky	Undercutting if price Undercutting less than price risky

Table 2: Player B best response

Strategy (Player A)	Player B best response
Timid	Safe if price Safe less than price Timid
Undercutting	Safe and Risky if price Risky less than price undercutting
Withholding	Safe and Risky

Under the latter system, as we can see in Table 1 and Table 2, which show the players best response of each strategy, we would get a pure Nash Equilibrium if player B (the one that is dominated) played S (Safe) and player A played W (Withholding) (see Table 3).

Table 3: Under uniform system NE

	T	U	W
S	π A, π B	π A, π B	π A, π B
R	π A, π B	π A, π B	π A, π B

Whereas if we focus on the Tables 4 and 5, which show the players best response of each strategy, we would see that the Nash Equilibrium is mixed under pay-as-bid system, as we seen in (Fabra, 2006), and not pure as before, since the players might choose probability distributions over a set of actions available to them and then, depending on the probabilities they get, the results will be different (see Tables 4, 5 and 6).

Table 4: Player A best response

Strategy (Player B)	Player A best response
Safe	Withholding
Risky	Undercutting if price Undercutting less than price risky

Table 5: Player B best response

Strategy (Player A)	Player B best response
Timid	Safe if price Safe less than price Timid
Undercutting	Risky if price Risky less than price undercutting
Withholding	Risky

Moreover, as we mentioned at the beginning of the section, this paper does not hold the ”revenue equivalence theorem”, since depending on the systems,

Table 6: Under uniform system NE

	T	U	W
S	π A, π B	π A, π B	π A, π B
R	π A, π B	π A, π B	π A, π B

the authors use different formulas to obtain the final revenue. On the one hand, in the uniform system, there is a price cap, which is fixed by the marginalist technologies. Therefore, all quantities will have the same price, the price cap, whereas N is the total number of unit sold. The final revenue will be the following:

(1) $TRUnif = N$p*, where p* is the market clearing price, the rest of the sellers who own less than N, are price takers. So, the remuneration is hold by p*.

On the other hand, in the discriminatory system, each generator bid their prices (It is not the same price for all the generators), i.e, sellers get its bid price as its income. Hence, the formula will be the following:

(2) $TRDisc = \sum_{i=1}^{n} piN$,

where pi is the price of each generator.

4 Empirical approach

Once, the theoretical part is displayed, we will start dealing with the empirical part of the master thesis, in which conclusions are drawn strictly from concrete and verifiable empirical evidence. In this case, the evidences have been gathered using quantitative market research (Spanish energy market), which will be explained how Spanish Energy Market works out . Apart from that, all the steps which have been chosen to find out the findings will be shown.

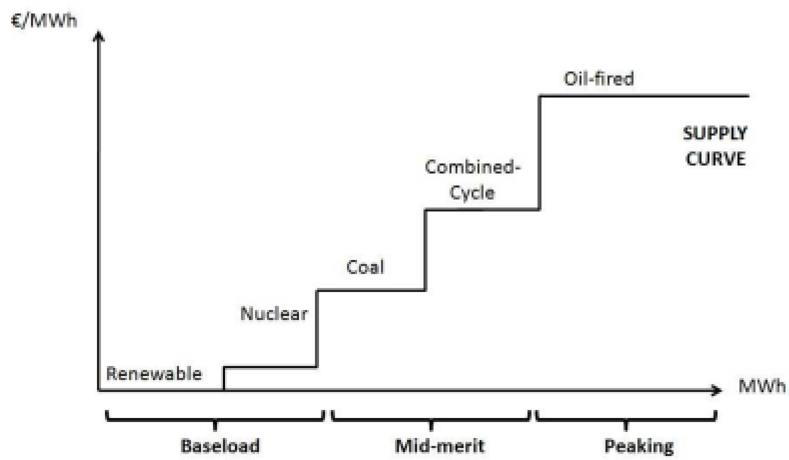
For each hour and output unit, sellers and buyers submit bids to the Spanish pool the day before, with prices ranging from 0 to 180.3 EUR/MWh (during our time series analysis). Indeed, there are two different types of electricity sale bids: simple (”ofertada”) or complex (”casada”). Simple bids offer only state price and energy (without any technical or economic restriction), whereas complex selling bids incorporate technical or economic restrictions like minimum revenues. Hence, we decided to get only simple bids to facilitate and simplify the work in finding the data.

Returning to the market, since July 2007 (The Iberian Electricity Market (MIBEL) was created as the result of a cooperation process developed by the governments of Spain and Portugal), there is a single hourly fee for both the Spanish and Portuguese markets whenever there is no physical congestion (a situation where in the existing transmission and/or distribution lines are unable to accommodate all required load during periods of high demand for example). Otherwise, the price differs. Moreover, we assume that the hours of market splitting in our actual (with RES-E, which refers to the electricity generated from clean energy) and counterfactual (without RES-E) time series are the same while coping with congestion (Ciarreta et al., 2014)

4.1 Merit Order effect

In the Spanish energy market the supply curve goes from the cheapest to the most expensive technology in the generation mix and presents the costs and capacities of all units. Each generation plant is shown as a step in the curve. The differences between costs are mainly due to the technology used and fuel consumed. So, the supply curve could be called as the merit order curve.

Figure 1: The shape of supply curve



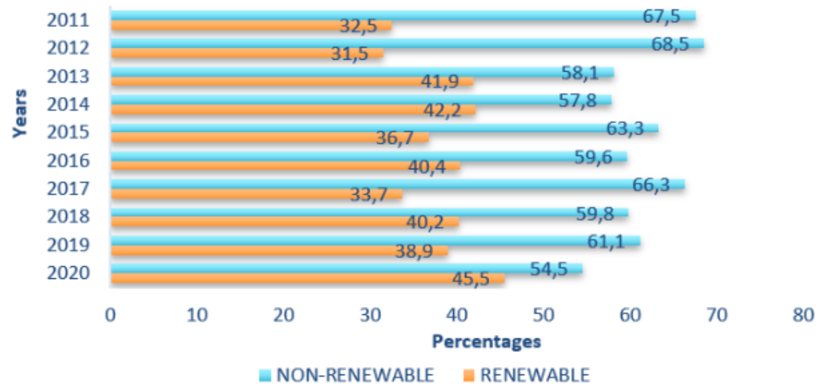
Source: Own elaboration

Hence, as it is shown in the Figure 1, each technology have their own prices and quantity. It can be observed how the bids from nuclear and renewable sources enter first the supply curve at the lowest level, since their marginal costs are the lowest, whereas traditional technologies like fossil-fuel plants (combined-cycle or oil-fired) enter in the end due to their highest marginal costs of power.

