ANALYSING THE ECONOMIC IMPACT OF THE NEW RENEWABLE ELECTRICITY SUPPORT SCHEME ON SOLAR PV PLANTS IN SPAIN

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Abstract

A complex regulatory package implementing a new support scheme for renewable electricity has recently been adopted in Spain as a response to escalating support costs, which have mostly been related to solar PV promotion. The new remuneration scheme can be considered retroactive and negatively affects the profitability of existing solar PV plants. The aim of this paper is to analyse the implications of the new retroactive regulation on the profitability of those plants in Spain. Using real data from a very common PV plant, the results show that, indeed, the new support scheme has a considerable impact on the cash-flows of those plants. However, our simulations also show that the degree of reduction in the internal rates of return critically depends on several factors, assumptions and scenarios.

Key words: solar PV, cost-containment, new regulation, retroactivity, Spain.

I. Introduction.

A recent regulatory package has led to the implementation of a new scheme for the promotion of electricity from renewable energy sources (RES-E) in Spain, which has involved a substantial rupture with the pre-existing system. A main feature of the new scheme, which was passed in 2014, is its retroactivity, i.e., it applies to existing plants which were subject to the previous regulation (either the Royal Decree (RD) 661/2007 in 2007 or the RD 1578/2008 in 2008). Those plants had already suffered retroactive cuts due to cost-containment measures adopted between 2010 and 2013 (see [1] for details). The aim of this paper is to analyse the implications of the new retroactive regulation on the profitability of solar PV plants in Spain.

Indeed, the promotion of RES-E in Spain has received a lot of attention in the past, given the significant increase in the deployment of RES-E in general and solar PV in particular, which was mostly a result of stable and generous feed-in regulations. Some articles are devoted to the analysis of the public promotion of RES-E in Spain ([2] [3] [4] [5] [6] [7]), whereas others have specifically focused on solar PV ([8] [9] [10] [11] [12]).

Spain has also received worldwide attention due to the implementation of the aforementioned measures to contain the costs associated to this deployment between 2010 and 2013. The government was concerned about the substantial increase of RES-E support costs (see, e.g., the Special Report of the IPCC on Renewable Energy, [13]). This increase in support costs, which triggered the implementation of cost-containment measures, was mostly due to solar PV promotion, with support costs escalating more than fifteen-fold from 215 M€ in 2007 to 3267 M€ in 2013. These cost-containment measures included a cap on the electricity generation being eligible for support (Royal Decree Law 14/2010), a grid access charge (Royal Decree Law 14/2010 and RD 1544/2011), a generation charge (Law 15/2012), a shortening of the remuneration period (Royal Decree 1565/2010 and RDL 14/2010) and the updating of tariffs below the consumer price index (Royal Decree Law 2/2013). Their impact on solar PV plants has been analysed by several authors (e.g. [14] [15] [1]). However, to our best knowledge, the economic impact of the new regulation has not been researched. This paper tries to cover this gap in the literature.

The retroactive cuts of the new regulation in Spain can also be set in the context of retrospective measures directly attacking the stability and viability of existing PV installations in several EU countries in recent years (see, e.g., [16]).

Accordingly, this paper is structured as follows. The next section provides a brief background and details of the new regulation for RES-E support in general and solar PV in particular. Section 3 discusses the methodology, data and main assumptions which have been used to analyse the economic impact of the new regulation on the profitability of a solar PV plant. This analysis is carried out in section 4. The paper closes with some concluding remarks.

2. The new renewable energy promotion scheme in Spain.

2.1. The motivation for the new regulation.

The RES-E support scheme in Spain has been based on feed-in tariffs (FITs) and feed-in premiums (FIPs) since 1998, with some rather minor reforms of the whole scheme taking place in 2004 and 2007. As it is well known, FITs provide total payments per kWh of electricity of renewable origin, whereas a payment per kWh on top of the electricity wholesale-market price is granted under FIPs.

Until 2007, the trends of solar PV capacity deployment, triggered by the feed-in regulations were gradual, from less than 1MW in 1999 to 690 MW in 2007 and 3398 in 2008. However, a substantial increase was experienced between 2007 and 2008, partly triggered by the 2007 FIT reform (developed by royal decree RD 661/2007). From mid-2007 to September 2008, the Spanish PV sector experienced an investment boom, which led to a ten-fold increase in solar PV deployment. While this boom was circumscribed to the solar PV sector, it led to a substantial increase in RES-E support costs (see Table 1)[1]. A new regulation specifically for solar PV deployment was adopted in 2008. It implemented a flexible degression scheme and a capacity cap for new plants (RD 1578/2008). In addition to the economic crisis and some characteristics of the Spanish electricity market (the so-called tariff deficit, a declining electricity demand leading to excess electricity installed capacity and very limited interconnections with other countries), the concern of the government about the large increase in these support costs led to the implementation of the aforementioned cost-containment regulations, which affected all renewable energy technologies[2]. Furthermore, a

[1] For an analysis of the factors leading to this boom, see [15] [2].

[2] For a decade, the revenues (electricity prices for utilities) have been regulated and below the electricity system costs. This has led to a "Spanish anomaly", i.e., to an accumulated "tariff deficit" which at the present time amounts € 30,000 M (~3% GDP). Recently, the governments have increased electricity bills in order to reduce such deficit. Moreover, Spain is virtually an energy island, with limited interconnection or trading with neighboring countries.

moratorium on RES-E support was implemented by RDL 1/2012 and entered into force on January 2012. Plants installed later would not receive any support. Several regulations were approved in 2013 and 2014 (including RD 413/2014 which regulates the production of electricity from renewable energy sources [17]) which have put an end to this moratorium.

Table 1

The new scheme for the promotion of renewable electricity is based on four pieces of legislation: a Royal Decree Law (RDL 9/2013[3]), a Law (Law 24/2013[4]), the Royal Decree 413/2014 and the Ministerial Order IET/1045/2014 [20]. The new regulation was mostly driven by the concern of the government about the "financial sustainability of the electricity system". It is mentioned that the (previously) highly favorable support scheme as well as the reduction of technology costs led to deployment above expectations and made it necessary to correct the regulatory framework (RD 413/2014, [17 p. 43877]).

