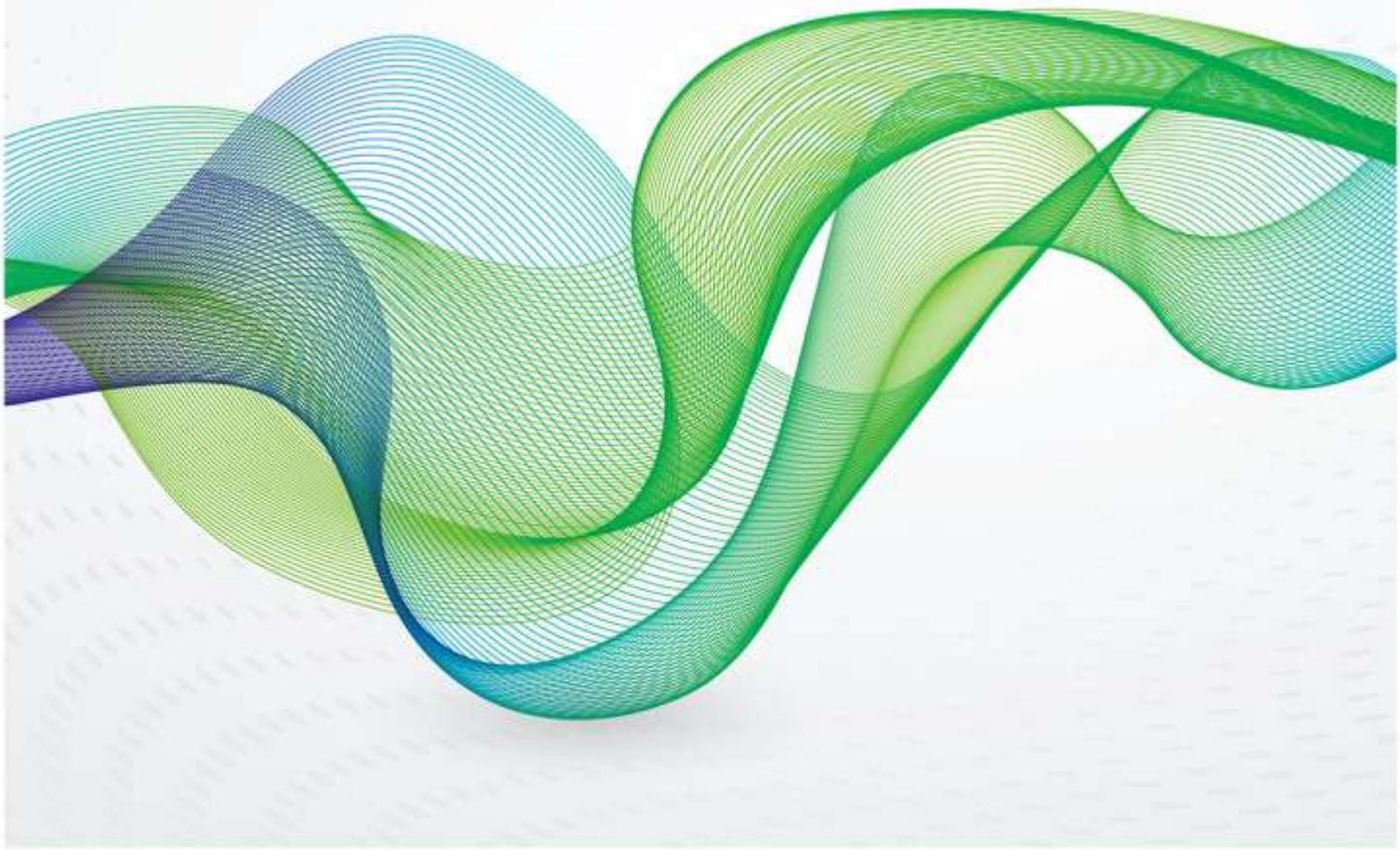
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An empirical study on the drivers of financial leverage of Spanish wind farms

