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**Working Paper**

## From forward to spot prices: Producers, retailers and loss averse consumers in electricity markets

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# Working Paper

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## **From Forward to Spot Prices: Producers, Retailers and Loss Averse Consumers in Electricity Markets**

**Valeria Di Cosmo, Elisa Trujillo-Baute**

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### From Forward to Spot Prices: Producers, Retailers and Loss Averse Consumers in Electricity Markets

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#### Summary

The benefits of smoothing demand peaks in the electricity market has been widely recognised. European countries such Spain and some of the Scandinavian countries have recently given to the consumers the possibility to face the spot prices instead of having a fixed tariffs determined by retailers. This paper develops a theoretical model to study the relations between risk averse consumers, retailers and producers, both in the spot and in the forward markets when consumers are able to choose between fixed tariffs and the wholesale prices. The model is calibrated on a real market case - Spain - where since 2014 spot tariffs were introduced beside the flat tariffs for household consumers. Finally, simulations of agents behavior and markets performance, depending on consumers risk aversion and the number of producers, are used to analyse the implications from the model.

Our results show that the quantities the retailers and the producers trade in the forward market are positively related with the loss aversion of consumers. The quantities bought by the retailers in the forward market are negatively related with the skewness of the spot prices. On the contrary, quantity sold forward by producers are positively related with the skewness of the spot prices (high probability of getting high prices increase the forward sale) and with the total market demand. In the spot market, the degree of loss aversion of consumers determine the quantity the retailers buy in the spot market but does not have a direct effect on the spot prices.

**Keywords:** Electricity Spot Market, Electricity Forward Market, Risk Aversion

**JEL Classification:** D40, L11, Q41

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# From forward to spot prices: producers, retailers and loss averse consumers in electricity markets

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Elisa Trujillo-Baute<sup>†</sup>

## Abstract

The benefits of smoothing demand peaks in the electricity market has been widely recognised. European countries such Spain and some of the Scandinavian countries have recently given to the consumers the possibility to face the spot prices instead of having a fixed tariffs determined by retailers. This paper develops a theoretical model to study the relations between risk averse consumers, retailers and producers, both in the spot and in the forward markets when consumers are able to choose between fixed tariffs and the wholesale prices. The model is calibrated on a real market case - Spain - where since 2014 spot tariffs were introduced beside the flat tariffs for household consumers. Finally, simulations of agents behavior and markets performance, depending on consumers risk aversion and the number of producers, are used to analyse the implications from the model.

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# 1 Introduction

In April 2014, the Spanish regulation authority (NRA) changed the pricing regime for the consumers included in the "last consumer tariff", which involve all the household consumers who did not opt for any specific provider in the free electricity market (about 60% of the total).<sup>1</sup> The NRA proposed to switch from an auction mechanism, which kept the wholesale electricity price constant for 3 months, to the spot electricity price (CNMC, 2014b). The last auction took place on 19th December 2013. The day after, the NRA did not validate the results of this auction, '*given the atypical circumstances in which the auction was held*'. The change in the pricing mechanism announced for the second quarter of 2014, and the declaration of the NRA about the auction mechanism had quite an impact on the final consumers.

Literature highlights that consumers usually prefer a flat tariff over a variable tariff either because they overestimate their future consumption due to quasi-hyperbolic discount rates (DellaVigna and Malmendier, 2006) or because consumers would like to be insured against future risks and uncertainties (Train et al. (1989) and Herweg and Mierendorff (2013)). This motivated Train et al. (1989) to introduce the concept of 'flat-tariff bias', which characterize consumers who prefer a flat tariff even through this type of tariff may be suboptimal with respect to a measured tariff. This results is confirmed by a number of experiments both in the US (see Faruqui and Sergici (2010)) and in Europe (see Aubin et al. (1995), Filippini (1995) and Di Cosmo et al. (2014)). These works investigate whether consumption reacts more to prices when the cost of electricity follows wholesale costs more closely. These experiments find that there is a negative relation between high peak prices and consumption, but the magnitude of these effects was not constant between the experiments, varying between 3 and 6%. Reaction of consumers is typically higher in peak times, but the estimated elasticities are quite low for the remaining hours of the day (Di Cosmo and O'Hora, 2017).