2.2. Main concepts in the new regulation.

The new legislation is based on several main concepts:

- *Reasonable profitability*. This is a main concept which is defined by RDL 9/2013 as a project profitability based on the average yield (pre-tax) of Spanish 10-year government bonds in the secondary market plus 300 basis points (i.e. 3%). The "average yield" refers to the average of the yields in the 10 years before the entry into force of RDL 9/2013 in July 2013. This profitability may be revised every 6 years. According to such calculation, the reasonable profitability level was 7.39% at the time the Law 24/2013 was passed (December 2013). This concept applies to, both, existing and new installations (i.e. it is retroactive).
- *Efficient and well-managed firm*. The reasonable profitability level is the one which corresponds to an efficient and well-managed firm. RDL 9/2013 states that according to European Community jurisprudence, this concept refers to a

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This fact, along with poor long-term planning, has resulted in the Spanish electricity system having significant excess electricity generation capacity [15].

[3] Royal-Decree Law 9/2013 which adopts urgent measures in order to guarantee the financial stability of the electricity system.

[4] Law 24/2013 of the electricity sector.

firm which is endowed with the necessary means to develop its activity and whose costs are those of a firm with a reasonable benefit. The aim is to ensure that the high costs of an inefficient firm are not taken as reference.

- *Plant type and retributive parameters*. Each installation, taking into account its main features, will be associated to a standard plant or "plant type". These plant types are defined and classified according to their technology, installed capacity and age in the Ministerial Order. The so-called reasonable profitability of the plant type will then be used to set the remuneration level for the specific plants. The most relevant retributive parameters include the remuneration for the initial investment of the plant (R_{inv}), the remuneration for the operation of the plant (R_o), the useful regulatory life, the number of minimum and maximum generation full-load hours, the functioning threshold, the annual lower and upper limits of the market price and the average annual market price[5]. The expected electricity demand levels and the general situation of the economy will be taken into account in the setting of these retributive parameters.
- *Existing installations*. Existing installations which fell under the previous support scheme before July 14th 2013.
- *Regulatory period and revisions*. The retributive parameters will be revised every six years in order to comply with the reasonable profitability principle. The first regulatory period will last from 2013 to 2018. In addition, there will also be "semi-regulatory periods" of 3 years. Revisions can also take place after each semi-regulatory period but these revisions will only apply to the estimates of the revenues of the plant types which are related to the sale of electricity at market prices.
- *Useful regulatory life*. Once the installation has exceeded its useful regulatory life (i.e., 30 years), it will not receive any support (i.e., neither support for investment nor operation). These installations may receive the electricity market price if they continue to sell their electricity in the market after their useful regulatory life has expired.
- *Competitive concurrence scheme*. This term is synonymous to "auction". This type of instrument will be used to allocate support to new plants.

[5] In addition, an incentive for investments (I_{inv}) can also be provided for "isolated electricity systems in non-peninsular territories" on an exceptional basis (art.11).

2.3. A description of the new remuneration scheme.

Under Law 24/2013, RES-E plants will receive the market price plus a "specific complementary remuneration". This means that RES-E installations would participate in the electricity market and receive the wholesale price of electricity as well as a "specific remuneration", i.e. an additional remuneration which allows these technologies to compete on an equal footing with the rest of technologies in the market. This specific remuneration will allow these technologies to cover their costs and has two elements, the remuneration for investment and the remuneration for the operation of the plant:

- The remuneration for the investment (R_{inv}) refers to a payment per kW that allows installations to recover those investment costs which cannot be recovered by the sales of electricity in the market. This payment is received during the useful regulatory life of the installation.
- The specific remuneration for the operation (R_o) refers to a payment per kWh for those technologies whose operational costs are above the average wholesale electricity price.

Therefore, the specific remuneration for RES-E plants would be the total revenues received by the plant owner (which includes R_{inv} and R_o) minus the revenues from the electricity sold in the wholesale electricity market. Formally, it can be expressed as follows:

$$TR_t = p_t \cdot q_t + SR_t = p_t \cdot q_t + R_{inv} + R_o = p_t \cdot q_t + I_t^* \cdot s + O_t^* \cdot q_t \qquad [1]$$

where,

TR_t Total revenues received by a given plant in year t (€).

p_t Annual average wholesale price of electricity (€/kWh).

q_t RES-E sold in the wholesale electricity market (kWh).

SR_t Specific remuneration received by a given plant in year t (€).

R_{inv} Remuneration for the investment of the plant (€)

R_o Remuneration for the operation (€)

I_t^* Unitary remuneration for the investment of a plant type (€/kW)

s Size (installed capacity) of the plant (kW).

O_t^* Unitary remuneration for the operation of a plant type (€/kWh).

The unitary remuneration for the investment of a plant type (I_t^*) is calculated as follows

$$I_t^* = \rho \cdot V_0^j \cdot \frac{i^*(1+i^*)^{\hat{T}}}{(1+i^*)^{\hat{T}} - 1}$$

where:

ρ is the adjustment coefficient for the plant type. It refers to the investment costs which cannot be recovered by the sale of electricity. It is calculated according to regulated criteria which include the net value of the plant and an estimate of the flows of revenues and expenditures along its useful regulatory life.

V_0^j Net value of the plant at the start of the regulatory period (*j*) for the plant type. For new plants, this value equals the initial investment of the plant type.

i^* Interest rate (average yield (pre-tax) of Spanish 10-year government bonds in the secondary market plus 300 basis points).

$\hat{T}$ Residual regulatory life, e.g., the regulatory life minus the number of years since the date of commissioning of the plant until the start of the semi-regulatory period.