Furthermore, the hourly spot markets SMP (marginal price) is determined by where the energy supply and demand curves meet and where it matches the final unit quote. So, the SMP determines the revenue generated for all electricity generators regardless of the price offered. Since, energy production from renewable sources is generally offered at zero or low cost, (unlike other technologies such as nuclear power which is very expensive) market-clearing prices are generally expected to decrease as renewable supply increases. The growth in renewable production drives products with higher marginal costs out of the market; as a result, demand may be satisfied with less expensive technologies, bringing down power prices (Ciarreta et al., 2014).

This price reduction is exactly what is referred as the merit order effect. The more the production of renewable energies rise, the less expensive technologies will be required to satisfied the demand.

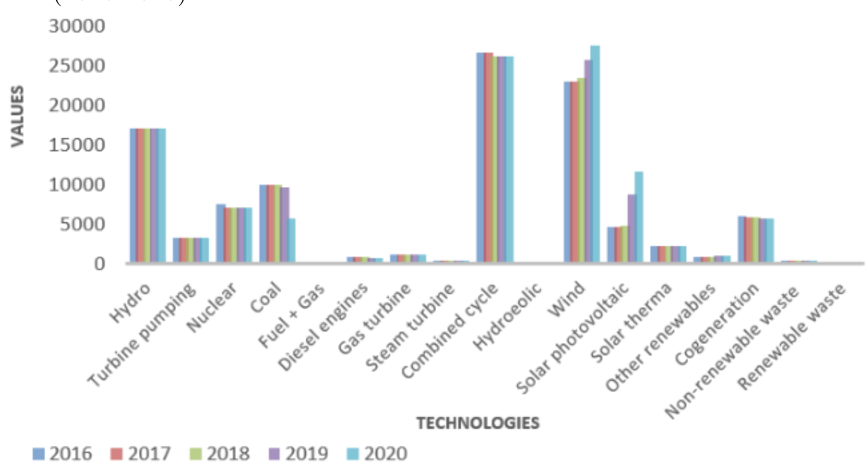
Figure 2: Evolution of renewable and non-renewable electricity generation



Source: Own elaboration; The Spanish Electricity System Report, 2020, REE

According to this, in Figure 2, it can be seen how renewable energy gains importance over time, which depicts the evolution of renewable and non-renewable electricity generation in the Spanish peninsula from 2011 to 2020.

Figure 3: Evolution of renewable and non-renewable electricity generation in Spain (2016-2020)



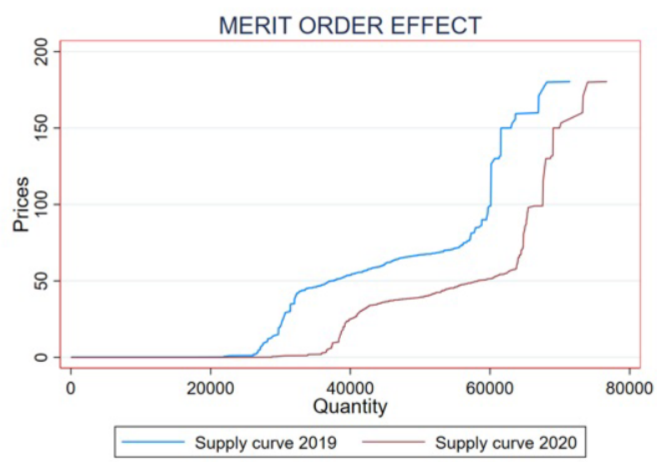
Source: Own elaboration; The Spanish Electricity System Report, 2020, REE

Whereas, Figure 3 would explain how the structure of installed electricity capacity has changed between 2016 and 2020. However, we shall concentrate on the time frame that this master thesis will be analyzed (2019 and 2020). The figure 2 demonstrates that renewable energy increased its participation in the peninsular power generating mix, setting a new all-time high with a share of 45.5% compared to 38.9% in 2019, due to an increase in hydroelectric and solar photovoltaic energy generation (REE, 2020).

Once, we show how the share of renewable energies increase in 2020, we must wonder why. Hence, Figure 3 demonstrates that, compared to 2019, the installed capacity of solar photovoltaic, wind, and other renewable energies increased, leading to an increase in the power generation of renewable energy in 2020. That is why, as a result of the final shutdown of the Compostilla II, Guardo, La Robla, Meirama, and Teruel thermal power seasons, the installed non-renewable generating capacity in the peninsular system dropped. (REE, 2020)

Then, we present how the production of renewable energies has increased over the years, Figure 4 shows the comparison that would exist in the supply curve in 2019 and 2020. As an example, we illustrate the merit order effect. We reproduce the aggregate supply curve for the same day, hour and month of 2019 and 2020 (10th April at 16:00). Hence, it can be observed that the energy offers at zero prices is a little higher in 2020, when the generation of renewable energies increase as we saw in Figure 2.

Figure 4: Merit Order effect: 2019 vs. 2020



Source: Own elaboration; data from OMIE

Moreover, on the electricity exchange, supply and demand determine the prices at auction. Therefore, as the figure shows, the supply curves shift to the right when the production of RE is higher, so the prices go down, and finally the merit order effect is hold. It is important to highlight the concept we observed above, since as we observe in the Figures 2, 3 and 4, changes in prices could be affected by merit order effect. Moreover, one of the main causes would be the effect caused by the increase in renewable energy production. On the other hand, the prices would also be affected as a cause of Covid-19, since consumer demand went up but industry demand went down considerably, generating an overall decrease in demand.

4.2 Empirical strategy

In this section, we show the empirical strategy used throughout this master thesis. It should be worth mentioning that the data come from OMIE (the market operator). In which, first of all, the curves for each month of the years analyzed (2019 and 2020) have been taken. In these curves, we can observe the prices and quantities that are bid in the market, i.e., on the one hand, we will see the bid prices of the demand side (pD) and those of the supply side (pO), whereas the quantities of the demand and supply side would be (qD) and (qO). Indeed, we compute all the hourly prices for the period 2019-2020. Hence, we build an algorithm to compute the day-ahead electricity market outcomes under different conditions. The algorithm is applied generally by these three different equations (3)-(5), which characterize the amount of energy traded and the equilibrium price on an hourly basis. The clearing price (SMP) is determined according to the maximum volume and minimum price criteria, which means that if there is more than one price with equal volume of energy, those with lowest price is chosen. So, the minimum price will be the equilibrium price at which the biggest possible volume can be executed as will be show in the following.