However, the electrification envisaged for the next years with the increase of the number of electric vehicles and the electrification of heating and cooling systems may change the rate of responsiveness of final consumers to real prices. The option for the consumers to choose between real time tariffs and a flat rate has been applied not only in Spain but also in Norway and Sweden.<sup>2</sup>

To have an idea about the interest of consumers in the announcement made by the Government to swap the default tariff for consumers from the auction to the spot price, we analysed the number of searches done by Spanish consumers on internet for the term 'Electricity Price'. The main intuition is that not only consumers under the default tariff but also the other consumers may be interested in switching from flat to spot prices. Figure 1 shows that consumers actively look for electricity prices between December 2013 (when the auction mechanism got suspended) and in

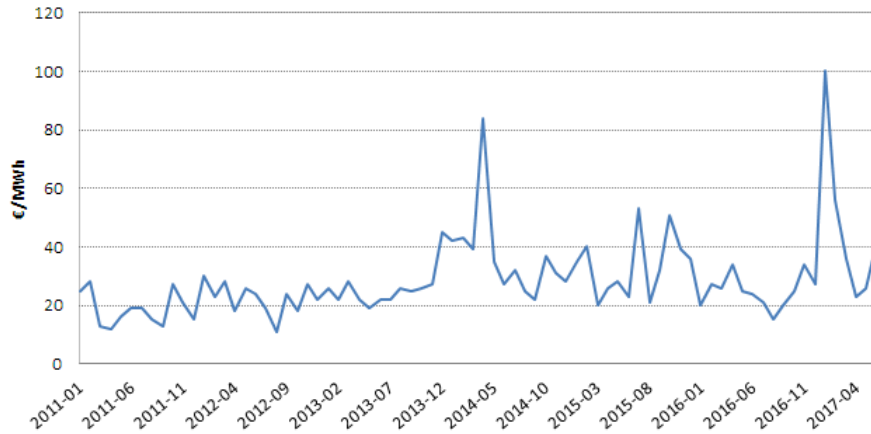
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<sup>1</sup>Only to low-voltage consumers who have a power supply of less than 10kW.

<sup>2</sup>See CNMC (2014b) and Olsen and Johnsen (2011).

April 2014 (when the spot price was set as default option). Also, after April 2014 the number of searches have always been higher than when the price was fixed, with some peaks when the news announced high price levels in the spot market.

Figure 1: Google trend on ‘Electricity Price’ search in Spain, 2011-2016



Although data from Google trend cannot be grouped by the socio-economic characteristics of the consumers, Figure 1 gives an idea about the effects of the change made by the Government, and make interesting to check how the Spanish market can change in the near future, following the change in tariff proposed by the NRA.

The attention devoted to the change in regime proposed by the Spanish authority suggests that at least some of the Spanish consumers not under the default tariff may opt for the spot price in the future, or switch back to the default tariff.<sup>3</sup> As a result, consumers facing spot prices are likely to be the the majority of the market in the near future.

With most of the consumers buying at the spot price, also retailers are affected by the change in the market design, as they are not able to sell most of their electricity at a fixed price to the final consumers, passing-through them the forward contracts. Thus, liquidity in this market may decrease. Finally, producers may be affected as well as a consequence of market changes and their relations with both retailers and consumers. Bessembinder and Lemmon (2002) highlights that producers and retailers are linked not only in the spot, but also in the forward markets. Retailers who sell electricity to consumers at a fixed price hedge their position in the forward market, buying electricity from producers who wish to hedge against uncertainty (Deng and Oren, 2006).

This paper focuses on the relation between consumers, producers and retailers in a market in which is possible for consumers to buy at the spot price. In particular, we analyse the consequences of loss-averse consumers in both the spot and the forward markets and investigate the implications of consumer preferences on the liquidity of forward markets.

This is particularly interesting as a wide literature has investigated the impact of liquid forward markets on competition in the spot markets, as summarized by Di Cosmo and Lynch (2016).

<sup>3</sup>By law, consumers are allowed to change tariff scheme once a year.

Green and Newbery (1992), Allaz and Vila (1993), Wolak (2000) and Borenstein (2002) show how, under some conditions, forward liquidity forces the producers to keep the prices in the spot at a competitive level.

We extend the analysis of Bessembinder and Lemmon (2002) in order to include loss-averse consumers. First, we set up a theoretical model to describe the relations between consumers, producers and retailers both in the spot and in the forward markets. Second, we calibrate the results of our model on the Spanish data, in order to estimate the effects of the change in the tariff structure on both the forward and the spot markets. Third, we investigate how changes in the loss aversion of consumers, in the number of producers (and retailers) affect prices and quantities in both the spot and the forward markets.

Our results show that an increase of consumers willing to buy at the spot price negatively affects liquidity in the forward market. However, increases in the number of producers reduce both the spot and the forward prices and increase the quantities traded in the forward market.

This paper continues by describing and solving our model in Section 2. Section 3 describes the Spanish market and calibrates the model on the Spanish data. Section 4 concludes.