ρ may have a negative value in some cases which, as indicated in the Report 18/2013 from the (formerly) National Energy Commission ([21]), is contradictory with its complementary character and, thus, with renewable energy deployment. Furthermore, such specific remuneration will only be received if the capacity of the plant is above a minimum threshold value, which is set annually by the government in a Ministerial Order (art. 31.5). The specific value of the specific remuneration for investment cannot be anticipated by potential investors, since it depends on the parameters defined for each plant type and the length of the useful regulatory life.

Since the wholesale electricity prices constantly change, an upper and a lower threshold have been set on the average annual electricity price in the daily market. If the electricity price is above the upper limit, this will lead to payment obligations for electricity generators and if the annual electricity price is below the lower limit, then generators will receive the corresponding monetary compensation. Both monetary flows are called “adjustment values”. The threshold can be revised every three years.

The scheme could be considered retroactive for existing plants, i.e. for plants being deployed before 2012 under the previous support schemes (RD 1578/2008 or RD

661/2007). The “rules of the game” for these plants have clearly changed, i.e., they are no longer subject to the remuneration conditions of RD 1578/2008 or RD 661/2007, but to RD 413/2014. The detrimental impact is particularly strong for solar PV plants, as 30% of them may have to close ([22]). The government can revise crucial parameters influencing the remuneration levels every six years, which represents a main source of risk for potential investors. Under the new regulation, investors cannot anticipate which will be the support levels after 6 years or even after 3 years regarding the estimates of the revenues of plant types related to the sale of electricity at market prices.This is likely to lead to higher capital costs, given the high risk premiums which are likely to be charged by banks[6].

3. Methods.

The analysis of the impact of the new regulation on the cash-flow and internal rate of return (IRR) of solar PV plants in Spain is based on real data of the different features of a very common PV plant. The economic flows of the plant for each year of the plant lifetime have been simulated with an excel sheet. Then, we have calculated the impact of the new regulation taking into account the reduction in support levels that it envisages. The support levels (tariffs) and the inflation rate until 2013 are observed data. Ranges of possible values for different variables were considered in the sensitivity analysis, leading to different IRR values. In particular, since the cash flows need to be projected to the future, some assumptions about those variables critically affecting the remuneration received by the plant have had to be made. The following subsections describe the data on the features of the plant (3.1), general assumptions about the plant (3.2) and data and assumptions on key regulatory variables affecting the plant (3.3).

3.1. Data on the features of the reference plant.

The plant used for this analysis (called the “reference plant”) was built in 2008. It has 99.33 kW of nominal power and is located in poor agricultural land, 25 kilometers away from the city of Lleida in Catalonia (Spain). The owners have another 9 plants which add up to 0.9933 MW. All these plants have a similar size and are close to each other. Other main features of the plant are:

[6] For an analysis of the new regulation taking into account different criteria, see [23].

- The plant is subject to RD 661/2007
- It is located in radiation zone III.
- The plant occupies 5,700 square meters of land.
- The land was bought at a market price of € 7,850.
- The length of the evacuation line is 500 meters.
- The average number of full load hours in the 2008-2012 period was 2,100 hours, with a load factor of 23.9%. Therefore, the plant generates 210,000 kWh/year (2100 times 100kW).
- The peak power of the investor component is 5% above the nominal power of the plant.
- The upfront investment for the 99.33 kW plants amounted to €639,614.31. According to the plant's managers, if this plant had been a turnkey plant, then its costs would have been 13% higher.
- 80% of the initial investment is financed with a loan at an interest rate of 6% over 12 years.
- Annual operation and maintenance (O&M) costs (including insurance costs): € 3,600. Land tax: € 30 per plant per year.
- The plant is equipped with arrays with a 2-axis tracking system.

Table 2 provides details on the different cost concepts of the plant.

Table 2

3.2. General assumptions about the plant.

The analysis is based on the following key assumptions for the plant:

- An annual degradation rate of 0.75% has been assumed, i.e., the generation capacity of the plant is reduced by 0.75% each year. PV systems are often financed based on an assumed 0.5 to 1.0% per year degradation rate [24]. According to the studies reviewed in [25] the average degradation rate is 0.7%. Therefore, we assume the middle value, 0.75, as done in [26].
- A new inverter is purchased every ten years. The inverter for the years 10 and 20 are entirely financed with a loan at a 6% interest rate.

- The costs of the inverters are shown in Table 3. Their value is added to the initial investment. The net present value is calculated with a discount rate of 2%.

Table 3

- O&M costs increase by 2% annually.
- Until 2013, the CPI has been used for the annual updating of the tariffs. We assume a 2% CPI after 2013 in the scenario without cost-containment measures[7]. This is in line with the goal of European Central Bank, which aims at inflation rates of below but close to 2% in the medium term (see www.ecb.europa.eu/mopo/html/index.en.html).
- We assume an underlying inflation rate of 1% after 2013. This can be justified since we assume a 2% CPI and the average underlying inflation rate in Spain was half the CPI between 2010 and 2012.This rate is the one used for the updating of the remuneration after 2013, according to RDL 2/2013.
- A useful life of 30 years for the plant has been assumed.
- The wholesale electricity price (pool price) for those kWh of electricity generation which are above the generation cap and, thus, are not eligible for the FITs is calculated as the average electricity price of the daily and intra-daily markets. This price is assumed constant since 2013.
- It is assumed that the residual value of the plant and its components are null.
- The decommissioning costs and the corporate tax have not been included in the calculation.

3.3. Data and assumptions on key regulatory variables affecting the plant.

- According to RDL14/2010, the remuneration of plants equipped with arrays with a 2-axis tracking system is capped to 1,707 full-load hours until 2013. The cap is increased to 2,015 full-load hours after 2013.
- According to RDL 14/2010 and RD 1544/2011, there is a grid access charge of 0.05 €cents/kWh after 2011.

[7] Recall that, according to RD661/2007, the tariffs will be annually updated by the CPI minus 25 basic points (0.25%) during the first four years and the CPI minus 50 basic points (0.50%) thereafter.