Returning back to the equations, Equation (3) shows the fact that for each price the quantity traded would be the short side of the market. Indeed, the supply (ask offers) and demand (buyers) data is read first, then, the aggregate supply (AS) and aggregate demand (AD) curves are computed. However, offers are arranged by ascending prices, so that Bid Volume (BV) is written in descending order, whereas Ask volume (AV) in ascending way. Once, AS and AD are ordered, the market-clearing price could be solved by Equations (4) and (5). Hence, Equation (4) expresses the maximum quantity obtained in Equation (3), which is called as Maximum Tradable Volume (MTV). Finally, Equation (5) finds out the market clearing price (SMP) according to the market rules explained in Equations (3) and (4).

(3) $q_{min} = min(q_{ask}(p_i), q_{bid}(p_i))$,
where $q_{ask}(p_i)$ shows the aggregate volume of ask orders (SA), whereas $(q_{bid}(p_i))$ presents the aggregate volume of buyers (DA)
(4) $q_{traded} = max q_{min}(p_i)$
(5)$p_{traded} = q_{bi}{}_{d}^{-}1(q_{traded})$

Anyway, it could be better if we show and simplify how the market rules by these Tables: Firstly we generate the aggregate supply and demand supply. Once, the aggregate values are obtained, we will compute the MTV and MSP.

Table 7: Aggregate Supply curve

Price	Quantity	Cum quantity
0	200	200
2,6	150	200+150=350
47	350	350+350=700
180,3	300	700+300=1000

Table 8: Aggregate Demand curve

Price	Quantity	Cum quantity
180,3	700	700
47	500	700+500=1200
2,6	300	1200+300=1500
0	100	1500+100=1600

Hence, Tables 7 and 8 shows how the quantity is ordered in different ways: ascending (supply) and descending (demand). Indeed, it can be observed that prices are accumulated in the third column of each table (see Tables 7 and 8). Anyway, Table 9 shows that the MTV is the minimum between the supply and demand aggregate values. In order, to obtain the SMP, we chose the maximum quantity (in our case it would be 700) and choose those with minimum price, 47. In fact, it has been shown how the maximum quantity and minimum price criteria is hold.

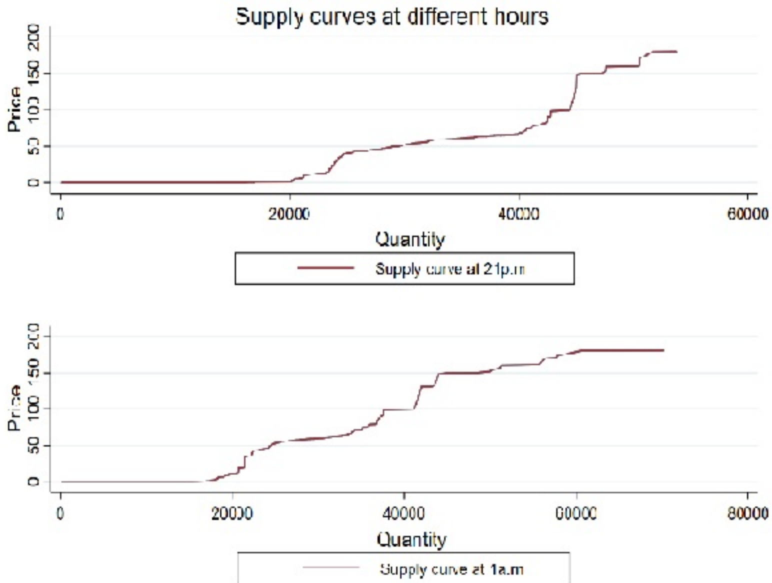
Table 9: System Marginal Price

Price	AS	AD	MTV	SMP
0	200	1600	200	-
2,6	350	1500	350	-
47	700	1200	700	47
180,3	1000	700	700	-

Once, we know how the market rules in the energy market, it will be interesting to observe how prices change depending on the hour we are considering. Although the way of calculating the SMP are the same for both hours, the prices and quantities will be different. So, we would see different shapes of the supply curve (see Figure 5) according to the day and hour.

Hence, if we look at Figure 5, it can be observed as the supply curves have different shapes even though we are considering two days that are equivalent, so in our example it would be April 10 for 2019, for 2020 it would be April 8. Indeed, the second Wednesday of April of each year. The only difference in these curves is the time they have been set, the upper graph has been set at 21 p.m., the peak hour, whereas the other graph has been set at 1 a.m., the off-peak hour. This is why the prices and quantities of energy are different at the two hours. On the same day at the peak hour, the curves start to increase

Figure 5: Supply Curves at different hours



Source: Own elaboration

around 25000 MWh whereas at the off-peak hour, the curves start to increase around 20000 MWh, a little earlier. Therefore, more energy is sold at a price of 0€ in the peak hours. This is because the supply companies know that more energy will be needed in those hours and make more offers at a price of 0€. In addition, the off-peak curve is much steeper than the on-peak curve.

As we have seen, the price would change at different time ranges, that is why we wonder how big differences in prices and revenues we would get if we change the system (from uniform to discriminatory) or even if we change the behaviour of bids and strategies. Hence, we will continue our analysis with the presentation of different scenarios to see whether the concept of revenue equivalence is followed in our case or whether windfall profits would change if we switch from one scenario to another.

Indeed, by the first scenario called as benchmark, we would see how the revenues change if we switch from uniform system to discriminatory (following a pay-as-bid system). Therefore, the equations that have been explained in the theoretical background section, obtained from the paper of (Baldick et al. , 2004) will be used to calculate the revenues of the uniform system and the discriminatory system.

Once the benchmark is showed, we will analyze two different scenarios that are created by ourselves.