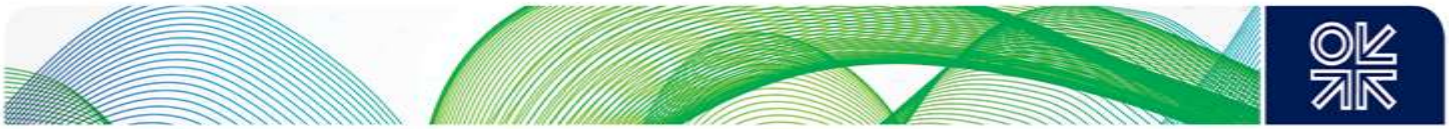


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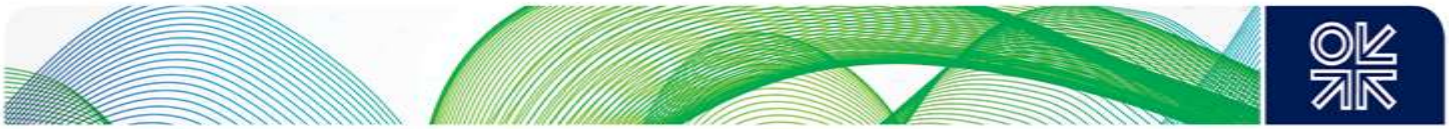
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An empirical study on the drivers of financial leverage of Spanish wind farms

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Abstract

For renewable energy projects, financing is a major bottleneck to accelerate the transition towards a decarbonized energy mix. Multilateral international institutions are developing new financing instruments to address the barriers and risks that hold back private investment in renewable energy technologies, while minimizing the possibility of crowding out the private sector. Within this context, our study explores the drivers of external financing for Spanish wind farms using a dataset of 318 projects commissioned in the period 2006–13. Thanks to the granularity of this dataset, our analysis provides some results that help explain why some projects are more attractive than others from a financial perspective. This study has three main takeaways. First, the costs of a renewable project are the main drivers that determine the access to external financing, whereas the capacity factor, which determines the revenues, has a minor relevance. Second, the behavior of banks changed after the financial crisis of 2008. Before the crisis, expensive projects tended to have higher debt leverage ratio while after the financial crisis, these projects were penalized in terms of access to external financing. Third, the standard metric to assess the competitiveness of renewable projects, the levelized cost of electricity (LCOE), does not help understand the access to external financing and leverage.

JEL classifications: Q42, Q43, G32, C20

Keywords: wind farms, capital and operational costs, debt leverage ratio, levelized cost of electricity

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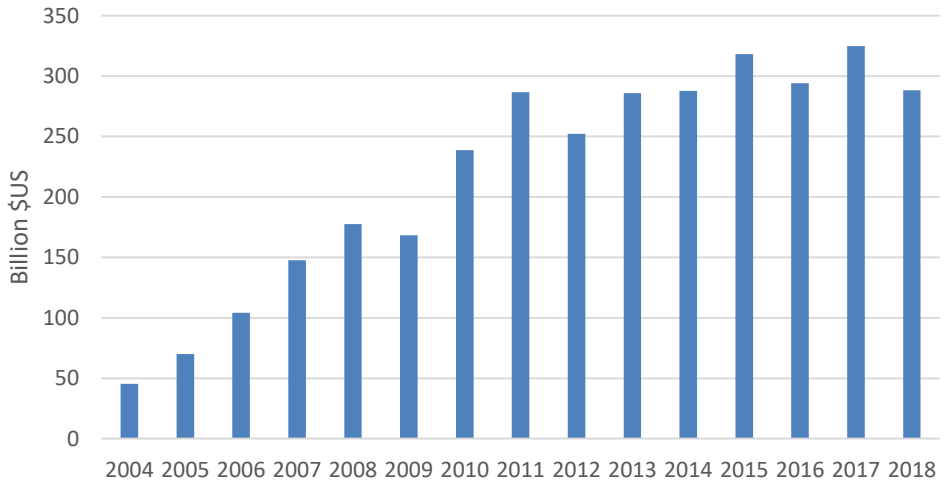
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1. Introduction

The accumulation of anthropogenic greenhouse gases and their impact on climate change are backed by a large number of scientific studies. The planet average temperature has risen around 1°C since the late 19th century, a change driven largely by human-made emissions into the atmosphere (NASA, 2020). In this context, in December 2015 195 countries adopted a binding agreement on global climate change aimed to keep global temperatures below 2°C, known as the Paris Agreement. A necessary, but not sufficient, condition to keep global warming below the 'two degrees scenario' is a massive deployment of renewable energy. According to BP (2019), the share of renewables in 2040 should rise to 30 per cent of the world's primary energy, from 4 per cent in 2017, to be consistent with Paris Agreement targets.