- According to Law 15/2012, a generation charge of 7% of total revenues is set.
- Although we assume that the plant has a useful life of 30 years, the remuneration period was set to 28 years in RDL 14/2010.
- The plant type relevant for out plant is IT-00058 ([23] p. 46474), since ours is a plant subject to RD 661/2007, with a capacity higher than 100 kW but lower than 2 MW, with arrays with a 2-axis tracking system and in operation since 2008.
- According to Order IET/1045/2014 [20], the remuneration levels corresponding to the plant typeIT-00058 are the following:

  -For the period between July 14thand December 31st 2013:a remuneration for investment (R_{inv}) of €/kW 318.281 is provided. This amounts to€ 31,614.85 for a 99.33 kW plant. The remuneration for operation (R_o) amounts to €cents/kWh 2.0572(IET/1045/2014, [20] p.46516).

  -For the period 2014-2016

  - The remuneration for investment is €/kW 679.372 (67,482.02 € for a 99.33 kW plant) for each of the considered years.
  - The remuneration for the operation (R_o) for 2014 is €cents/kWh 2.542 (IET/1045/2014, [20] p.46560), 2.4686 c€/kWh for 2015 and 2.5314 c€/KWh for 2016 (IET/1045/2014, [20] p.46637). It can be observed that the coefficient to obtain $R_o(O_t^*)$goes down by 2.8% between 2014 and 2015 and increases by2.5% in 2016 with respect to the previous year.
- The Order sets a useful regulatory life of 30 years, with an adjustment coefficient of one. For half the year 2013, the maximum number of full-load hours in order to receive R_o is 995, the minimum number of hours is 255 and the operation threshold is 149 hours (IET/1045/2014 [20], p.46516).For the period 2014-16, these values on the number of hours are, respectively, 2124, 1274 and 743 (IET/1045/2014 [20], p.46560). The number of full load-hours for 2014, 2015 and 2016 in our simulation has been set at 2020, 2005 and 1990 hours, taking into account the degradation of the modules. Those numbers of hours are below the aforementioned maximum hours set in the IET.
- As previously mentioned, the new regulation only affects the second half of 2013. In this period, the number of full-load hours was set at 995, which entails 98,833 kWh for a 99.33 kW plant. In the first semester of 2013, electricity

generation amounted to 103,408 kWh according to our simulation. This electricity has been remunerated at €cents/kWh 47.56. Such amount of electricity and the corresponding hours are below the 1149 full-load hours which have been set for the first half of the year (IET/1045/2014 [20], p. 46753).

- The simulation for 2014-2016 includes the requirements of the new regulation, as well as the revenues due to the sales of electricity in the wholesale market, i.e., R_{inv} (whose value is the same for the three years), in addition to the annual value of O_t^* (the coefficient to obtain R_o) multiplied by the electricity generation simulated plus this electricity generation times the wholesale electricity price (daily market). This price is published by the Iberian Electricity Spot Market Operator (OMIE). For the second half of 2013, this price was 5.129€cents/kWh and is now 4.821 €cents/kWh, 4.952 €cents/kWh and4.975 €cents/kWh for 2014, 2015 and 2016, respectively. We have assumed a price of 5.308 €cents/kWh for the years after 2017 (IET/1045/2014 [20], p.46753).

In addition, the following assumptions on key regulatory variables have been made.

- The simulation for the years after 2017 includes the following assumptions:
    - For simplicity, a constant wholesale electricity price has been assumed since 2017 until the end of the useful lifetime of the plant.
    - It has been assumed that the value of $R_{inv}$is the same between 2017 and 2019.
    - From 2020 to 2037 it has been assumed that the only investment that has to be paid off is the renewal of the inverter and, thus, the amount of R_{inv} is adapted to the amount of the financial costs that this implies[8].
- The calculations have been carried out considering a regulatory life of 30 years (as established in RD 413/2014), instead of 28 years.

4. The economic impact of the new regulation on solar PV plants.

[8] This assumption, which can be deemed a pessimistic one, is later relaxed in section 4.

This section simulates the impact of the new regulation on the cash-flows and profitability (IRR) of the solar PV plant (4.1) and carries out a sensitivity analysis on the impact of several factors on its profitability (4.2).

4.1. Simulating the impact of the new regulation on the cash-flow and profitability of the solar PV plant.

According to our calculations, the profitability of a solar PV plant under RD 661/2007 was relatively high, with IRRs above 11% (Table 4). The impact of the new regulation has been calculated with the data and assumptions for the plant mentioned in section 3. We have taken into account different factors affecting such profitability, e.g. different borrowing levels and whether the plant is turnkey or not. The reference plant is financed with a loan of 80% of upfront costs. For the turnkey plant, two cases are considered (80% and 100%). In all cases, the interest rate is 6% and the loan is fully repaid after 12 years. The new regulation results in lower remuneration flows for solar PV plants compared to those established in RD 661/2007, leading to lower cash-flows and, thus, substantially lower IRRs, which are in the 0.31% to 3.28% range. The lower extreme of the range refers to a turnkey plant with a loan of 100% of upfront costs. But the lowest IRR in RD 661/2007 was also for the turnkey plant with a 100% borrowing level. Whether the plant is turnkey or not seems to be more influential on the reduction of the IRR caused by the new regulation than the impacts of different borrowing levels.

Table 4

The following two figures show the evolution of the cash flows over the period in the "best" (a reference plant with 80% borrowing) and the "worst" (a turnkey plant with a 100% borrowing level) cases (Figures 1 and 2, respectively). The solid line in both figures represents the cash flows under RD 661/2007. The discontinuous lines indicate the cash flows for the same plant under the cost-containment measures in 2010-2013 and the new regulation (for a turnkey plant). The line with a parallel lay-out in Figure 1 indicates the cash flows for a non-turnkey plant under the cost-containment measures in 2010-2013 and the new regulation.