On the one hand, we opt for the possibility of creating a scenario where marginal and non-marginal technologies act in a totally different way. Therefore, the first step in this scenario has been to classify the plants by their technology: nuclear, coal, combined cycle, hydro and renewable energies. In this scenario, marginal plants will continue to bid the marginal system price obtained by computing the equilibrium as explained above, whereas non-marginal plants will bid their cost instead of the SMP. Essentially, when calculating the share of non-marginal technologies (nuclear, renewable and coal in our master thesis) we will only focus on the cost of each technology and compute as prices.

However, we have not used the same type of costs for all technologies. On the one hand, in the case of nuclear or coal, we consider the variable costs, since they are technologies that have been used in Spain for a long time and therefore are amortized. On the other hand, for renewable technologies, we consider the levelized cost of energy (LCOE), also referred to as the levelized cost of electricity or the levelized energy cost (LEC), which is a measurement used to assess and compare alternative methods of energy production. Moreover, since in this scenario the bid prices are equal to the costs for the not marginal technologies, not as in the case of the benchmark, we will obtain different results when computing the SMP of each hour.

On the other hand, we have created an scenario in which the non-marginal plants bid the estimated marginal price - 0.5*standard deviation. Hence, the first followed step has been to compute the standard deviation, called epsilon by some papers (Baldick et al. , 2004), which refers to the price difference between the price bid of the agents and the marginal price. Let imagine that the marginal price is 30 and the agents bid at 28, the epsilon would be 2. Hence, once the standard deviation is calculated, we could use the following equation (6) to compute the revenues of the non- marginal plants, whereas the marginal plants will act the same as in the benchmark, that is, we would use the system marginal price as a reference to compute the revenues, equation (7):

(6) Revenues Non-Marginal plants: p*-0.5σ,

where p* is the market clearing price. So, the remuneration is hold by p*.

(7) Revenues Marginal plants: $Np*$,

where p* is the market clearing price, the rest of the sellers who own less than N, are price takers. So, the remuneration is hold by p*.

5 Data

This section describes the data we obtain through the master thesis. Indeed, we will analyze the prices of 2019 and 2020 to see an overall analysis of the behave of prices of both years and see how both years differ. Before the results are showed, it must be mentioned that we decided to get only simple bids ("ofertada") to facilitate the work in finding the data and thus not to consider the restrictions that are necessary with complex offers.

Moreover, bids in the Spanish pool are submitted the day before by sellers and buyers for each hour and production unit, covering the price range from 0 to 180.3 EUR/MW h (in 2019 and 2020).

Actually, in this section different descriptive statistics of the prices of both years will be computed and showed to see how the prices change over the years, which will be helpful to obtain some conclusions.

In Table 10, which shows the descriptive statistics of year 2019, if we look at the averages price bids for each month, we can see that the prices are different depending on the season. In winter and summer the prices are higher than in autumn and spring, since the demand is higher in the months of maximum cold and maximum heat. The most curious month, with respect to the average prices offered, is December. Although, it is one of the coldest months of the year (the month in which, respectively, more electricity is needed) it is also one of the months with the lowest prices of the whole year. This is mostly due to the higher use of renewable energies in this month (month where it was very windy), compared to previous months (REE, 2019).

Table 10: Price bids 2019

Months	Price bids	Mean	Median	Percentile 10	Percentile 90
January	Demand	62,81	59,17	30,00	100,00
	Supply	59,75	61,86	10,10	81,96
February	Demand	56,07	52,05	11,00	99,00
	Supply	55,69	56,72	8,85	77,10
March	Demand	52,81	47,46	15,00	99,00
	Supply	52,86	52,98	8,70	74,82
April	Demand	53,85	49,12	14,40	100,00
	Supply	55,12	55,06	9,20	80,01
May	Demand	52,81	48,01	11,32	100,00
	Supply	53,85	53,54	10,30	78,07
June	Demand	52,38	46,07	10,22	100,00
	Supply	50,97	49,07	9,19	75,68
July	Demand	57,19	51,55	20,00	104,10
	Supply	53,02	52,32	11,40	78,07
August	Demand	53,13	45,03	20,00	99,82
	Supply	50,13	47,17	10,00	78,05
September	Demand	50,74	41,00	15,00	100,00
	Supply	48,67	45,26	9,14	76,26
October	Demand	53,04	45,01	20,13	100,00
	Supply	50,24	48,35	11,00	73,87
November	Demand	50,42	39,65	10,13	100,00
	Supply	47,78	44,78	7,26	73,42
December	Demand	48,30	38,00	5,00	100,00
	Supply	47,01	44,41	5,36	74,07

Moreover, it is also interesting to see as the functioning of the market is shown, since the demand is higher than the supply in most cases, due to different technologies that are entering the market until the demand is completely covered.

Once we observed the year 2019, we will look at year 2020 and see how the results differ due to the lower bid prices caused by the effects of Covid-19.

Table 11: Price bids 2020

Months	Price bids	Mean	Median	Percentile 10	Percentile 90
January	Demand	29,76	24,00	0,00	82,72
	Supply	45,76	42,82	7,18	69,55
February	Demand	46,14	34,83	7,10	99,00
	Supply	43,29	40,41	7,26	68,04
March	Demand	41,20	27,40	2,50	97,00
	Supply	40,58	36,20	7,18	67,27
April	Demand	35,88	18,29	2,13	95,00
	Supply	37,70	31,14	7,13	66,15
May	Demand	37,35	21,00	2,49	97,82
	Supply	36,21	29,57	7,57	64,69
June	Demand	43,33	30,00	6,00	100,00
	Supply	39,38	35,52	7,43	65,07
July	Demand	46,19	34,94	12,80	100,00
	Supply	41,09	38,70	11,30	61,07
August	Demand	30,22	23,29	0,00	88,61
	Supply	41,73	38,46	9,00	66,35
September	Demand	51,78	43,19	16,00	100,64
	Supply	44,09	40,58	9,00	66,35
October	Demand	46,81	36,38	8,75	99,41
	Supply	42,44	39,57	8,00	64,07
November	Demand	49,06	38,66	11,83	100,00
	Supply	44,18	41,30	10,13	65,62
December	Demand	51,01	41,50	10,00	99,00
	Supply	48,16	45,86	9,70	74,53

Table 11 shows the descriptive statistics of year 2020. If we focus on the percentiles 10 and 90 we can reiterate that prices in 2020 are lower than in 2019, since 10th and 90th percentiles values are lower than in 2019. These percentiles mean that both, 90% of the bid prices are below the value of 90th percentile, and 10% of the bid prices are below the value of 10th percentile. Apart from January, in the first months of 2020, when the Covid-19 crisis hit, price bid demands are lower than offer price bids (In March and April), due to the low demand (specially in industries) caused by the Covid-19, since many industries were paralyzed, specially in March.