## 2 The Model

Bessembinder and Lemmon (2002) identify the optimization problem of retailers and electricity producers both in the spot and in the forward market. In our model, we complete this scheme introducing consumers, who can choose whether to buy electricity from the spot market (at the spot price  $p_W$ ) or buy from retailers the electricity at a fixed price  $p_R$ . In the forward market, retailers and producers contract the quantities that should be sold (bought) forward. In the spot market, consumers maximise their utility, determining the quantity of electricity that they buy in the spot market and at the fixed price. This choice takes into account the spot prices and also the loss aversion of the consumers. Producers determine the quantity to produce in the spot market taking into account the quantity sold to the retailers in the forward market. Producers and retailers have the incentive to sell at a flat tariff  $p_R$  in order to hedge their position in the forward market. Consumers' preference for a flat tariff may be explained as rational behaviour if they want to insure themselves against the risks associated with changes in tariffs, when future consumption is uncertain (Train et al., 1989). Based on the seminar work of prospect theory by Kahneman and Tversky (1979), Herweg and Mierendorff (2013) highlight that standard risk aversion fails to explain the insurance motive, as price variations are small compared with consumers' income. As a result, they introduce the concept of "expectation-risk aversion" that we follow in this work. A consumer is loss adverse in the sense that he incurs in a loss when the price is higher than the reference price the consumers have in mind. In the extreme scenarios in which all the consumers want to pay the spot prices, retailers just operates in the forward market. For simplicity, we

assume that producers, consumers and retailers buy and sell only a baseload product. We discuss the implications of this in section 3.

## 2.1 Spot market

We solve the model backward, starting from the spot market in which consumers, retailers and generators maximise their utilities taking the prices and the quantities determined in the forward market as given. In section 2.2, we solve the forward market using the spot results.

### 2.1.1 Consumers

Following Herweg and Mierendorff (2013) we assume that the consumers take as reference price the fixed price they had in their past bills ( $p_R$ ). The reference price  $p_R$  should reflect both the fixed costs of the producers  $F$  and the retailers' hedging premium.

Thus, the utility function of the consumers is of the type  $u - \mu$  in which  $\mu = \lambda(\max(T - p_R, 0))$  where  $T$  is the tariff the consumer has to pay for the electricity and  $\lambda$  is the parameter that reflects the degree of the consumer's loss aversion.

When  $\lambda = 0$  the preferences of the consumer are loss neutral, as they do not take into account the reference price. When  $\lambda > 0$  consumers are loss averse, as they compare the wholesale price they face with the reference price and then determine the relative cost they face with the wholesale price. The utility function of the  $i$ -th consumer is of the type:

$$u(q_{Ci}) = \theta q_{Ci} - \frac{1}{2}(q_{Ci})^2 - F - p_W * q_{Ci} - \lambda p_W * q_{Ci} \quad (1)$$

$$\text{where } \theta = 2 * \lambda * p_W + (1 - \lambda) * (q_D + p_W)$$

### 2.1.2 Retailers

Retailers face an uncertain demand both in the spot and in the forward markets. Taking the quantity bought on the forward market ( $q_F^{Ri}$ ) as given, the single retailer sell the quantity  $q_{Ri}$  to the consumers that opt for the fixed tariffs. In the spot market the uncertainty linked to the demand is resolved, then the retailers buy (at the spot prices) the difference between the quantity demanded by consumers that they fail to forecast in the forward market. Following Bessembinder and Lemmon (2002), the profit equation for the retailers is:

$$\pi_{Ri} = p_R * q_{Ri} - p_F * q_F^{Ri} - p_W (q_{Ri} + q_F^{Ri}) \quad (2)$$



### 2.1.3 Producers

Producers maximise the following profit function:

$$\pi P_i = p_W * q_{W_i} + p_F * q_F^{P_i} - TC \quad (3)$$

where  $i$  is the single producer,  $q_W$  is the quantity the producers sell in the spot market (equal to  $q_{C_i}$  plus the quantity  $q_{R_i}$  the retailers need to buy to adjust their position),  $q_F^{P_i}$  is the quantity they commit in the forward market (here taken as given) and  $TC$  are the total costs they face in their production process, equal to

$$TC_i = F + \frac{a}{2} * q_{P_i}^2 \quad (4)$$

where  $F$  reflects the fixed costs and the quadratic (variable) component reflect the convex cost function that characterizes the electricity markets and  $q_{P_i} = q_F^{P_i} + q_{W_i}$ .<sup>4</sup>

### 2.1.4 Equilibrium

#### 2.1.4.1 Producers

We assume that  $q_R = \sum_i q_{R_i}$  and  $q_C = \sum_i q_{C_i}$ . And then the total quantity sold in the market either of the peak or the off-peak product is  $q_D = q_R + q_C$ . The optimal price and the optimal quantities traded on the spot market are:

$$q_W^* = \frac{1}{a} p_W - q_F^P \quad (5)$$

$$p_W^* = a \left( \frac{q_D}{NP} \right) \quad (6)$$

The spot market price depends on the total quantity demanded by the market divided by the number of producers.

#### 2.1.4.2 Consumers

Total demand ( $q_D$ ) is determined exogenously by the market, and it is mainly determined by whether and seasonality. This assumption is fairly standard and assumes that total demand is not elastic with respect to prices.