Figure 1

Figure 2

Both figures show that the net cash flows are substantially reduced from the start of the period (and, especially, since 2011) with respect to those envisaged in RD 661/2007, due to the cost-containment measures adopted in 2010-2013. In the case of the turnkey plant, the situation is even worse until 2020 since the cash flows are almost null in some years. After 2019, the debt of the plant is cancelled but the support for investment (R_{inv}) is no longer received. One effect partly offsets the other and, thus, the cash flows are still low after 2020, and much lower than in RD 661/2007.A turnkey plant with a 100% borrowing level results in negative cash flows from 2011 to 2020. Again, the loan is fully repaid in 2020, but this positive effect on the cash flow is partly offset by the lack of support for investment after that year. Therefore, the cash flows after 2020 are positive but very low, leading to very low IRRs for the whole period (Table 4).

The detrimental effects of the new regulation on the profitability of the plant adds to the negative impacts of the cost-containment measures adopted between 2010 and 2013. The following figure (Figure 3) shows that the effects of the new regulation are even more detrimental for the profitability of the plant than those related to those cost-containment measures. While the cost-containment measures reduced the IRR by a couple of percentage points in both a reference plant with a loan of 80% for the initial investment (solid line) and in the worst of cases, i.e., a turnkey plant with a loan of 100% of the initial investment (discontinuous line), the new regulation sinks the IRR by six additional percentage points. This is mostly due to the virtual elimination of support for investment after 2020 (R_{inv}).[9]Therefore, the combined impact of the cost-containment measures in the 2010-2013 and the new regulation has led to very low IRRs.

Figure 3

4.2. Sensitivity analysis on the impact of several factors on the profitability of the plant.

[9]The situation in the real world could be even worse because the simulation does not include the opportunity costs of the funds provided to cover the negative cash flows.

Several factors affect the reduction in the profitability of the plant as a result of the new regulation. These factors include different borrowing levels, changes in the initial investment, whether the plant is turnkey or not and continuation of support after 2019.Therefore, we have carried out simulations to identify the impact of the new regulation on the IRRs in different scenarios, e.g., under different values for those factors. Table 5 summarises the results, which are further discussed below.

Table 5

4.2.1. Impact of different borrowing levels.

Borrowing levels refer to the percentage of the initial investment which is financed by a loan. The impact of different borrowing levels on the IRR of the plant has been calculated (40%, 60%, 80% and 100%). Obviously, greater percentages entail lower IRRs because the financial expenditures associated to the loan are greater. In some cases the IRR can vary by as much as 3% between the 40% and 100% borrowing levels. In fact, this factor seems to amplify the negative influence of the new regulation. For example, the difference in the IRR between the 40% and 100% cases in the RD 661/2007 is 1.67% (9.10% to 10.77%), whereas this difference is wider in the new regulation (2.79%, from 2.35% to 5.14%)[10]

4.2.2. Impacts of changes in the initial investment.

Since solar PV is a capital-intensive technology, the amount of the initial, upfront investment is a main factor affecting the profitability of the plant. Higher levels of initial investment significantly reduce the IRR. The influence of this variable on the impact of the new regulation is considerable. We consider four cases (increases of 20% and 10% and reductions of 20% and 10% with respect to the base case of €639,614). This factor also amplifies the impact of the new regulation. The difference in the IRRs between the 20% increase and 20% reduction in the case of RD 661/2007 is less than 6% (from 8.89 to 14.82), whereas this difference rises to 7.25% with the new regulation.

4.2.3. Turnkey vs. reference plant.

[10] Reference plant (not turnkey) without investment support post 2019.

The IRR of the plant is substantially reduced (about two percentage points for each scenario and case) when it is a turnkey plant. The reason is that it would be 13% more expensive. Therefore, this factor also amplifies the impact of the new regulation on the IRR of the plant since the difference in the IRR is 1.65% in RD 661/2007 (from 9.14% to 10.79%)[11]. Turnkey plants were very common at the time in Spain, i.e. between September 2007 and September 2008, due to easy and cheap access to credit before the financial crisis. The fact banks were eager to lend and the very attractive economic conditions established in RD 661/2007 led to project developers being relatively unconcerned about the high costs of the initial investment.

4.2.4. Continuation of support after 2019.

After the loan for the initial investment is fully repaid after 2019, the support for investment (R_{inv}) established in the new regulation is assumed to be negligible, amounting to a small compensation for the purchase of the inverter. In the absence of investment support beyond 2020, the solar PV plants could still sell their electricity in the wholesale market, receiving the price in this market as revenue. They would also receive the support for O&M (R_o), which represents a modest amount.We have followed a conservative approach and have assumed that the wholesale electricityprice remains constant during the considered period[12]. The assumption of the removal of investment support can be justified because those plants subject to both RD 661/2007 and RD 1578/2008 will have repaid most of their loans by then, since those loans were generally contracted on a 12-year period under project finance. Thus, the end of the debt for those plants will be an appropriate moment to suppress the investment support.

However, in this article we have also calculated the IRR if such investment support was extended post-2020. This continuation could be justified by the government in order to offset the poor economic conditions of the solar PV plants, given their very small revenue flows (low wholesale price and lowR_o), which leads to very low cash flows and, possibly, to the closure of many solar PV plants. Therefore, we have

[11] It is assumed that the 100% is financed by a loan.

[12]According to our calculations, the wholesale price should double since 2017 (from 0.053€/kWh to 0.106€/kWh) in order to obtain a 5% IRR. There would be two opposing influences on this price: the increase in fossil fuel prices and its reduction due to the merit order effect with increasing RES penetration levels. We assume that one offsets the other.

simulated what would be profitability of the firm if investment support continued after 2019.In this case, the value for R_{inv} for the first six-year regulatory period (2014 to 2019) would be 67,482€ (the amount set in EIT/1045/2014). For the second six-year regulatory period, we have used the value of 661000€/MW established in the report of Roland Berger for the Instituto para la Diversificación y el Ahorro de la Energía (IDAE)([27], p.154), which results in 65,657€ for our plant. This amount is maintained until the end of the remuneration period. The results in Table 4 and 5 show that the IRR would be much higher with the continuation of support, compared to a situation without investment support after 2020 (between 5 and 6 additional percentage points in the IRR). Notwithstanding the profitability levels associated to the conditions set up in RD 661/2007 would not be attained even in this case. The calculations provided in this section represent the minimum and maximum values for the profitability of the plant.