However, as the months go by, demand start to reach the level of previous years and finally the demand bid price are a little higher than demand bid prices and we see as the functioning of the market is shown, since different technologies are entering to the market until the demand is covered

Apart from that, it should be noted that in winter, bid prices are higher compared to the rest of the months of the other seasons, it is logical because in winter more electricity is required due to the cold and less sunshine hours (more demand for electricity).

Once, we see how the prices down in 2020, we could claim that revenues would be affected with respect to 2019. As bid prices are lower, the SMP, the price set by the market will also be lower and therefore the final revenues will be lower in 2020 than in 2019, as will be seen in the benchmark scenario in the next section.

6 Results

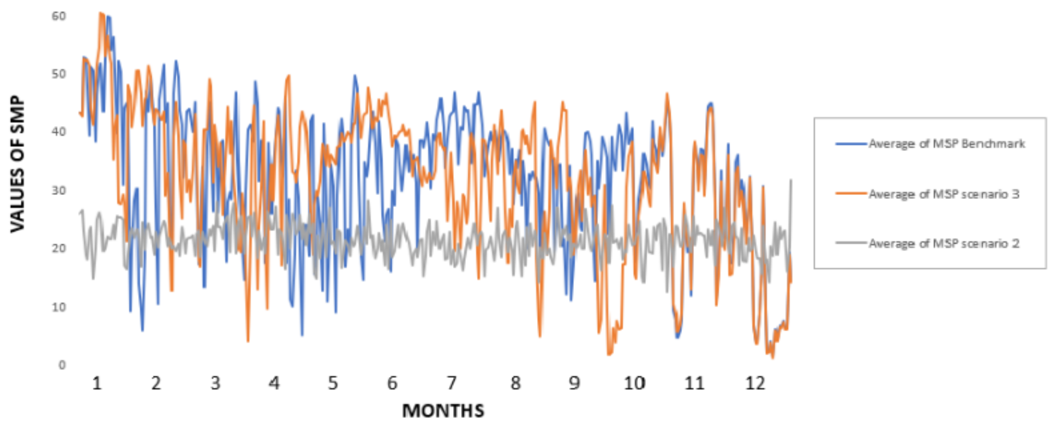
This section will show the different findings we get through the master thesis. Hence, the findings will be analyzed in 4 different sections, with the function of presenting them in an orderly and clear way. The first analysis will be focus on the SMP (marginal prices), since different strategies that have been explained among 2019 and 2020 will show a change of trend and behaviour in the clear marginal prices. Next, we will analyze the correlations that exist between the benchmark and the different scenarios created by us, both in 2019 and 2020. Once we have seen how prices behave, we will start to see the effect caused by the change in bidding and Covid-19 (when looking at 2020) on the revenues and scenarios of our time series analyzed. On the one hand, we will look at the results of the revenues for different months, in which will be observed how the revenues and trends are totally different in the seasons of the year. On the other hand, we will analyze the different technologies used by electricity generators and how the revenues are not the same according to the scenario and year we are considering.

6.1 Analysis of SMP

As we mentioned above, we will start by explaining the trends of System Marginal Prices (SMP) and how it behaves during the different months of both, 2019 and 2020.

We will analyze first the year 2019, in which some conclusions can be mentioned by looking at Figure 6. Hence, if we look the trends of the graph, which shows the SMP of the benchmark (system without changing the bidding strategy, uniform system) the second scenario (where generators bid at their cost price) and third scenario (where generators bid the marginal price - standard deviation), can be claim that system marginal prices in the second scenario, where non-marginal technologies bid their cost (both variable costs and LCOE), are more stable throughout the year. This is mostly due to the fact that we have not considered that costs vary by hours. Indeed, we consider that costs are always the same throughout the year, which consequently has taken away the volatility of the price series. However, the marginal prices of the system in scenario 3, which depends on the expected price (the marginal price - standard deviation) is closer to the prices and price volatility of the Benchmark. Apart from that, it is worth noting the general decrease in prices during the year.

Figure 6: Analysis of the SMP in 2019



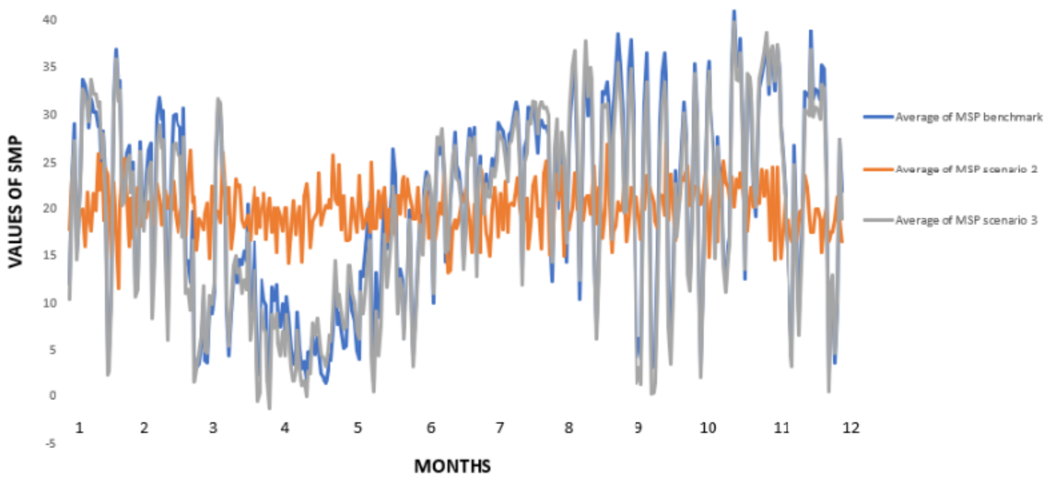
Own elaboration; data from OMIE

That is to say, if we take January as a reference and move forward through the months, we can see that marginal prices are decreasing due to lower demand, even in December, where the demand for electricity is considerable. However, this drop of prices in December is generally due to the higher use of renewable energies in this month (month where it was very windy).

