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Application of Real Options Theory to the Assessment of Public Incentives for Onshore Wind Energy Development in Spain

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ABSTRACT

This paper discusses the important development of electricity production from renewable energy in Spain. The regulatory framework has played a key role in this process, particularly the 661/2007 Royal Decree of May 25. The legislation grants certain rights to promoters. These rights can be characterized as options, allowing us to utilize a significant number of theoretical and empirical studies in the field of financial option pricing in our analysis. Insofar as these derivative assets have underlying real and non-financial assets (i.e., a wind farm), the rights provided for in Royal Decree 661/2007 can be considered real options. In this paper, a method is proposed to evaluate investment projects in Spanish wind power based on the Royal Decree. The value of these projects is certainly affected by the real options contained in the Royal Decree. Finally, public aid granted by the administration for the development of renewable energies is evaluated.

Keywords: Real Regulatory Options, Renewable Energy, Project Valuation
JEL Classifications: C63, H43, H54, H71, L51, L94, L98

1. INTRODUCTION

Over the last 10 years, electricity generation from renewable sources has grown by more than 40% in Spain. In 2009, renewable technologies accounted for approximately 25% of total electricity generation. Furthermore, renewable energy accounted for 12% of gross final energy consumption.

The development experienced in Spain has been one of the most significant internationally and has been made possible through an established regulatory framework for renewable energies.

This article presents a methodology for evaluating investment projects in Spanish wind power through application of the theory of real options, based on the Royal Decree 661/2007 of May 25, which creates a special regime for regulating energy production activity.

Royal Decree 661/2007 was repealed in January 2012, but it remains highly useful for our analysis because the development of renewable energy in Spain has been among the most significant in the European Union, motivated primarily by the real options contained therein.

This article is motivated by the importance of renewable energies in the context of electricity generation in Spain, both presently and in the future.

Moreover, there remains a gap in the literature on project evaluation in relation to the role of real regulatory options. Along these lines, this paper offers as a novel contribution the application of real options theory to the evaluation of public support for developing renewable energy.

The objectives of this article are the following:

- Identifying existing real options in RD 661/2007 to regulate the production of electricity under the special regime

- Assessing existing real options in a 50 MW wind farm investment project
- Analyzing the impact of regulatory real options on the real value of the project under review.

This paper is organized as follows. In Section 2, the literature on project valuation with real options is reviewed. Section 3 analyzes the regulatory framework in Spain for projects to generate renewable energy. Section 4 presents the project characteristics to be evaluated and the main uncertainties of the project. Section 5 identifies and evaluates the real options in the regulatory framework. Section 6 presents the results of the project evaluation, and Section 7 presents the results of the public subsidies. Finally, Section 8 presents the conclusions.

2. SCIENTIFIC LITERATURE IN THE FIELD OF REAL OPTIONS

Real options theory is mainly inspired by the theory of financial options. The field of research and the use of financial options has undergone tremendous progress in the 30 years since the evaluation methodology developed by Black and Scholes (1973), as well as the work presented by Merton (1973) and Cox et al. (1979), among others, was reported. The term "real option" was first used in an article by Myers (1977) in which he describes the evaluation of non-financial assets using option theory. Real options theory was developed by Brennan and Schwartz (1985), Pindyck (1988), and Dixit and Pindyck (1995), among others.

The first applications of real options arose in the area of investment in non-renewable natural resources (Tourinho, 1979; Brennan and Schwartz, 1985; McDonald and Siegel, 1986; Pindyck, 1988; Paddock et al., 1988; Bjerksund and Ekern, 1990; Trigeorgis, 1990; Laughton and Jacoby, 1991; Ingersoll and Ross, 1992; Cortazar and Schwartz, 1993; Smit, 1997).

The majority of applications of real options in the electricity market context has been in the field of electricity generation. Several papers have been published in the area of nuclear generation (e.g., Gollier et al., 2005; Rothwell, 2006). The technique of real options is also employed in deciding which technology to implement in the construction of power plants (Botterud et al., 2005; Murto and Nesse, 2002; Näsäkkälä and Fleten, 2005; Abadie and Chamorro, 2005; Sekar, 2005; Alstad and Foss, 2003; Caminha et al., 2006; Wang and Tao, 2003; Botterud, 2004; Murto, 2003) as well as in renewable generation (Venetsanos et al., 2002; Davis and Owens, 2003; Siddiqui and Marnay, 2007; Menegaki, 2008; Kumbaroglu and Madlener, 2008; Fleten et al., 2007; Bøckman et al., 2008; Boomsma et al., 2012; Lamothe and Mendez, 2006; Fernandes et al., 2011; Reuter et al., 2012). The application of the real options technique in the field of power transmission has been covered by Saphores et al. (2002), Hedman et al. (2005), Boyle et al. (2006) and Wijnia and Herder (2005).