5. Conclusions.

The new regulation on RES-E support has raised concerns about the impact of the retroactive changes on the profitability of existing solar PV plants. These concerns are related to the potential negative impact on the effectiveness of the scheme and, thus, on compliance with the RES Directive targets. 20% of gross energy consumption in Spain has to come from RES in 2020. Two recent reports from the European Commission [28] and the European Environmental Agency [29] suggest that this is unlikely to be the case[13].

This paper has shown that, indeed, those concerns are justified. The new regulation has a considerable negative impact on the profitability of solar PV plants. However, the degree of reduction in profitability levels critically depends on several factors, assumptions and scenarios. Therefore, upper and lower bounds for profitability levels have been provided in this article.

The cuts and retroactive changes are likely to have a highly detrimental effect on future deployment. On one hand, they will certainly increase the risk-premium associated to renewable energy investments in Spain, increase investor risks and reduce the attractiveness to invest in this country. These negative impacts on effectiveness and cost-effectiveness in deployment (due to higher capital costs) should have been weighed

[13] The analysis performed in European Commission (2015) shows that the expected RES deployment in 2020 will be several percentage points below the 2020 target. According to the European Environmental Agency (2014) In order to reach its 2020 target, Spain needs an average annual growth rate of 6.7% in the run-up to 2020. In absolute terms, this is equivalent to 2.1 times its cumulative effort so far, i.e., an ambitious task

with the reductions in the promotion costs paid by electricity consumers as a result of the new regulation. The project developers who invested in solar PV plants in the last years of the previous decade are highly frustrated. Lack of investor confidence will remain in the future. A possible way out of this situation might be to implement a new regulatory scheme which is based on the promotion of repowering of the existing solar PV plants, given that the costs of the modules has substantially been reduced in the last years.

The analysis performed in this article suggests fruitful lines for future research. First, our data refer to a single solar PV plant and, thus, the results have to be taken with caution. Further research should replicate the analysis for plants with different features to the one considered in this paper. In addition, further research should be dedicated to the analysis of the impact of the new regulation on the costs of renewable energy promotion in general and solar PV support costs in particular.

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References

[1] Mir-Artigues P, Cerdá E and del Río P (2015) Analysing the impact of cost-containment mechanisms on the profitability of solar PV plants in Spain. Renewable and Sustainable Energy Reviews 46: 166-177

[2] Del Río P, Mir-Artigues P. Support for Solar PV deployment in Spain: Some policy lessons. Renewable and Sustainable Energy Reviews 2012; 16: 5557-5566.

[3] Ortega M, del Río P, Montero E. Assessing the benefits and costs of renewable electricity. The Spanish case. Renewable and Sustainable Energy Reviews 2013; 27: 294-304

[4] del Río P, Gual MA. An integrated assessment of the feed-in tariff system in Spain. Energy Policy 2007; 35: 994-1012.

[5] Dinica V. Support systems for the diffusion of renewable energy technologies- an investor perspective. Energy Policy 2006; 34: 461-480.

[6] del Río P (2008) Ten years of renewable electricity policies in Spain: An analysis of successive feed-in tariff reforms.Energy Policy 36: 2917-2929.

[7] Burgos-Payán et al 2013), Burgos-Payán M, Roldán-Fernández JM, Trigo-García AL, Bermúdez-Ríos JM, Riquelme-Santos JM. Costs and benefits of the renewable production of electricity in Spain. Energy Policy 2013; 56: 259-270

[8] de la Hoz et al 2013a, De la Hoz J, Martín H, Ballart J, Córcoles F, Graells M. Evaluating the new control structure for the promotion of grid connected photovoltaic systems in Spain: Performance analysis of the period 2008–2010. Renewable and Sustainable Energy Reviews 2013; 19: 541-554

[9] de la Hoz J, Martín H, Martins B, Matas J, Miret J. Evaluating the impact of the administrative procedure and the landscape policy on grid connected PV systems (GCPVS) on-floor in Spain in the period 2004–2008: To which extent a limiting factor? Energy Policy 2013; 63: 147-167

[10] Movilla et al 2013, Movilla S, Miguel L, Blázquez LF. A system dynamics approach for the photovoltaic energy market in Spain. Energy Policy 2013; 60: 142-154

[11] Zubi G Technology mix alternatives with high shares of wind power and photovoltaics—case study for Spain Energy Policy, 2011; 39(12): 8070-8077

[12] Talavera DL, de la Casa J, Muñoz-Cerón E, Almonacid G. 2014. Grid parity and self-consumption with photovoltaic systems under the present regulatory framework in Spain: The case of the University of Jaén Campus. Renewable and Sustainable Energy Reviews 2014; 33: 752-771.

[13] Mitchell C et al (2011) Policy, Financing and Implementation. In: IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlomer, C. von Stechow (eds)], Cambridge, Cambridge University Press, available at http://srren.ipcc-wg3.de/report/IPCC_SRREN_Ch11.pdf

[14] de la Hoz J, Martín H, Ballart J, Monjo L. Evaluating the approach to reduce the overrun cost of grid connected PV systems for the Spanish electricity sector: Performance analysis of the period 2010–2012. Applied Energy 2014; 121: 159-173

[15] del Río P and Mir-Artigues, P (2014) A Cautionary Tale: Spain's solar PV subsidy and investment bubble. International Institute for Sustainable Development (2014).Geneve. Available at http://www.iisd.org/gsi/sites/default/files/rens_ct_spain.pdf

[16] European Photovoltaic Industry Association (EPIA) 2013.Retrospective measures at national level and their impact on the photovoltaic sector. 10 December 2013.