Once we have looked at 2019 prices, we will see how marginal system prices have behaved in 2020. If we look at Figure 7, which shows the marginal prices of the system of three different scenarios for the year 2020, we can see that the price trend of scenario 3 and benchmark are similar, i.e. the prices are volatile. Since, as in 2019, when generating scenario 3 we have considered estimated prices (the marginal price - standard deviation) which change per hour, as in the benchmark scenario. On the other hand, as it was the case in 2019, the marginal prices of the second scenario are more stable, since costs do not change during the year. Continuing with the second scenario, as we have mentioned above, as costs being the same throughout the year, it can be observed that there has been no effect of Covid-19 (there is no any month in which prices drop considerably), unlike in the other scenarios. As the case of scenario 3, since at the time when Covid-19 hit hardest, the demand for energy became practically vertical (very inelastic) and any change in bids had a much greater effect, the prices drop especially in April. In any case, once the economy gets back on track and energy demand becomes less inelastic, prices rise back to the levels of previous years.

Overall marginal prices in 2020 were lower than in 2019, and it is also worth noting that in December 2020, even being renewable energy as predominant during that year, the month was not as windy as in 2019, so prices were high due to the high demand of energy required.

Figure 7: Analysis of the SMP in 2020



Own elaboration; data from OMIE

6.2 Analysis of correlations

Once, we have analyzed the trends of the different marginal prices of the scenarios, we will observe the statistical correlation of those marginal prices of the system to determine the relationship or dependence that exists between the different variables (scenarios). In other words, we will determine whether any change in one variable influence in the other. Therefore, for the year 2019 we will analyze the correlation between the benchmark and scenario 2 (where they bid the cost) and for the year 2020 we will make a deeper analysis, since it is a year that had many changes caused by Covid-19, in which we will show the correlation between the benchmark, scenario 2 and scenario 3 (the estimated price is bid - standard deviation).

Table 12: Correlation table 2019

	SMP benchmark2019	SMP scenario022019
SMP benchmark2019	1,0000	
SMP scenario022019	0,0110	1,0000

If we look at Table 12, which shows the correlation of scenario´s marginal prices system, can be observed that in 2019, there is no correlation between the benchmark scenario prices and the second scenario prices (is close to 0), since under the second scenario the price bids are measured by the costs which are constant throughout the year. Therefore, changes that may arise in the benchmark scenario do not influence the second scenario at all.

Table 13: Correlation table 2020

	SMP benchmark2019	SMP scenario022019	SMP scenario032019
SMP benchmark2019	1,0000		
SMP scenario022019	0,0127	1,0000	
SMP scenario032019	0,9896*	0,0136	1,0000

As mentioned above, this analysis is useful to a large extent if we do it in 2020, since Covid-19 had an effect on energy prices and we will be able to observe whether these changes would also be as noticeable in the other scenarios. Therefore, if we look at the correlations of the year 2020 (see Table 13), we can see how the correlation of benchmark and scenario 2 still to be low (the value of correlation is near to 0). Otherwise, if we focus on the correlation between the third scenario and the benchmark, it can be claimed that whether Covid-19 effects arise in the benchmark scenario influence the third scenario at all, since the correlation between the two variables is high and significant at 5% level.

6.3 Analysis of revenues

Once, the analysis and behaviour of system marginal prices are observed, we will look at the revenues obtained in each of the scenarios and compare them.

Table 14: Generation of energy 2019

	Benchmark	Scenario2	Scenario3
Type of tech	Generation (Twh)	Generation (Twh)	Generation (Twh)
Nuclear	8,95	2,90 (-68%)	2,89 (-68%)
Combined-cycle	71,13	36,45 (-49%)	35,17 (-51%)
Hydro	10,75	26,77 (+149%)	24,09 (+124%)
Coal	30,73	27,44 (-11%)	27,44 (-11%)
Renewable	122,02	143,69 (+18%)	174,15 (+43%)
Total	243,59	237,74 (-3%)	263,74 (+8%)

Table 15: Generation of energy 2020

	Benchmark	Scenario2	Scenario3
Type of tech	Generation (Twh)	Generation (Twh)	Generation (Twh)
Nuclear	11,44	1,05 (-91%)	1,22 (-89%)
Combined-cycle	61,99	44,11 (-29%)	37,38 (-40%)
Hydro	13,52	11,17 (-17%)	20,58 (+52%)
Coal	19,28	19,36 (+0,01%)	29,68 (+54%)
Renewable	129,98	125,79 (-3%)	152,21 (+17%)
Total	236,21	201,48 (-15%)	241,07 (+8%)

In any case, it would be interesting if we first emphasize the amount generated by each technology, so we could came up with which scenario generates more revenues, although we will see that this is not always the case, i.e., the scenario that generates the highest amount of energy is not always the one which generate the most revenues. Hence, if we look at Tables 14 and 15, it can be stated that the amount generated in 2020 is lower than in 2019 in all scenarios, due to the stoppage caused by the first months of Covid-19. Since during these months the demand of the industries was lower, and therefore, it was not "necessary" to generate so much energy, compared to other years where the demand has been higher.

Going back to the comparison of the scenarios and the benchmark, it can be seen how scenario 2 is where less energy is generated, whereas scenario 3, on the other side, generates more energy than the benchmark.

If we focus on the generation of each technology, it can be said that in 2019 in most cases, the benchmark technologies generate more energy, although there are exceptions such as the case of hydro and renewable energies, which those energy generated by hydro in scenario 2 is 149% higher than in the benchmark and for renewable energies is 18% higher. In the case of hydro, it must be emphasized that they generate energy according to the opportunity cost, i.e. they can spend days without watering, and the exact day when they would generate more revenues, is when they dump the water. It may be that in scenarios 2 and 3 the opportunity cost was different in 2019 and for this reason they generate more energy.

Continuing with the analysis of each technology, we can observe that in the case of nuclear energy, the energy generated is much lower compared to other technologies, since the abandonment of nuclear energy is a consistent political option taken in recent years, to prioritize other technologies such as renewable energies. That is why, even if in 2020 energy generation is lower than in 2019, the renewable generation has not stopped growing. Hence, the big loser would be nuclear, as can be seen from the data (68% less energy generated in the scenario 2 (in 2019) comparing with the benchmark and in 2020 the generation was even less, 91% and 89% less) .