However, the abovementioned studies and other similar contributions emphasize the evaluation of projects that consider the ownership of real options in the hands of project developers but do not consider the real impact of regulatory options that are available to the administration's regulatory authority. In this area, we should mention the contributions made by Monjas and Balibrea (2013; 2014). It is precisely in this area that this article aims to contribute.

3. REGULATORY FRAMEWORK FOR RENEWABLE ENERGY IN SPAIN

Royal Decree 661/2007 of May 25, which regulated electricity production activity under a special regime, established a new compensation structure for renewable energy plants to achieve the 2010 objectives contained in the 2005-2010 Renewable Energy Plan.

In Article 24, RD 661/2007 established that selling all or part of the net electricity produced required operators of installations covered by this royal decree to choose, for periods not exceeding 1-year, between giving electricity to the system through the transmission or distribution network, receiving a regulated rate, or selling electricity on the market under an electricity production price schedule that would result in a daily market, supplemented where appropriate by a premium.

Under Article 25 of RD 661/2007, the regulated tariff consisted of a fixed amount to be determined depending on the category, group and subgroup to which the installation belongs, as well as its age based on the date of its commissioning.

In Article 27, the premium was defined as an additional cost to the schedule price that varied daily depending on the reference market price. A reference premium and upper and lower limits for the sum of the market price reference and benchmark premium were fixed and had to be the sum of the upper and lower limits.

Article 30 stated that the facilities had chosen the option of the selling price from the National Energy Commission, which was the difference between the net energy actually produced, valued at the price of the regulated rate that corresponded to them, and the amount calculated by the operator market and system operator, and the corresponding supplements. For their part, the facilities had chosen the option to receive wholesale market prices from the National Energy Commission, the share of premiums and allowances that would apply.

Onshore wind was classified into Group b.2.1., and tariffs, premiums and upper and lower limits were set in the RD 661/2007 as shown in Table 1.

Royal Decree 1/2012 of January 27 was later approved, which proceeded to suspend pre-allocation procedures and the removal of economic incentives for new production facilities electricity from cogeneration, renewable energy and waste. This measure was intended to provide a resolution to the problem of a high electricity tariff deficit in the system in a more favourable environment.

In adopting the measure as a matter of urgency, the government chose to limit its scope to the special regime facilities that had

Table 1: Values of tariffs, premiums and upper and lower limits for onshore wind, established in Royal Decree 661/2007 (January 2011)

Group	Subgroup	Term	Regulated tariff c€/kWh	Premium reference c€/kWh	Upper limit c€/kWh	Lower limit c€/kWh
b. 2	b. 2.1	First 20 years	7.9084	3.1633	9.1737	7.6975
		Thereafter	6.6094	0.0000		

Source: Royal Decree 661/2007

not yet obtained registration in the pre-allocation register, save for those cases in which this circumstance was the result of a breach of the relevant period of resolution by the administration.

Similarly, with respect to the installations of the ordinary regime, which were not subject to a pre-allocation mechanism, it was decided that the scope of the measure would be limited in terms that excluded its impact on investments executed.

This Royal Decree kept the remuneration regime legally fixed for installations in operation and those that would have been registered in the pre-allocation register.

4. THE GENERAL CHARACTERISTICS OF THE PROJECT

4.1. Project Specifications

The investment project is a hypothetical wind farm with an installed capacity of 50 MW. It is not a specific project but rather a generic project that corresponds to the most common type of wind farm.

The wind turbine chosen for the production model considered in this article is the Bazán-Bonus 1.3 MW model. Assuming the installation of 38 wind turbines, the net installed capacity is 49.4 MW.

The construction of the wind farm is expected to begin in 2015, with a start-up date the following year.

We hypothesize that the investment cost is 1,250,000 euros per installed MW, i.e., 62,500,000 euros in total, and that park exploitation costs will exhibit annual incremental increases with their respective consumer price indexes (CPIs). For the start-up date (2016), the exploitation costs are as follows:

- Operation and maintenance costs amount to 1,871,000 €/year
- Staffing and insurance costs amount to 422,500 €/year
- Site leasing costs amount to 100,000 €/year.

We assume a period of 1-year for the completion of work and 25 years for the amortization of fixed assets.