[17] RD 413/2014 Royal Decree 413/2014 which regulates the production of electricity from renewable energy sources, cogeneration and waste. Boletín Oficial del Estado, n. 140, 10/6/2014, pp. 43876-43978. Available at http://www.boe.es

[18] Comisión Nacional de la Energía (National Energy Commission, CNE) 2011. Información mensual de estadística sobre las ventas de régimen especial. Madrid.

[19] CNMC 2015. Información mensual de estadística sobre las ventas de régimen especial. http://www.cnmc.es/es-es/energ%C3%ADa/energ%C3%ADael%C3%A9ctrica/r%C3%A9gimenespecialyliquidaciones.aspx?p=p4&ti=Ventas%20r%C3%A9gimen%20especial

[20] IET/1045/2014.Orden IET/1045/2014, de 16 de junio, por la que se aprueban los parámetros retributivos de las instalaciones tipo aplicables a determinadas instalaciones de producción de energía eléctrica a partir de fuentes de energía renovables, cogeneración y residuos. Boletín Oficial del Estado, n. 150, 20/7/2014, pp. 46430-48190. Available at http://www.boe.es

[21] CNE 2013. Report 18/2013 of the CNE on the proposal of Royal Decree which regulates the production of electricity from renewbale energy sources, cogeneration and residues. http://pt.krannich-solar.com/fileadmin/content/pdf/spain/Legislacion/Informe_CNE_18_2013_propuesta_rd.pdf

[22] UNEF (2014)El 30% de las plantas fotovoltaicas necesitan una quita de hasta el 60%. Available at http://unef.es/2014/04/el-30-de-las-plantas-fotovoltaicas-necesitan-una-quita-de-hasta-el-60/

[23] Del Río P, Iglesias G, Anxo C. The New Renewable Electricity Support Scheme in Spain: A Comment. Renewable Energy Law and Policy 2015; 6(1): 17-24

[24] SunPower Corporation, Levelized Cost of Electricity - The Drivers of The Levelized Cost of electricity for Utility-Scale Photovoltaics, August, 2008: 1-27.

[25] Jordan D C, Kurtz S R. Photovoltaic Degradation Rates - an Analytical Review. Progress in Photovoltaics: Research and Applications 2013; 21: 12-29.

[26] Branker K, Pathak MJM, Pearce JM. A review of solar photovoltaic levelized cost of electricity. Renewable and Sustainable Energy Reviews 2011; 15(9): 4470-4482.

[27] Roland Berger-IDAE (2014) Análisis de estándares de proyectos de producción de electricidad en régimen especial-IDAE Informe Técnico. Madrid, Roland Berger

Strategy Consultants and IDAE.Available at http://www.minetur.gov.es/arce.Accessed in May 2015.
[28] European Commission 2015. Renewable energy progress report. Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Brussels, 15.6.2015. COM(2015) 293 final.
[29] EEA (2014) Climate and Energy profiles 2014. Spain. file:///C:/Users/pablo/Downloads/EEA_2014_country%20profile_Spain.pdf

TABLES

Table 1.Trends in key data regarding the solar PV sector.

	Installedcapacity (MW)	Electricitygeneration (GWh)	Number of installations	Total support (M€)	Averagesupport (cent€/kWh)
2014	4.667	8.190	61.238	2761	33.6
2013	4.662	8.299	61.181	3267	39.3
2012	4.534	8.168	60.065	2877	35.2
2011	4.243	7.414	57.889	2665	35.9
2010	3.838	6.405	55.034	2897	45.2
2009	3.398	6.074	52.119	2868	46.2
2008	3.398	2.503	51.310	1155	45.3
2007	690	473	20.284	215	43.3
2006	146	99	9.875	45	42.7
2005	47	38	5.391	16	39.9
2004	23	17	3.266	6	36.7

Source: [18] [19].

Table 2. Cost concepts for the plant.

Concept	**Value (€)**	% of total value
Modules HIP 215	375,196	58.66
2-axis tracking system DegertTraker 7000 NT	70,197	10.98
Inverters (Sunny Central)	43,301	6.77
Engineering project	2,534	0.40
Assessment	1,150	0.18
Civil works	14,957	2.34
Installation works	52,576	8.22
Electrical evacuation line (deep connection rule)	59,942	9.37
Project direction	6,165	0.96
Taxes and charges	675	0.11
Financial expenditures	12,916	2.02
Total	639,614 €	100.00

Table 3. Cost of the inverters.

€/W nominal	2007*	2014**	2018**
100 kW	0.288	0.192	0.168
500 kW	0.252	0.168	0.144
1000 kW	0.264	0.156	0.132

* Observed values

** Estimated values

Table 4.Impact of the new regulation on the profitability (IRR) of the plant (%).

	Reference plant (100%)	Turnkey plant	
		80%	100%
RD661/2007	11.32	10,29	9.14
New regulation	3.28	1.23	0.31

Table 5.Summary of profitability rates (IRR) under different assumptions and scenarios.