Figure 1 shows that renewable energy investment in nominal terms at a global level has been relatively stagnant since 2010. The insufficient financing for renewable technology deployment is perceived as one of the main obstacles to a rapid decarbonization of the energy system. For example, a World Bank report (Hussain, 2013) states that the high financial cost of renewable technologies, relative to fossil fuel generation technologies, is one of the main barriers to their deployment. The International Renewable Energy Agency (IRENA) in a report (Wuester, 2016) states that fundamental market barriers constrain the financing of renewable projects, especially in developing countries. De Jager et al. (2011) develop recommendations for improving financing instruments and the access to capital markets to reach the European targets for renewable energy. In the case of the US, Mendelsohn and Feldman (2013) note that meeting a significant expansion of renewable sources will require access to new sources of financial capital. Finally, Justice (2009) points out that the financial sector approaches renewable energy in the same manner as any other investments, but this sector requires specialized knowledge to correctly assess the risk of renewable investments.

Figure 1: Global new investments in renewable energy, excluding large hydro

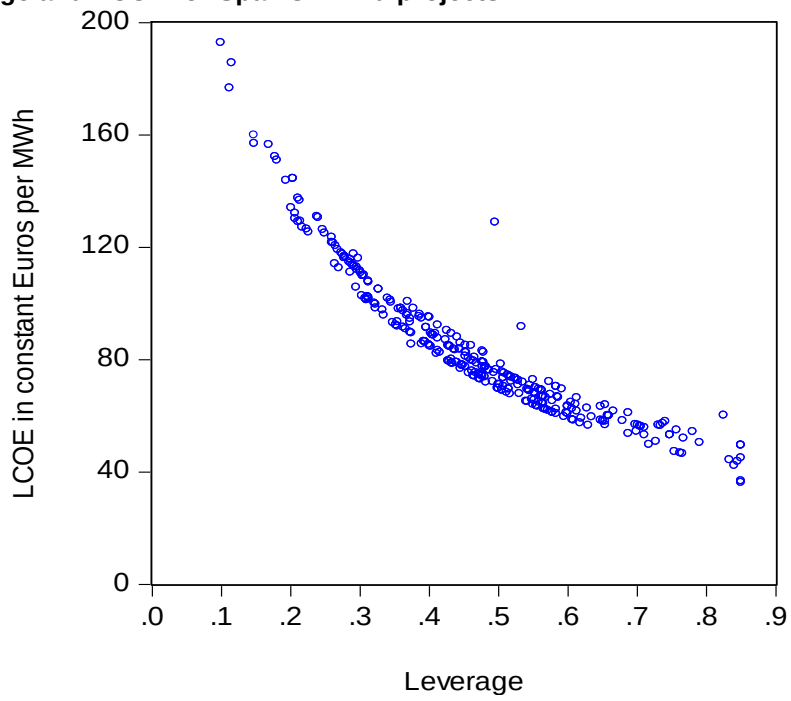


Source: International Renewable Energy Agency.

It is important to highlight that financing is also a key element for the competitiveness of these types of technologies. Renewable technologies are characterized by extremely low operational costs creating an atypical cost structure and making it impossible to adopt the standard economic approach based on increasing marginal costs. In economic terms, the marginal cost of renewable energy is close to zero, with the average total cost per MWh produced the relevant variable. The Levelized Cost of Electricity (LCOE) is a proxy of this variable and the standard way to assess the cost of the electricity produced by means of renewable sources (IRENA, 2018). As is well known, the LCOE is the sum of the costs

over the lifetime of the project divided by sum of the electricity produced during the same period, with the discount rate playing a critical role. As a result, the cost competitiveness of a renewable project is strongly affected by the discount rate that is used to assess its economic profitability, as suggested by Ondraczek et al. (2015). The Weighted Average Cost of Capital (WACC) is the standard discount rate used by renewable companies to calculate the LCOE and the Net Present Value (NPV) of investment projects (see, for example, the seminal study by Short et al., 1995). The WACC is a weighted average of the cost of internal and external financing. In general, debt tends to be cheaper than equity because it has lower risk. The reason is that financial debts have priority claims in case of bankruptcy and liquidation of the company. As a result, companies with a higher level of debt tend to have a lower WACC and, consequently, a lower LCOE, and a higher competitiveness. Figure 2 shows the relationship between leverage (as debt over total capital costs) and LCOE for 318 Spanish wind projects commissioned in the period 2006–13.