Indeed, another major loser would be the combined cycle technology, which as with nuclear, in the scenarios 2 and 3 there is a notable drop in the generation of this technology, but to a lower extent than nuclear.

Finally, we would highlight the differential behaviour that coals have had in 2019 and 2020, since in 2019 this technology generates more energy in the benchmark than in the scenarios (discriminatory systems), whereas in 2020 the opposite occurs, more energy was generated (in the second scenario 0,01% and in the third scenario 54%).

Once, we observed how the technologies would behave (how many quantity they generate) in each scenario and how they differ from the benchmark, we will start by analyzing the revenues. First, we will see how the revenues of each technology change if we switch from the benchmark to the scenarios and secondly we will consider the revenues of each month from both year, 2019 and 2020, to state whether the season changes has any effect in the revenues of generator.

Hence, in Table 16, which shows the revenues obtained for each technology in 2019, can be observed that the benchmark, is the scenario which generated more revenues and the scenario 1 the one which generated less.

Table 16: Revenues for technology 2019

	Benchmark	Scenario1	Scenario2	Scenario3
Type of tech		Pay as bid	Cost	Standard Deviation
Nuclear	0,08	0,02 (-76%)	0,08 (+1%)	0,01 (-88%)
Combined-cycle	1,04	0,62 (-40%)	0,96 (-8%)	1,16 (+11%)
Hydro	0,41	0,05 (-89%)	0,40 (-0,6%)	0,83 (+104%)
Coal	0,88	0,24 (-73%)	0,52 (-41%)	1,05 (+19%)
Renewable	7,71	0,13 (-98%)	7,05 (-9%)	6,43 (-17%)
Total	10,12	1,07 (-89%)	9,03 (-11%)	9,47 (-6%)

Moreover, if we focus in the third scenario we note that our results are of the same sign and order of magnitude as in (Baldick et al. , 2004), which was about 16% more beneficial to consumers.

In 2019, if we focus on the study of each scenario, different results can be seen. For the first scenario, if we switch from uniform system to pay-as-bid system, it can be observed that for all technologies the revenues are lower than in uniform system, since in this scenario they bid their prices and not the marginal price (generally combined-cycle and hydro). If we look at scenario 2, in which for non-marginal technologies the prices are based in their costs, the revenues are mostly less than in benchmark, except for nuclear generators, whereas if we look at third scenario not all technologies generate less revenues than in the benchmark case, as is the case of hydro , combined-cycle and coal.

Looking at the results, it can be stressed that in general, in aggregate, even though generators update their bids (change strategies) if we switch from a marginalist system to a discriminatory system, the system costs for consumers would still lower in the discriminatory system. Therefore, the uniform system would be the least economic/beneficial for the consumer.

However, if we observe Table 17, which shows the revenues generated for each technology in 2020, different findings can be shown. As we expected, the system costs for consumer are lower in the discriminatory (in all scenarios) than in marginalist system, since the revenues that generator received in uniform system are greater. Moreover, comparing with data of 2019, the revenues obtained by generators are lower. Hence, consumer will enjoy more economical scenarios. If we look at the different scenarios, we can claim that the first scenario is the most beneficial for consumers because of lowest system costs. If we look at each technology, we can notice how the revenues of hydro are higher in discriminatory system than in uniform. Indeed, the increase of revenues obtained for hydro in 2020 can be explained due to the increase of generation hold in the third scenario comparing with the benchmark (Recall Table 15).

Indeed, for hydro when we are considering change bidding strategies, the revenues differences are notorious, since for the second scenario the revenues are 294% greater and for the third scenario are 336% greater than in benchmark.

Table 17: Revenues for technology 2020

	Benchmark	Scenario1	Scenario2	Scenario3
Type of tech		Pay as bid	Cost	Standard Deviation
Nuclear	0,04	0,01 (-71%)	0,03 (-15%)	0,03 (-10%)
Combined-cycle	0,62	0,30 (-51%)	0,22 (-65%)	0,31 (-50%)
Hydro	0,03	0,05 (+84%)	0,12 (+294%)	0,13 (+336%)
Coal	0,12	0,07 (-37%)	0,04 (-64%)	0,12 (+4%)
Renewable	5,10	0,09 (-98%)	4,81 (-6%)	4,82 (-5%)
Total	5,90	0,52 (-91%)	5,21 (-12%)	5,41 (-8%)

Once, we have analyzed the behaviour and the revenues generated by the technologies in both years, we will focus on the analysis of the revenues by month and we will see that the seasons of the year will determine the revenues generated by each month.

Table 18: Revenues for month 2019

	Benchmark	Scenario1	Scenario2	Scenario3
Month		Pay as bid	Cost	Standard Deviation
January	0,98	0,15 (-85%)	0,83 (-15%)	1,27 (+30%)
February	0,90	0,10 (-89%)	0,72 (-20%)	0,89 (-0,2%)
March	0,92	0,07 (-92%)	0,75 (-18%)	0,77 (-17%)
April	0,88	0,06 (-93%)	0,74 (-15%)	0,75 (-15%)
May	0,86	0,07 (-92%)	0,74 (-13%)	0,81 (-6%)
June	0,81	0,07 (-90%)	0,68 (-17%)	0,75 (-8%)
July	0,84	0,14 (-83%)	0,70 (-17%)	1,05 (+25%)
August	0,86	0,07 (-88%)	0,72 (-17%)	0,85 (-2%)
September	0,83	0,07 (-91%)	0,74 (-11%)	0,62 (-26%)
October	0,73	0,10 (-85%)	0,76 (+4%)	0,75 (+3%)
November	0,91	0,06 (-93%)	0,80 (-12%)	0,66 (-28%)
December	0,62	0,02 (-96%)	0,83 (+35%)	0,32 (-49%)
Total	10,14	1,07 (-90%)	9,02 (-11%)	9,48 (-7%)

Hence, if we look at Table 18, which shows the quantity of revenues generated by each month for different scenarios in 2019, can be observed that all scenarios follow the same pattern, that is, the month that generates the most revenues is January. This is generally due to the high demand required for the fact of being the coldest and least solar month of the year. Therefore, it could be said that this month is the least economical for consumers. Since, January generates more revenues due to the fact of being a colder month, we could assume that December, being also one of the coldest months, would generate more benefits than other months. However, this is not the case, due to the high use of renewable energy and the high level of wind at that time.