4.2. Analysis of Project Uncertainties

The following uncertainties are considered in this work:

1. Price of electricity
2. Electric power produced.

4.2.1. Price of electricity

As we explain below, before analyzing the price formation in the daily electricity market, it is important to distinguish between the following concepts:

1. The market price of electricity
2. Remuneration for wind energy.

1. The electric power companies must submit daily bids to sell their electricity in the wholesale markets that are organized by the electricity market operator. Tenders intersect with the simultaneous demands made by marketers, distributors and some large consumers. The matching of supply and demand allows operators to set the price of electricity. The result is the price on the electricity market
2. The remuneration of wind power can be calculated using two policy instruments: (a) A feed-in tariff system, and (b) a feed-in premium system. Both systems involve a reward for the production of electricity from renewable sources.

The feed-in tariff represents the establishment of a single regulated tariff, which includes a premium. This tariff is expressed in euro cents per kilowatt-hour. The feed-in premium consists of a premium or surcharge that supplements the resulting market price of electricity. This premium is expressed in euro cents per kilowatt-hour.

To determine the value of real regulatory options and public support for the production of electricity from wind in this project, we use the concept of compensating for wind energy using either the feed-in tariff or the system feed-in premium.

4.2.1.1. The market price of electricity

We assume that the evolution process for the electricity price is a mean reversion continuous stochastic process with trends and jumps. This process can be interpreted as the result of adding a normal random variable with variance proportional to the interval under consideration, Δt, to the average value of the variable and then adding a Poisson process, $\eta\varphi$, to the result. Diffusion processes with Poisson jump models are widely used in financial and electricity price modelling (Deng, 2000; Duffie et al., 2000). This mixed process is also called the jump-diffusion process. To model jump events with Poisson distributions, we need two inputs: Jump frequency and jump size. The first specifies how many times jumps occur over a given time period, and the second one determines how large a jump is if it occurs.

The function of the jump-diffusion process is specified in the following formula, used in Monjas and Balibrea (2013; 2014).

$$Y_t = Y_{t-1} - b * (Y_{t-1} - [aX + c]) + \varepsilon * \sqrt{\Delta t} * \sigma + \eta\varphi, \quad (1)$$

Where,

Y_t = The simulated value of the variable in year t

Y_{t-1} = The simulated value of the variable in year $t-1$

b = The adjustment velocity with which the expected value of the variable Y_t is approximated (or the percentage difference between the value of Y_t and its expected value eliminated at each period of time). Therefore, if the value of Y_{t-1} is greater than the mean expected value, then the value of Y_t will likely be smaller than the expected value.

aX+c = a straight regression line obtained with the observed data of the variable, which shows the trend to be followed by the simulated values.

Δt = time interval (1-year)

σ = The observed standard deviation of the variable trajectory data

ε = A random value N (0,1)

A Poisson process is defined as φ η.

η = Indicates whether the Poisson jump occurs in year t, taking a value of 1 or 0: 1 if the magnitude of the jump exceeds a certain value and 0 otherwise.

φ = Random value defining the magnitude of the Poisson jump (φ).

The variables ε and φ are calculated by applying the inverse normal distribution function.

The simulation of the considered variables is discussed in the next section.

Table 2 shows the historical price of electricity in the spot market managed by Operador del Mercado Ibérico de Energía.

Figure 1 displays a simulation of the evolution of hourly matching prices corresponding to the daily market for electricity, i.e., the prices of the "pool" over the lifespan of the project until 2040, after the application of formula (1).

In Figure 2, the thick solid line represents the evolution of real electricity prices in Spain, and the thin solid line shows the linear trend of the previous function. Moreover, the thick dashed line represents the simulated evolution of the average electricity price throughout the lifespan of the project after 5000 simulations using formula (1), whereas the dashed line represents the linear trend of the previous simulation.

In fact, via Monte Carlo simulation, we have successfully reproduced the values of the observed variable.

4.2.1.2. Remuneration of wind energy

We obtain the annual remuneration of wind energy for the useful life of the project using the following elements:

1. Feed-in tariff:
   a. Tariff price: according to RD 661/2007
   b. Complement to reactive power, which is a percentage (4%) of € 78.441/MWh
   c. Average cost of production deviation penalties
   d. Selling agent fees.

We obtain the price by the formula $a + b - c - d$.

2. Feed-in premium:
   a. Daily market price of electricity (pool)
   b. Premium benchmark: The amount of the market premium in cents per kilowatt-hour for directly sold electricity that is actually fed into the grid system
   c. Complement to reactive power, which is a percentage (4%) of € 78.441/MWh
   d. Average cost of production deviation penalties: 1.80 €/MWh
   e. Selling agent fees: 0.30 €/MWh.

We obtain the price by the equation $a + b + c - d - e$.