Figure 2: Leverage and LCOE for Spanish wind projects



Source: Bean et al. (2017).

The purpose of this study is to shed some light on the drivers of external financing for renewable energy projects using an econometric approach. Using granular data for Spanish wind projects commissioned in 2006–13, this study tries to understand the relationship between the economic and technical variables of a project and the access to external financing. The analysis focuses on debt leverage, the size of the project, capital and operational costs, and capacity factor, using an econometric approach. It is important to highlight from the very beginning that the approach for this study is limited by the information of the database. As Krupa et al. (2019) shows, there are many elements that have an impact on renewable energy financial conditions. This study cites 14 different key elements, including long-term power purchase agreements (PPA), connection to grid, priority of dispatch, regulatory risk, political risk, and supportive financial institutions (among others).

The rest of the paper is organized as follows: Section 2 discusses previous academic research on this topic, Section 3 presents the database, Section 4 outlines the methodology, and Section 5 discusses the empirical results. Section 6 concludes the paper.

2. A review of existing academic literature

The interest in financial leverage and in companies' financial decisions can be traced back to influential work by Modigliani and Miller (1958). In their paper, the authors presented the famous 'irrelevance' proposition according to which, in the absence of transaction costs, tax subsidies on interest payments, and with the same interest rate on borrowing by individuals and corporations, a firm's capital structure is irrelevant, in other words, its value is independent of its leverage. This contribution opened a new area of financial economics with a host of papers purporting to explain the main determinants of financial leverage both at the theoretical and the empirical level. New theories were put forward, including models based on agency costs (Jensen and Meckling, 1976), asymmetric information and signaling (Ross, 1977), static trade-off and pecking order theories (Myers and Majluf, 1984) and transaction costs (Williamson, 1988). These models suggested several determinants of leverage which were subsequently considered in empirical applications. There are several empirical implications stemming from trade-off and pecking order theories, which serve as a guide to interpret the determinants of leverage and their expected impact. These factors can be divided into firm-specific determinants, industry-specific determinants, tax-related factors, and macroeconomic factors. Shyam-Sunder and Myers (1999), Chirinko and Singha (2000), and De Jong et al. (2011) (among others) explore the validity of these theories using company data.

Empirical studies on the determinants of leverage have typically focused on the capital structure of listed companies and corporations (Rajan and Zingales, 1995). Only a few papers study the determinants of the capital structure of companies in renewable energy or capital-intensive industries. Rashid (2013) finds that both firm-specific and macroeconomic uncertainty have a significant negative impact on UK leverage ratios of energy firms. Leverage is found to be negatively related to profitability and to market-to-book ratios (i.e. investment opportunities), and positively related with asset tangibility and firm size. Bobinaite (2015) focuses on wind electricity-producing companies in Latvia (with numbers varying from 15 in 2005 to 21 in 2012). A negative relationship is found between financial leverage and profitability and the effective tax rate, whereas leverage positively correlates with growth, collateral value of assets, size of the company.

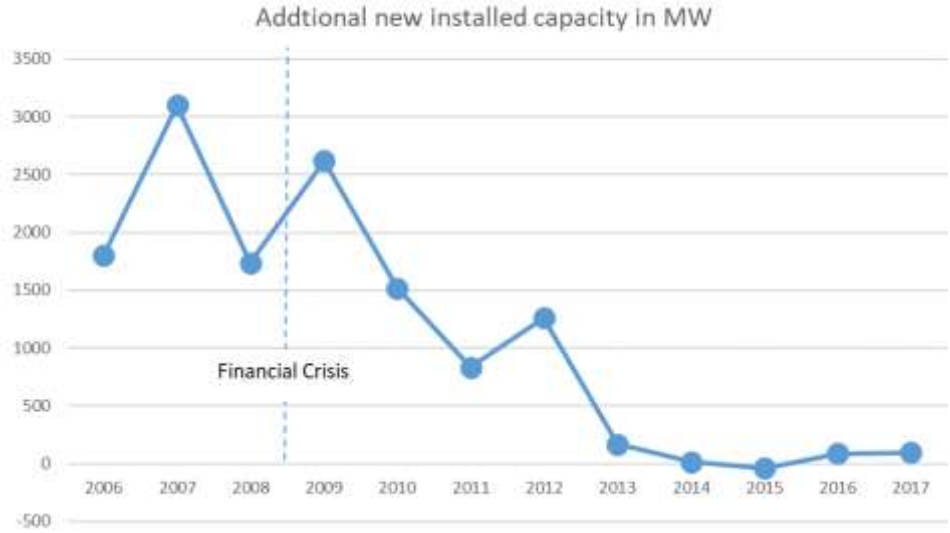
In the field of renewable energy, Krupa and Harvey (2017) explore a range of existing and new emerging options for financing renewable power projects in the US. Poudineh at al. (2018) suggests that renewable energy in oil-rich Middle East economies faces financial difficulties due to institutional and technical barriers, in addition to subsidies to fossil fuels. This study also finds that a PPA minimizes the risk associated with market price fluctuations favouring cost-efficient auctions. Mazzucato and Semienick (2018) explore the role of the public sector investing in renewables, finding that it tends to invest in portfolios with higher-risk technologies. Agrawal (2012) discusses risk mitigation as a strategy to help project developers and investors alike to select good projects. Steffen (2018) explores the use of project finance in the power sector in Germany, finding that independent renewable developers heavily rely on it. Finally, Krupa et al. (2019) conduct a detailed analysis of the financing of renewable energy in the region of the Gulf Cooperation Council.