Furthermore, if we make an analysis of each scenario, we can observe that scenario 1 is the most economical for the consumers in all months, since the system costs are lower. Scenario 2 is the scenario that shows the seasonality of electricity prices in the clearest way, since in winter profits rise, due to the high demand required, and in spring, summer and autumn profit levels fall. It should be remembered that this scenario has been generated by costs that are the same for all the year, and the price is less volatile than in the other scenarios, as we see in the analysis of SMP.

This is why we can see that December is the month with the highest profit (following seasonality of electricity prices), contrary to the other scenarios. Finally, scenario 3 shows results that follow the same pattern as the benchmark, since January and summer are the months that generate the most profits for the generator. In fact, during these months, scenario 3 generates more revenues than the benchmark (30% greater in January and 25% greater in July). However, there is a significant drop of 49% for the month of December.

Table 19: Revenues for month 2020

	Benchmark	Scenario1	Scenario2	Scenario3
Month		Pay as bid	Cost	Standard Deviation
January	0,47	0,06 (-90%)	0,50 (+6%)	0,52 (+10%)
February	0,47	0,04 (-92%)	0,44 (-5%)	0,50 (+7%)
March	0,51	0,02 (-96%)	0,45 (-11%)	0,26 (-49%)
April	0,40	0,01 (-98%)	0,40 (+0%)	0,12 (-70%)
May	0,47	0,02 (-96%)	0,38 (-19%)	0,48 (+2%)
June	0,42	0,04 (-92%)	0,36 (-15%)	0,43 (+1%)
July	0,44	0,07 (-84%)	0,37 (-16%)	0,54 (+21%)
August	0,46	0,06 (-86%)	0,38 (-18%)	0,64 (+39%)
September	0,42	0,07 (-84%)	0,45 (+7%)	0,58 (+37%)
October	0,57	0,04 (-92%)	0,46 (-19%)	0,45 (-21%)
November	0,60	0,07 (-88%)	0,49 (-18%)	0,42 (-30%)
December	0,66	0,04 (-94%)	0,52 (-22%)	0,47 (-29%)
Total	5,90	0,53 (-91%)	5,21 (-12%)	5,41 (-8%)

Anyway, different conclusions can be drawn for the year 2020 due to the Covid-19 effect. If we look at Table 19, which shows the revenues we obtain for each month, we can see that scenario 1 is the most economical for the consumers, it is 91% more economical than the scenario followed by marginal system for example. If we look at the seasons of each scenario, we can determine that in winter the benefits will be higher for the generators in all scenarios, whereas in spring and summer the benefits will be lower (seasonality of electric prices). This pattern is hold in all scenarios, except in scenario 3, where it seems that the effect of Covid-19 is quite noticeable.

By month, we observe that in March and especially in April 2020, when energy demand became almost vertical (very inelastic), any change in bids would have a much larger effect than for other months (-70%). Indeed, in the summer months, even demand becomes less inelastic, the change in bids still would also have a greater effect than in the rest of the year. Moreover, if we focus in the third scenario, as it was in 2019, we note that our results (8% more economic for consumers) are of the same sign and order of magnitude as in (Baldick et al. , 2004). Hence, it can be claimed that the third scenario is more beneficial for consumer than the benchmark, even the behaviour of the SMP is similar for both scenarios.

7 Conclusions

This Master Thesis analyzes the electricity market auctions, both uniform and discriminatory. We modelled different scenarios to observe, on the one hand, how revenues could change if we switch from a uniform to discriminatory system (including the scenarios created for us); and on the other hand, how revenues would change if we use different bidding strategies.

The electricity market is characterized by its complexity and this is corroborated by our results, since we observed important changes by technology and seasonality, affecting the revenues in each scenario.

Nevertheless, several conclusions can be drawn, once the results have been presented. We note that, in aggregate, despite the fact that generators may change their bidding strategies, if we switch from a uniform to a discriminatory system, system costs for consumers are still lower under the discriminatory scheme. Hence, the overall revenues will always be higher in uniform systems, being more beneficial for generators and less for consumers, since they would be supposed to face higher costs. For this reason, it can be claimed that we refuse the concept of revenue equivalence, as it can be observed in our findings.

However, if we analyze the electricity seasonal behaviour by month, we observe that for the winter/autumn months in 2019, the uniform system could be cheaper (i.e. less revenues for generators), since in October in the third scenario, revenues are somewhat higher, 3%; and in December of the second scenario, we would obtain revenues 35% higher than in the benchmark. By month, we also note that in April 2020, when energy demand became practically vertical (very inelastic) due to the lockdown policies to tackle the Covid-19 pandemic, any change in bids would have a much greater effect than for any other month (-70%). Therefore, it has been shown how the effect of Covid-19 affected the demand and therefore the revenues obtained. From this result we can also conclude that the elasticity of demand would be another important factor to take into account. However, this is beyond the scope of this research and we leave it for further research.

Moreover, if we consider each technology separately, we observe that the uniform system generates more profits for some generators, but not for all of them. In particular, for the case of nuclear in 2019 and hydro in 2020, the uniform system would provide less revenues for these technologies.

Apart from analyzing the revenues reduction, we have also observed how the marginal prices behave in the different simulated scenarios. In scenario 2, where non-marginal firms bid following their costs, we conclude that the marginal price becomes more stable (i.e. less volatile). This is mostly due to the fact that, for the sake of simplicity, we have considered that costs do not vary at an hourly level, which reduces the volatility of the price series. For further research we propose to change the bidding costs by hour, in order to have a more realistic simulation for scenario 2. However, in scenario 3, which is computed based on the expected price (which does change by hour), simulated prices are closer to benchmark prices. We have also observed that the price of scenario 3 and the benchmark (which is the same as in the ceteris paribus scenario 1) are correlated in 2020. That is, we get a high value (close to 1), positive and significant at the 5% significance level. However, in scenario 2 is not. Therefore, we could say that scenario 3 and the benchmark are correlated.

We note that our results are of the same sign and order of magnitude for scenario 3 as in (Baldick et al. , 2004), which gives us a hint that the results generated may be on the right track. Finally, our results may be a bit overestimated, because we have considered that the only plants that can be marginal are hydro and combined cycle. However, the rest of the technologies, to a lesser extent, could also be marginal at some hours. For the future, we propose to identify at the hourly level the marginal technology, so that the hourly bidding structure would be more accurate.

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