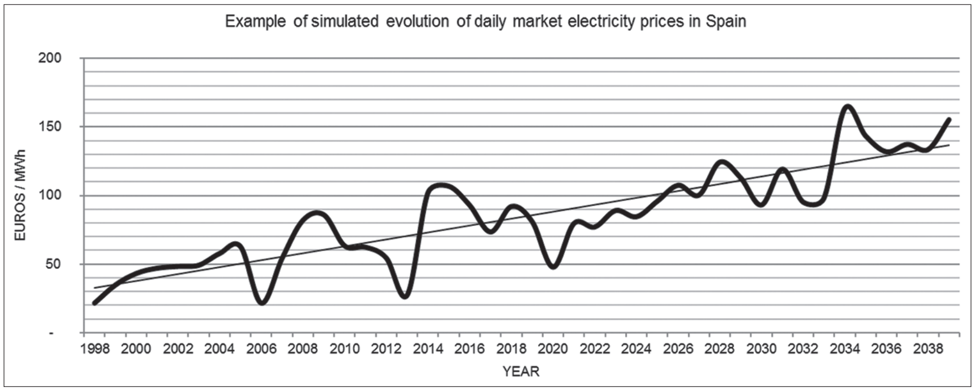
Figure 3 shows the evolution of the different prices over the lifespan of the project; the Y-axis represents €/MWh, and the X-axis represents calendar years.

Table 2: Historical price of electricity in Spain

Year	Average annual price (€/Mwh)
1998	25.61
1999	26.74
2000	31.83
2001	31.27
2002	38.67
2003	30.05
2004	28.73
2005	53.63
2006	50.67
2007	42.19
2008	64.44
2009	37.57

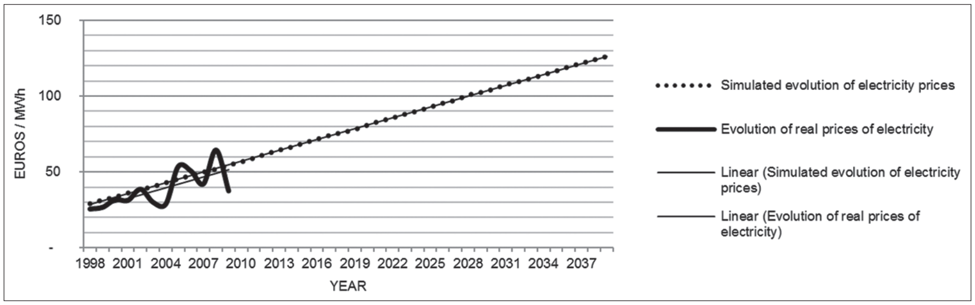
Source: http://www.omel.es

Figure 1: An example of the simulated evolution of the daily market electricity prices in Spain



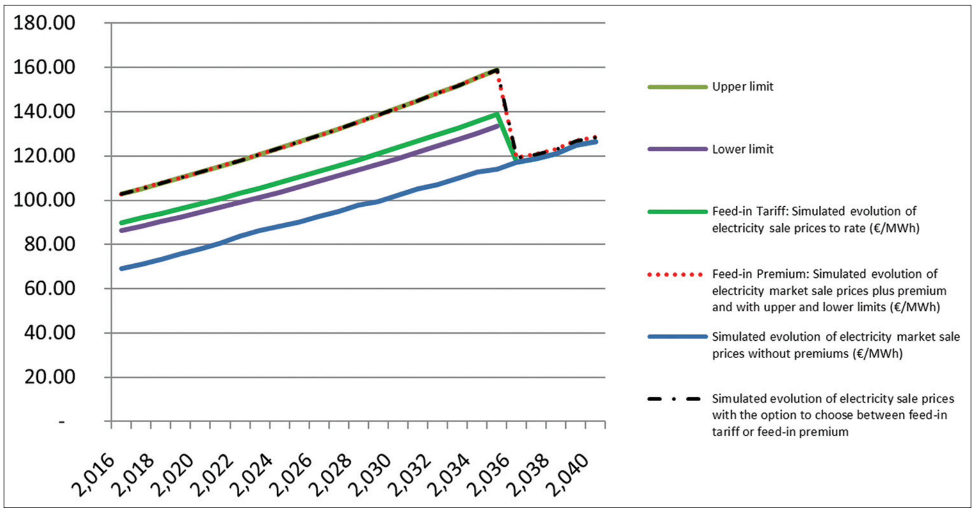
Source: Own elaboration

Figure 2: Simulated evolution of electricity prices in Spain



Source: Own elaboration

Figure 3: The simulated evolution of electricity market sale prices in Spain



Source: Own elaboration

Figure 3 shows that higher prices correspond to market prices plus premiums and to upper and lower limits. These values coincide with the simulated evolution of electricity sale prices with the option to choose between feed-in tariff and feed-in premium. The Figure 3 shows the sharp decline suffered in 2035 due to the elimination of premiums, according to the provisions of Royal Decree 661/2007. This feature reflects the effect of the upper limit on market prices plus premiums, preventing their growth during the years in which they are in force. Figure 3 also shows that the lower limit has no effect on market prices plus premiums because they are always above a certain threshold throughout the entire life of the project.