	RD 661	**Cost-containment 2010-2013**	**New regulation 2013**

					No investment support post 2019		Investment support post 2019	
			With cost-cont.	**Cost-cont. &Turnkey**	**With cost-cont.**	**Cost-cont. &Turnkey**	**With cost-cont.**	**Cost-cont. &Turnkey**
Financedb y a loan	**100%**	10.79 (9.14 turnkey)	9.10	7.52	2.35	0.31	8.14	6.63
	80%	11.32	9.64	8.04	3.28	1.23	8.68	7.15
	60%	11.87	10.20	8.59	4.21	2.16	9.24	7.69
	40%	12.42	10.77	9.15	5.14	3.11	9.82	8.25
Changes in the upfront investment	**Δ 20%**	8.89	7.31	5.91	0.29	-1.49	6.45	5.11
	Δ 10%	10.01	8.38	6.89	1.66	-0.24	7.48	6.05
	∇10%	12.89	11.14	9.41	5.2	2.98	10.14	8.64
	∇20%	14.82	12.98	11.08	7.54	5.12	11.93	10.07

FIGURES

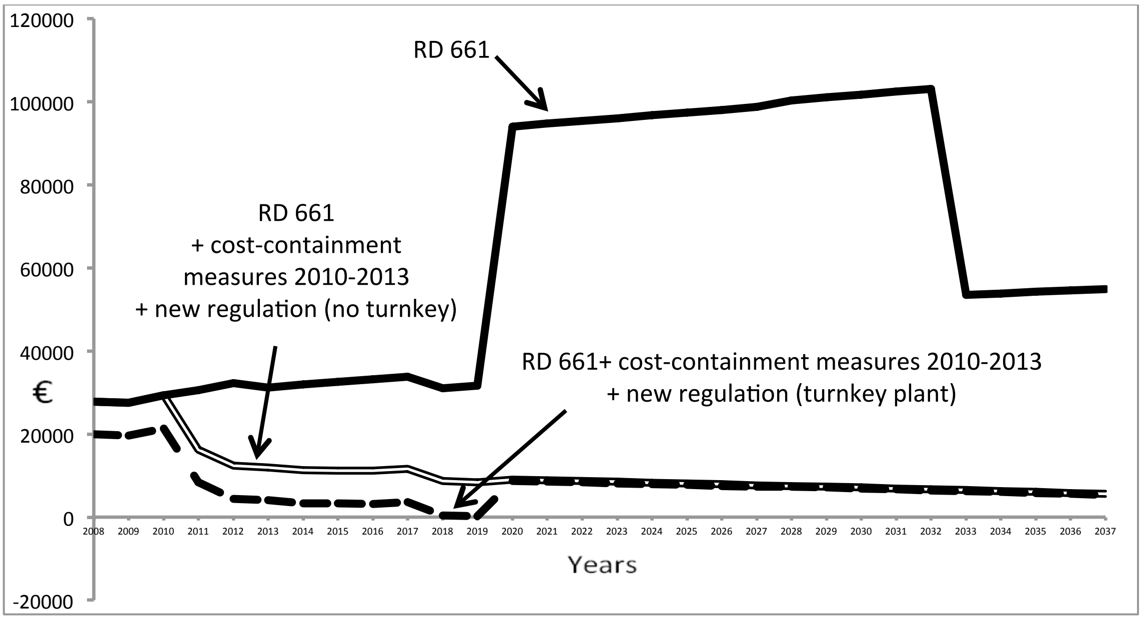

Figure 1.Net cash flows for a plant with a 80% borrowing level.

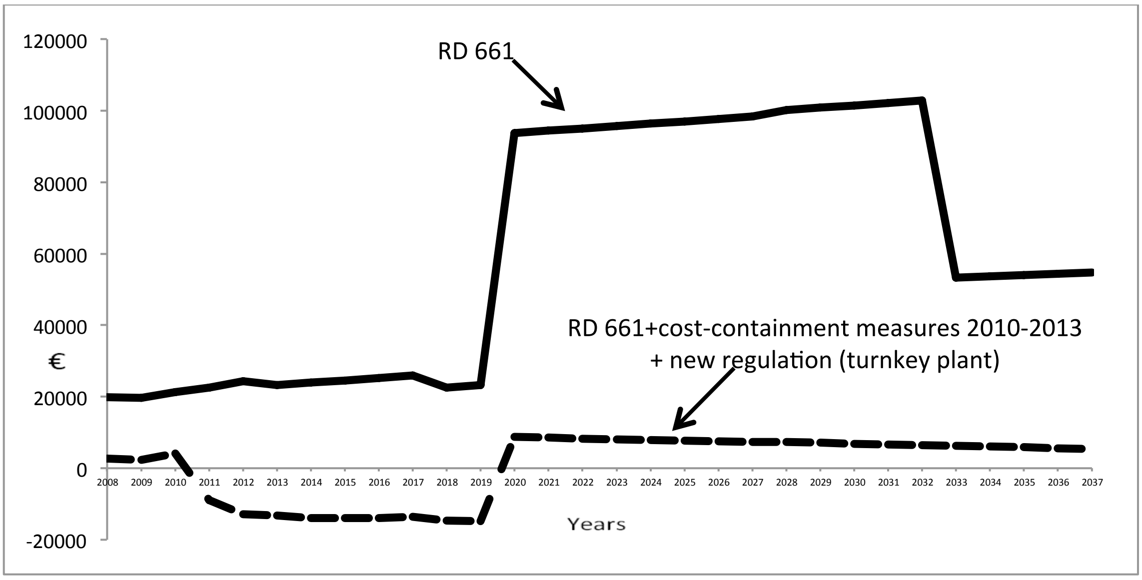

Figure 2.Net cash flows for a turnkey plant with a 100% borrowing level.

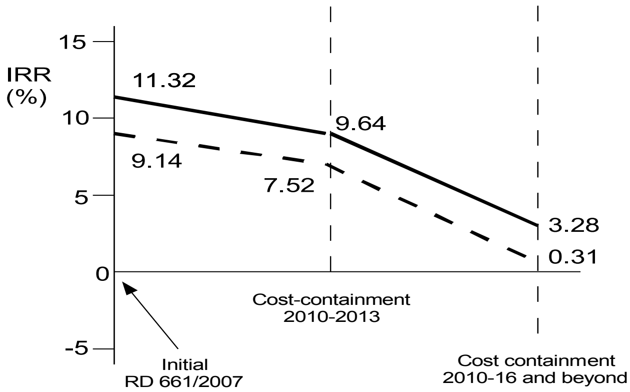

Figure 3.Evolution of the IRR in the successive regulations.

Note: "Cost-containment and beyond" includes the impact of the cost-containment measures 2010-2013 plus the impact of the new regulation.