The optimal quantity the consumers buy in the spot market is:

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<sup>4</sup>The hypothesis of quadratic costs simplifies the equations of producers and allows for a closed form solutions. A generic cost function like  $TC_i = F + \frac{a}{c} * q_{P_i}^c$  as in Bessembinder and Lemmon (2002) adds complexity but does not change the results.

$$q_{Ci}^* = \theta - p_W(1 + \lambda) \quad (7)$$

$$q_{Ci}^* = (1 - \lambda)q_D \quad (8)$$

The quantity the consumers buy at the spot price  $p_W$  is negatively related to the loss aversion coefficient  $\lambda$ .

### 2.1.4.3 Retailers

The quantity  $q_C$  results from the maximisation of consumers' utility, which depends on  $\lambda$ . With an inelastic demand, the price ( $p_W$ ) is determined by the supply curve (i.e. producers from and Eq. 8). Retailers decision is therefore limited to the quantity  $q_R$ :

$$\frac{q_R}{NP} = \frac{1}{a}p_W - \frac{1}{NP}q_C$$

The quantity sold in the spot market depend on prices (the higher the spot prices, the more the consumers wish to buy at the fixed price  $p_R$ ) and on the quantity bought on the spot market (the higher  $q_C$ , the lower  $q_R$ ).

## 2.2 Forward market

Consumers choose the quantity they buy in the spot market, and do not have an active role in the forward market. Retailers and producers contract in this market the quantities that should be bought and sold.

The profit equations of the producers in the forward market is:

$$\pi_{Pi}^F = p_W \left( \frac{q_R + q_C}{NP} \right) - F - \frac{a}{2} * \left( \frac{q_R + q_C}{NP} \right)^2 \quad (9)$$

which can be obtained replacing Eq (5) in Eq (3). The objective function of the retailers is:

$$\pi_{Ri}^F = p_R * q_{Ri} + p_W * q_{Ri} \quad (10)$$

Following Hirshleifer and Subrahmanyam (1993) and Bessembinder and Lemmon (2002) we assume that the objective function of the producers and the retailer is linear in expected profits, and that the variance of the profits is known. Then the quantity the producers and the retailers trade on the forward market is determined by:

$$q_F^{P,R} = \frac{p_F - E(p_W)}{AVar(p_W)} + \frac{Cov(\pi_{P,R}^F, p_W)}{Var(p_W)} \quad (11)$$

### 2.2.1 Producers

Let us focus on the profits in the forward market for the producers, given by Eq. 9. From Eq. 3 we have that:  $\frac{(q_R + q_C)}{N^P} = \frac{p_W}{a}$  Replacing that in Eq.(9) reads:

$$\pi_{P_i}^F = \frac{(p_W)^2}{2a} - F$$

We can then calculate the covariance between the producer's profits and the spot price  $p_W$  and replace that in Eq. 11:

$$Cov(\pi_{P_i}^F, p_W) = \frac{1}{2a} Cov(p_W^2, p_W) \quad (12)$$

Then Eq. 11 for producers becomes:

$$q_F^{P_i} = \frac{p_F - E(p_W)}{AVar(p_W)} + \frac{\frac{1}{2a} Cov(p_W^2, p_W)}{Var(p_W)} \quad (13)$$

### 2.2.2 Retailers

In our model, retailers buy forward quantities depending on the share of the electricity they can sell in the spot market at the fixed price  $p_R$ . Following Bessembinder and Lemmon (2002) we assume that:

$$Cov(\pi_{R_i}^F, p_W) = p_R Cov(q_{R_i}, p_W) - Cov(p_W q_{R_i}, p_W) \quad (14)$$

Replacing Eq.14 in Eq.11

$$q_F^{R_i} = \frac{p_F - E(p_W)}{AVar(p_W)} + \frac{p_R Cov(q_{R_i}, p_W) - Cov(p_W q_{R_i}, p_W)}{Var(p_W)} \quad (15)$$

### 2.2.3 Equilibrium

In order to find the optimal forward price and, then, the optimal quantities sold and bought on the forward markets by retailers and producers we impose that the forward market clears: ( $q_F^P$  and  $q_F^R$ ). The market-clearing equation is:

$$\sum_i q_F^{R_i} + \sum_i q_F^{P_i} = 0$$

solving that for  $p_F$ , and replacing  $q_R$  from Eq. (9) gives:

$$p_F = E(p_W) - \frac{N^P}{N} \frac{1}{2a} Cov(p_W^2, p_W) - \frac{N^R}{N} p_R Cov(q_R, p_W) + \frac{N^R}{N} Cov(p_W q_R, p_W) \quad (16)$$

Using the covariance property:  $Cov(p_W^2, p_W) = Skew(p_W) + 2E(p_W)Var(p_W)$  we rewrite Eq.16 as:

$$p_F = E(p_W) + \gamma Skew(p_W) + \gamma 2E(p_W)Var(p_W) - \left(\frac{N^P}{Na} + \frac{(1+\lambda)}{N}\right) N^R p_R \quad (17)$$

$$\text{in which } \gamma = \frac{2N^R(N^P + a(1+\lambda)) - N^P}{2aN}$$

The forward price is related with  $p_R$ , the expected level of the spot price  $p_W$ , its variance and its skewness. The higher the skewness of the spot price, the higher the probability of getting very high prices in the spot, so the forward price is higher. The same holds for variance: the higher the price variability, the higher the motivation of hedging on the future markets and the higher the forward price.