4.2.2. Electric energy produced

We use wind measurements to obtain the production of electricity. We assume a set of wind frequencies for each range of velocities and for each of the 12 months of the year (Table 3).

It is accepted that the wind speed can be modelled using a Weibull distribution (Carta et al., 2009; and Kollu et al., 2012). We use the empirical values of wind speed to model the Weibull random variable, from which we can obtain random values of the power production of wind turbines used in the simulation model.

We assume that the evolution process for the uncertainty in wind speed at a given site is generally described using the Weibull distribution. The equation for the cumulative distribution function of Weibull is given by:

$$F(x) = 1 - \exp(-(x/\beta)^{\alpha}) \quad (2)$$

Where,

- x: The measured variable, which in our case is the wind speed
- α: The form factor of the distribution function $F(x,\alpha,\beta)$
- β: The scale parameter of the distribution function $F(x,\alpha,\beta)$.

We use the wind frequency table to model the random variable wind speed, and from this variable, we obtain the wind farm's annual electricity production. This random annual electricity production is the one considered in the simulation model. It is understood that the greater the number of simulations performed, the greater the number of values and therefore the better the accuracy of the results will become.

We obtain the P percentiles of the distribution of frequencies. Because a percentile P is the value of the variable to be observed that is below a given percentage, these percentiles can be assimilated into the values of the distribution function:

$$F(x) = P(X \leq x) = P \quad (3)$$

Table 3: Wind frequencies

Velocity (m/s)	January (%)	February (%)	March (%)	April (%)	May (%)	June (%)	July (%)	August (%)	September (%)	October (%)	November (%)	December (%)
Calm	2.1%	1.5	0.6	2.2	3.1	1.8	3.2	2.0	2.2	2.0	1.2	1.1
0-2.57	2.9	3.5	1.8	2.1	5.0	3.7	4.3	6.1	9.9	2.3	2.3	1.6
3.08-5.14	2.1	3.0	3.9	2.6	8.5	12.9	18.8	21.4	18.2	5.1	4.5	3.5
5.65-7.71	62.1	64.5	42.8	48.8	44.7	48.2	44.6	41.5	39.7	35.0	38.2	38.1
8.23-10.28	16.4	17.5	35.6	36.4	37.4	32.4	29.0	28.4	29.6	41.9	32.9	31.1
10.8-12.86	8.5	7.0	14.0	5.6	1.2	0.6	0.1	0.3	0.2%	12.6	12.5	22.1
13.37-15.43	5.5	1.2	1.2	2.3	0.1	0.4	0.0	0.2	0.1	0.7	8.1	2.3
15.94-18	0.4	1.8	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.4	0.3	0.2
18.52-20.57	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Own elaboration

The variation of the wind at a given site is usually described using the Weibull distribution (2).

The simulation process requires the generation of data similar to those occurring in actual cases, which requires the ability to generate random variables. The particular algorithm to be used will depend on the distribution to be generated, but generally, it involves the following steps:

1. Generate one or more random numbers
2. Create a distribution-dependent transformation
3. Obtain *x* from the desired distribution
4. Introduce these values of velocity into the power curve to obtain the daily electricity generated in MWh.

We consider 1-day as the time interval for producing electricity, and we also make the assumption that for each day of the month, the velocity frequency distribution is identical.

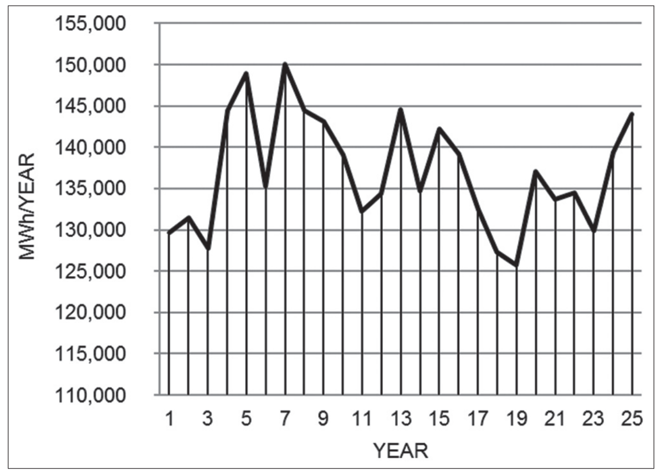
Using the daily simulated wind velocity data, we obtain the output of the wind turbine power curve for each day. Adding the output of each day, we obtain the monthly production, and by summing the output for all months of the year, we obtain the annual production.

The wind farm plant comprises up to 38 wind turbines; if we multiply the annual output of a wind turbine by the number of turbines that make up the plant, we obtain the plant's annual output.

The annual average wind speed that we obtain is 7.8 m/s. This value is the average speed of 5000 iterations performed using a Monte Carlo simulation. Figure 4 shows an example of a simulation of the annual electric output of a wind farm plant.

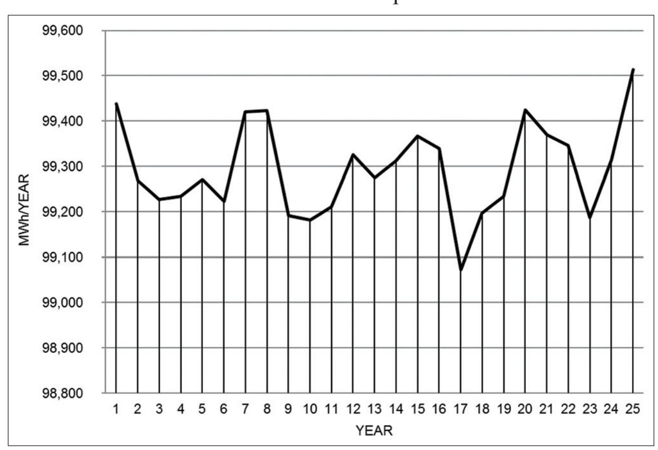
Figure 5 shows the evolution of the simulated average electricity output of the wind farm park throughout its useful life over 5000 simulations. The average annual electricity production of the park obtained by applying the Monte Carlo method is 99.295 MWh/year.

Figure 4: An example of a simulation of the annual electric output of a wind farm plant



Source: Own elaboration

Figure 5: Evolution of the average electric energy output production of the wind farm park



Source: Own elaboration

5. VALUATION OF REAL OPTIONS CONTAINED IN THE ROYAL DECREE 661/2007

The remuneration system of RD 661/2007 included a regulatory real option. The existence of a real option was rationalized as follows.

Royal Decree 661/2007 created the possibility that a promoter could sell its electricity at regulated tariff prices (feed-in tariff system) every year. At the same time, Royal Decree 661/2007 allowed for a promoter to choose to sell its electricity at a premium over market prices (feed-in premium system) every year. In addition, in this case, the upper and lower limits of the selling price of electricity were fixed.

In other words, there was a regulatory real option consisting of a choice at the end of each year between the feed-in tariff system and the feed-in premium system for sales of electricity during the following year. This system can be treated as a series of European put options held by the promoter. European options are exercisable only at the date of expiration, e.g., at the end of every year.

We can calculate the value of this option by the following expression:

Option value = Max (NPV with the option to choose between feed-in tariff or feed-in premium - $NPV_{\text{with tariff price}}$; 0).

Where,

- Net present value (NPV) with the option to choose between feed-in tariff or feed-in premium. This price is simply the result of choosing the tariff price or the market price plus the premium, depending on which has obtained a higher average over the previous year. In other words, the approach followed is to assume that with the information of year $t-1$, the promoter chooses the price for year t such that if in year $t-1$ the market price plus premiums is higher than the rate, at the beginning of year t the market price plus premiums and vice versa is chosen
- NPV with tariff price. This price is simply the tariff price.

To calculate the NPV values that compose the option, we apply the Monte Carlo method and perform 5000 simulations of each NPV. We seek the average value of these 5000 values.

In these simulations, the values of the uncertainties studied are randomly changed. For each combination of values, we obtain a value for NPV.

The discount rate used to calculate these NPV values that we will use to calculate the options is the risk-free rate (r_f), which is 4.13%. We consider the average profitability of the Spanish Government Bonds over 10 years during the period 2003-2013 (Source: http://www.investing.com/rates-bonds/spain-10-years-bond-yield-historical-data).

We assume that the growth rate of operating costs coincides with the CPI, and according to the Royal Decree, the growth rate of tariffs, premiums and upper and lower limits is as follows:

- To 31/12/2012: CPI - 0.25 basis points
- Thereafter: CPI - 0.5 basis points

The CPI we have remains unchanged throughout the life of the project. The value we adopt is 2.815%, which is the average of the harmonized indices of consumer prices (HICP) in the Spain series from 2001 to 2012. HICP values from 2001 to 2012 are reflected in Table 4.