From that, we can solve Eq. 13, replace Eq. 6 and get the optimal forward position for the producers as a function of the quantity and the prices in the spot market:

$$q_F^{Pi} = \frac{E(q_R + q_C)}{N^P} + \frac{PREM}{AVar(p_W)} + \frac{1}{2a} \frac{Skew(p_W)}{Var(p_W)} + \frac{1}{2a} \frac{Skew(p_W)}{Var(p_W)} \quad (18)$$

in which  $PREM = p_F - E(p_W)$  as in Bessembinder and Lemmon (2002). The producers want to sell more on the forward market the higher the expected demand. Loss aversion is negatively linked to the quantity sold forward by producers. The producers also consider the difference between the forward price and the expected spot prices (the premium) and the variance of the spot prices. The higher the variance, the lower the quantity sold forward. However, the variance of the spot prices is weighted by the skewness of the spot prices. The higher the skewness of the spot price, the higher the forward price, the higher the quantity producers want to sell in the forward market.

Solving Eq.15 we get the optimal quantity bought in the forward market by the retailers:

$$q_F^{Ri} = -2 * E(q_R) + \frac{PREM}{AVar(p_W)} + \left(\frac{N^P}{a} + (1+\lambda)\right) \left[\frac{p_R - Skew(p_W)}{Var(p_W)}\right] \quad (19)$$

The quantity the retailer  $i$  buy forward depends on the expected demand they face in the retail market  $q_R$ . The minus sign indicates that the retailer will take in the forward market the opposite position from the producers. The higher  $p_R$ , the higher the quantity that can be bought forward. The quantity traded by the retailer in the forward market also is affected by the possible bias between the forward and the spot prices (premium) and the skewness of spot prices. Consumers' loss aversion affects the quantity traded forward by retailers: the higher the loss aversion, the lower the quantity sold on the forward market by the retailers. Moreover, the higher the loss aversion, the

higher  $q_R$ , which (in turn) determines higher quantities bought on the forward market by retailers.

### 3 Testing the model

We use the equations of the model to determine how the price and the quantity in both the spot and the forward markets change after variations in the loss aversion parameter ( $\lambda$ ), in the number of retailers ( $N_r$ ) and in the number of producers ( $N_p$ ).

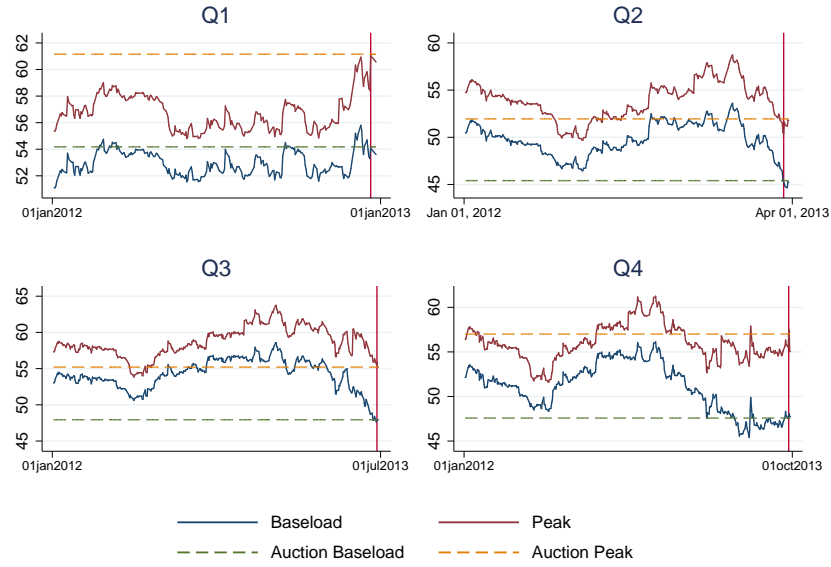
We calibrate our model on the Spanish economy, as the reform of the electricity prices happened in this country in 2014 is a good test case for our model. Like in any other liberalised market, the consumers in the Spanish electricity market are able to choose between different electricity providers. For the consumers that did not opt for any specific provider, the former incumbent companies offered since June 2010 the default service at a ‘default tariff’. This price was set by a quarterly auctions mechanism, in line with other liberalised markets such as New Jersey and Maryland using structured competitive solicitation processes to procure electricity for default consumers (LaCasse and Wininger, 2007)<sup>5</sup>. The quarterly descending clock auctions were used to calculate the wholesale cost for households with default contract. The resultant price was kept fixed during the following 3 months, similarly to the Danish case, where the reference price is calculated with the average of the relevant prices in quarterly contracts for the next quarter since 2005 (Olsen and Johnsen, 2011).