Table 5 shows the results obtained for the average values and standard deviations of the NPV obtained with different prices and the risk-free rate.

Thus, the value of the option held by the promoter is as follows:

Option value = Max (NPV with the option to choose between feed-in tariff or feed-in premium−$NPV_{\text{with tariff price}}$; 0) = Max (80,753,389 €−68,050,725 €; 0) = 12,702,664 EUROS

The shaded area in Figure 6 represents the value of the option.

6. PROJECT VALUATION

The project value is obtained by incorporating the option values to the NPV without flexibility. This NPV will be called NPV_{EXTENDED}. Thus, the NPV_{EXTENDED} for this project is

$$NPV_{\text{EXTENDED}} = NPV_{\text{without flexibility}} + \text{Option value}$$

The value of NPV without flexibility coincides with the value of NPV with the tariff price. This value is obtained from the cash flows generation dynamic model by applying the Monte Carlo method over 5000 simulations. The value we seek is the average value of these 5000 values. The discount rate used is the weighted cost of capital, or weighted average cost of capital (WACC), of the project. The WACC of the project is 5.57%.

Table 6 shows the results obtained for the average values and standard deviation of the NPV obtained with the tariff price and the WACC.

Considering the calculated option value, the NPV_{EXTENDED} of the project for the promoter is $NPV_{\text{Extended}} = NPV_{\text{without flexibility}}$ + Option value = 54,138,416€ + 12,702,664€ = 66,841,079 EUROS

Table 4: HICP

Year	HICP (%)
2001	2.507
2002	4.027
2003	2.685
2004	3.277
2005	3.722
2006	2.716
2007	4.286
2008	1.455
2009	0.893
2010	2.861
2011	2.356
2012	2.998
Average	2.815

Source: http://es.global-rates.com, HICP: Harmonized indices of consumer prices

Table 5: Average values and standard deviations of the NPV and risk-free rate rf

NPV with different prices	Average (€)	SD (€)
Values with tariff price	68,050,725	1,170,576 €
Values with the option to choose between feed-in tariff or feed-in premium	80,753,389	3,194,004

Source: Own elaboration, NPV: Net present value, SD: Standard deviation

Table 6: Average values and standard deviation of the NPV obtained with tariff price and WACC

NPV	Average (€)	SD (€)
Values with tariff price	54,138,416	1,048,304

Source: Own elaboration, NPV: Net present value, SD: Standard deviation, WACC: Weighted average cost of capital

7. VALUATION OF PUBLIC SUBSIDIES

There is a subsidy from the administration on behalf of the promoter. Limits on the premiums moderate the value of this subsidy.

Thus, the value of public aid granted by the administration can be calculated as the value of the NPV with the option of choosing between feed-in tariff or feed-in premium minus the NPV obtained by applying market prices without premiums and without upper and lower limits:

$$\text{Public Subsidies} = \text{NPV}_{\text{with the option to choose between feed-in tariff or feed-in premium}} - \text{NPV}_{\text{with market prices without premiums}}$$

These values are obtained from the cash flows generation dynamic model, applying the Monte Carlo method over 5000 simulations. The values we seek are the average values of these 5000 values. The discount rate used to calculate these NPV is the risk-free rate (r_f), which is 4.13%.

Table 7 shows the results obtained for the average values and standard deviation of the NPV obtained.

Public subsidies = 80,753,389 €−43,021,455 € = 37,731,934 EUROS

Table 8 shows the value of public subsidies for this project. The values of these aids are expressed in euros and in euros per megawatt-hour produced throughout the 25 years life of the project, considering that the cumulative production of the park over its 25 years life is 2,482,373 MWh.

The shaded area in Figure 7 represents the value of the public subsidies.

Table 7: Average values and standard deviation of the NPV obtained with different prices and risk-free rate rf

NPV with different prices	Average (€)	SD (€)
Values with the option of choosing between feed-in tariff or feed-in premium	80,753,389	3,194,004
Values with market prices without premiums	43,021,455	7,335,337