The products purchased by the last resort suppliers in the auctions were standard quarterly forward contracts (base load and peak products) similar to those traded in the forward markets. In this sense, according to the NRA ‘*there was a strong interrelation between the resulting equilibrium price in the auction and the price formation in the existing forward trading venues*’ (CNMC, 2014b). Implying that, from the NRA perspective, the auction-based price could be perceived as a competitive price. In the same line, supporting the NRA perspective, Figure 2 shows the auction prices and the evolution of future prices until the auction day during 2013, both for peak and baseload prices.

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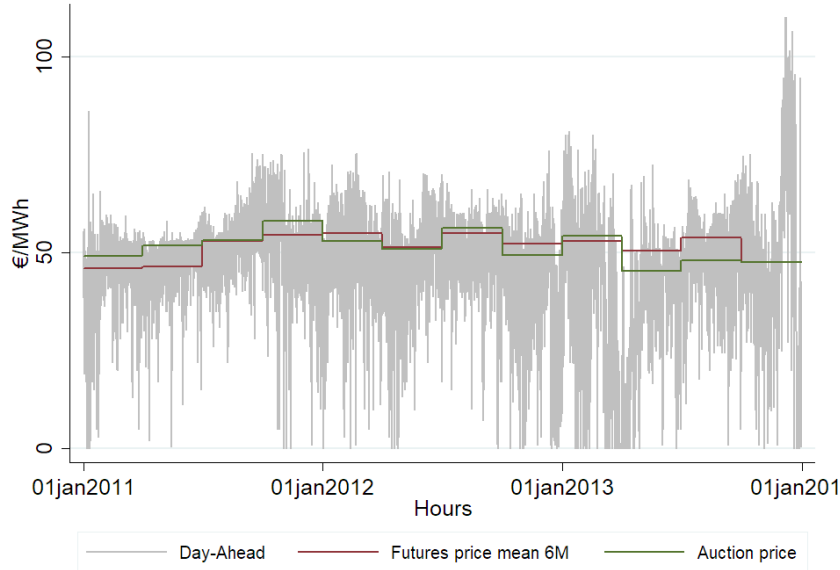
<sup>5</sup>It is more similar to the New Jersey because in Maryland there is a list of prices, but in Spain and New Jersey it is a single price directly used as the wholesale cost in the retail price.

Figure 2: *Price Auction vs. Future, 2013 (settlement price €/MWh)*



The last auction took place on 19th December 2013. A three-month base load product and a three-month peak product were offered at this auction for the first quarter of 2014, being the auction price, 61.83 €/MWh and 67.99 €/MWh, respectively. This auction was not validated and the price applied to the last resort consumers in Spain changed from fixed to a mechanism in which the consumers pay for the energy consumed valued at the spot price, facing the hourly variation of the spot market price. Comparing the prices at delivery date for the auctions, the 6 months-futures (which means the mean over the 6 months before delivery of the same future contract), and spot (see Figure 3) hints on the similarities and differences in terms of levels and volatility between the alternatives approaches. From the theoretical model we know that, loss-avers consumers compare the wholesale price they face with the reference price to determine the relative cost they face with the wholesale price. In this case, the reference price corresponds to the auction price ( $p_R$ ) and the wholesale price is the spot market price ( $p_W$ ). Therefore, the features of auctions, spot and future prices, in terms of levels and volatility, provide an excellent setting for testing the model and exploring the effects on markets from different levels of consumers loss aversion.

Figure 3: Prices at delivery date (baseload)



The summary statistics, shown in Table 1, highlight that the mean of the day ahead price is lower than the mean both of the auction and the 6 months-futures. However, the standard deviation of the spot prices is almost 4 times higher than the standard deviation of the auction and the future price. This relation between prices applies, in the same order of magnitude, for both peak and off-peak period. This implies that the results from the calibration and simulation would not show significant differences, with respect to the relevant elements of the analysis, when using either price period. Therefore, for simplicity of exposition, in the next section we present the analysis based on the the off-peak -baseload- prices for different markets.

Table 1: Summary statistics: spot, auction and future (6 months average), 2011-2014

Variable	Obs	Mean	Std. Dev.	Min	Max
Spot price	52,602	45.59	15.97	0	113.92
Spot price (Base)	41,642	44.12	15.85	0	110.00
Spot price (Peak)	10,960	51.18	15.17	0	113.92
Auction price (Base)	28,460	52.18	4.41	45.41	61.83
Auction price (Peak)	28,460	57.84	4.24	51.95	67.99
Future (6m, Base)	52,602	48.91	4.15	41.41	54.97
Future (6m, Peak)	52,602	54.08	3.99	46.12	59.97

Spot price peak hours: 17-21. All the other hours are off-peak.

### 3.1 Calibration and Simulation

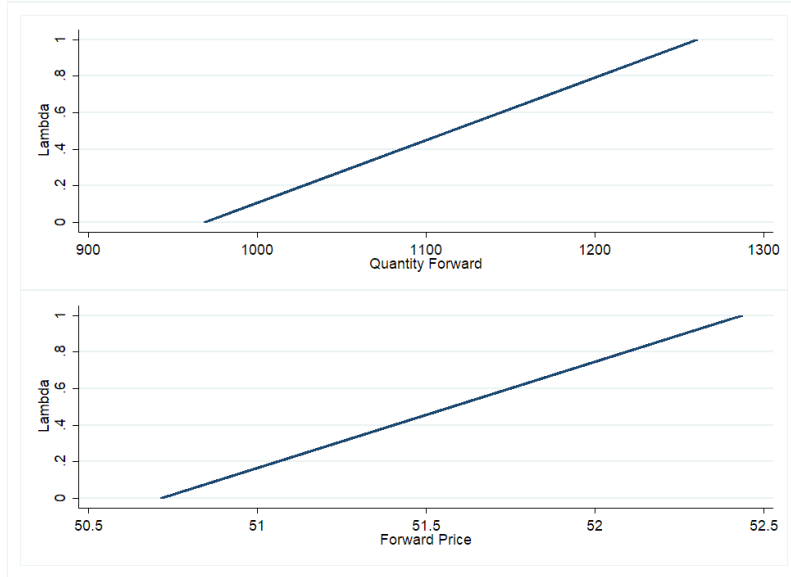
To calibrate the model on the Spanish market, we solve Eq. 19 replacing the values of  $p_R$ ,  $p_W$  and  $p_F$  as in Table 1 and constraining the value of  $\lambda$  between 0 and 1.<sup>6</sup> We initially assume the

<sup>6</sup>We draw 1000 replications assuming that  $\lambda$  has a uniform distribution. We then derive the value of the parameter  $A$ , which in our model reflects the propensity to risk of the firms and has an average value of 0.003.

number of producers equal to 9, which represented 86% of total generation (CNMC, 2016), and the number of retailers equal to 5, which covered 97% of the households demand (CNMC, 2014a).

Figure 4 shows that the quantities traded in the future market increases with  $\lambda$ . The more the loss aversion increases, the more the consumers want to be insured against spot price volatility, opting for a fixed tariff  $q_R$ . As  $q_R$  is positively related with the quantities the retailers buy on the forward market, liquidity in that market increases with lambda. The same holds for the forward price.

Figure 4: Effects from changes in the loss aversion

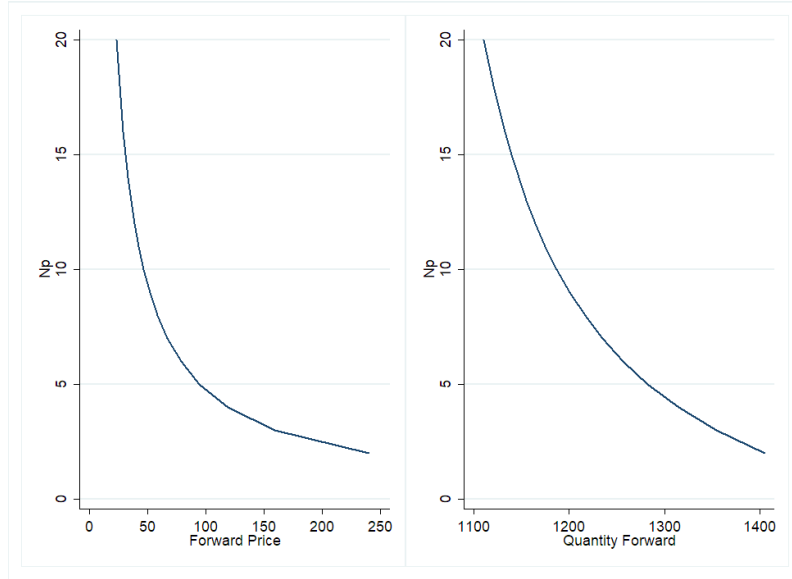


The link between the value of  $\lambda$  and the quantities traded in the forward market is particularly interesting. Our model highlights that if consumers opt for the spot price (with  $\lambda=0$ ), quantities in the forward market do not go to zero, but reach their minimum level. This is because producers need to hedge their position in the forward market against the changes in the variance and the skewness of the spot prices, so this market does not disappear, but may experience significant reduction in liquidity. Many works (Allaz and Vila (1993), Wolak (2000), Liski and Montero (2006) among others) highlight how forward markets help keeping the competition in the spot market high. Our results show that if consumers preferences point to spot pricing, liquidity in the forward market decreases. This, in turn, may represent a challenge for the competition in the spot market, which is usually characterized by a small amount of producers and retailers (as in the Spanish case).