Source: Own elaboration, NPV: Net present value, SD: Standard deviation

8. CONCLUSIONS

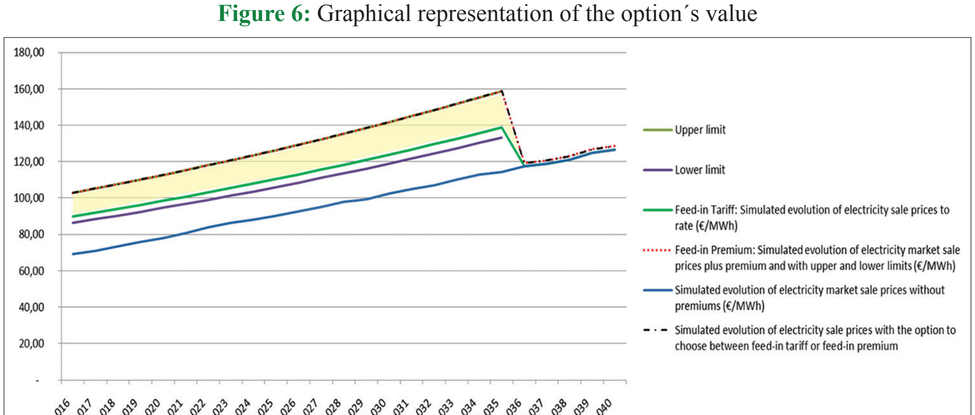
- The existing real option in Royal Decree 661/2007, as it applies to the case of a wind farm, was valuated in this article, representing an original contribution to the relevant literature
- The option held by the promoter increases the value of the project
- The approach used in this study, i.e., the use of real options, can provide decision support to private developers, allowing them to gauge the effect of a decrease or increase in incentives on the feasibility of projects
- The methodology developed in this work is very useful for policymakers because it can help them design effective policies to support renewable energy
- The use of regulatory real options allows the administration to gauge the a priori effectiveness of plans for the promotion of renewable energies. It also allows us to simulate a priori the economic impact of different regulatory policies and to select a priori the most appropriate policies from the standpoint of cost and performance. Finally, the administration may modify policy incentives in running and evaluating the economic impact of such changes
- The methodology developed in this work is based on the ability to accurately identify real options present in the project, either because they are contained in legislation (as in the particular case studied in this work) or in contractual relations. When options are properly identified, the methodology developed allows for their valuation and their incorporation into the decision-making process. However, there may be provisions or ambiguous contractual clauses that give rise to the appearance of options that cannot be properly quantified. An example is Article 44.3 of RD 661/2007, which states that in the year 2010 and every 4 years thereafter, fees, premiums, supplements and the lower and upper limits defined by Royal Decree shall be reviewed by the administration, guaranteeing rates of "reasonable" profitability with reference to the cost of money in the capital market. This type of provision creates

Table 8: Values of public subsidies

Public subsidies	Average (€)	Average(€/MWh)
Public subsidies	37,731,934	15.20

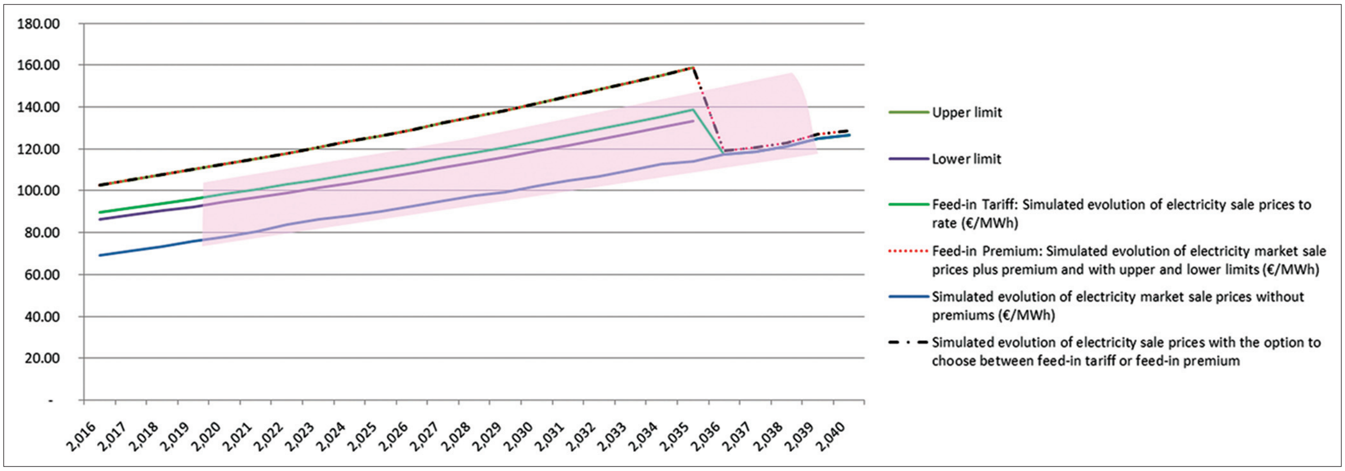
Source: Own elaboration

Figure 6: Graphical representation of the option´s value



Source: Own elaboration

Figure 7: Graphical representation of the public subsidies



Source: Own elaboration

certain options, in this case, on behalf of the administration, and is impossible to quantify due to the indeterminacy of the concept of "reasonable rates of return."

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