To mimic the effects on the forward market of different producers and retailers, we also investigate the effects of a shock on the number of producers and retailers. We run 1000 replications in which first the number of producers ( $N_p$ ), then the number of retailers ( $N_r$ ) varies between 2 to 20. Figure 5 and 6 show the effects of those shocks on the prices and the quantities traded in the forward market.

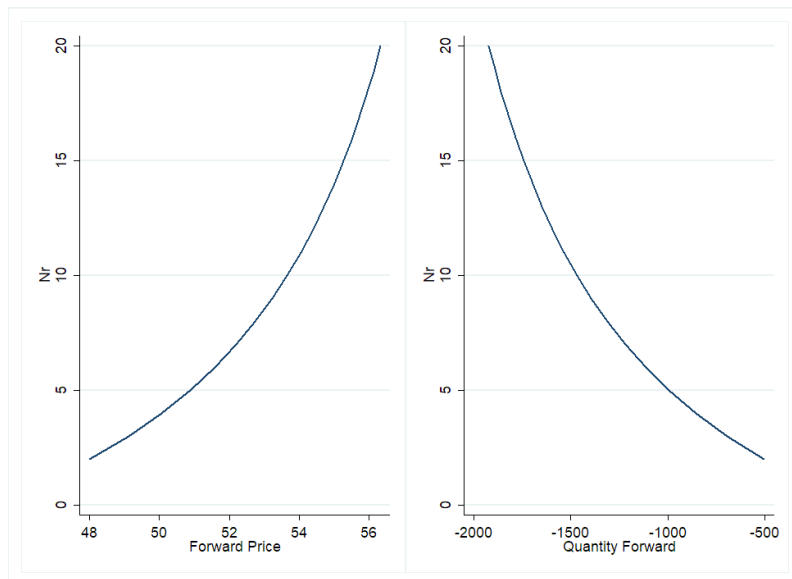


Figure 5: Effects from changes in the number of producers



An increase of the number of producers decreases the forward price but less than proportionally. Also, the rise of the number of producers (and the retailers) has a positive effect on the quantity traded in the forward market. Eq. 6 shows that the number of producers is negatively related with the spot price (i.e. an increase of the number of producers reduces the spot price). Thus our results show that when  $\lambda$  is close to zero, and consumers buy electricity at the wholesale price, competition in both the wholesale and the forward markets may be kept high by increasing the number of producers.

Figure 6: Effects from changes in the number of retailers



Retailers buy in the forward market (so quantities are negative). The highest the number of retailers participating in the forward market, the more the quantities traded. However, changing the number of retailers without changing the number of producers does not reduce the forward

price.

## 4 Conclusion

This paper develops a theoretical model to study the relations between loss-averse consumers, retailers and producers, both in the spot and in the forward markets. Consumers in our model may choose between fixed tariffs and the spot prices to pay for their electricity bills.

The model is calibrated on a real market case (Spain), where in 2014 the National Regulation Authority moved the consumers that were not with a specific electricity provider from a fixed tariff to the spot price. The announcement of the change in the tariff scheme together with the debate on electricity prices increased the interest of Spanish consumers for the spot tariffs. We develop a model to analyse how the consumer's choices between fixed and spot tariffs affect the other agents. We then simulate the behavior of the agents in the two markets, which depends on consumers loss aversion and the number of producers and retailers.

Our model confirms the results of Bessembinder and Lemmon (2002), as the forward price is positively linked to the expected spot price, its variance and skewness. As our analysis extends their model to the case of loss-averse consumers, we were able to identify how the loss-aversion parameter interacts with the variable of the model. In particular, the loss-aversion of the consumers is crucially linked with the liquidity of the electricity traded in the forward market. Loss averse consumers increase the liquidity in the forward market, as the quantities the retailers buy and the producers sell in the forward market are positively related with the degree of consumers' loss aversion.

Our model also highlights that the quantity of electricity the retailers sell forward is negatively related with the skewness of the spot prices. On the contrary, quantity sold forward by producers are positively related with the skewness of the spot prices (high probability of getting high prices increase the forward sale) and with the total market demand.

The number of retailers and producers are also important in determining the price levels and the quantity traded both in the spot and in the forward markets. In both the markets, the number of producers is negatively related with the price levels, so increasing the number of producers reduces both the spot and the forward prices.

Consumer's preference should carefully be taken into account in order to avoid unintended consequences in electricity markets. Indirect effects on the spot price caused by changes in preferences for the real-time tariffs may be offset by increasing the number of producers in the market. However, the role of forward markets in the near future should be examined as changes in the market design may change the role of these markets significantly.

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