This paper empirically studies the determinants of leverage for several projects undertaken by firms active in the renewable energy sector. The focus on individual investment projects and the focus on the renewable energy sector is what makes our analysis new and interesting. To the best of our knowledge, this paper is the first to explore the relationship between debt leverage and the economic and technical characteristics of individual renewable projects.

3. Description of the data

Our dataset includes financial and operational information on 318 onshore wind projects implemented in Spain from 2006 to 2013. The database is the same one used by Bean et al. (2017). For the sake of completeness, we provide a description of the database here. Projects included in the dataset have a minimum installed capacity of 15 megawatts (MW). They represent 10.7 gigawatts (GW) of installed capacity – 83 per cent of the total wind installed capacity during 2006–2013, according to BP (2019). Figure 3 shows the evolution of new investments in wind energy in Spain during the period 2006–2017. The dotted line represents the start of the financial crisis in Spain, a key year for our analysis.

Figure 3: Additional installed capacity



Source: Authors.

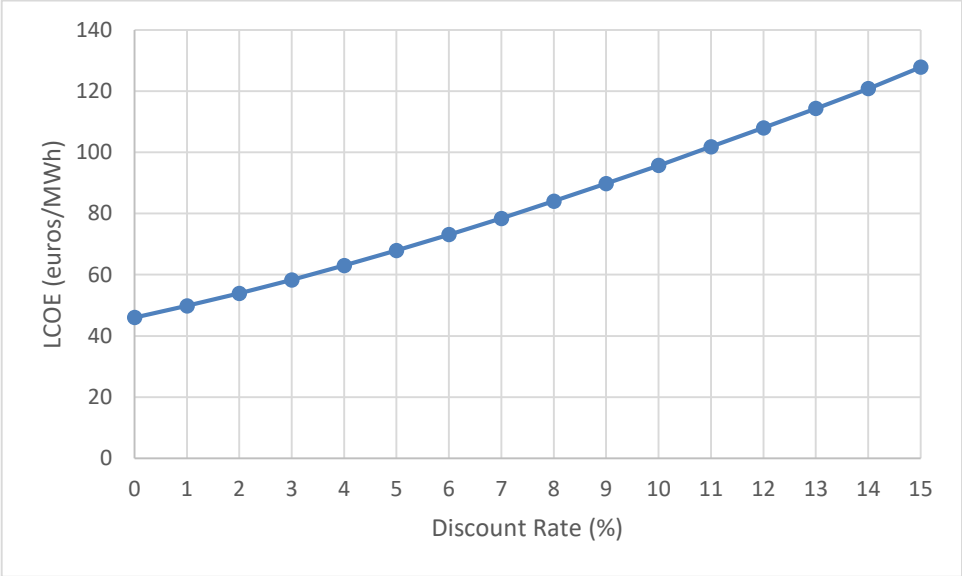
The database has been built using different sources of information. For each project, the dataset provides information on the year in which the project was commissioned, the capital cost in €/MW, the operational cost in €/MWh, the size in MW, the leverage (ratio of debt relative to total capital expenditure), the LCOE in €/MWh, the WACC and the capacity factor (CAPF). Capital and operating costs, which cover a period of 8 years, have been translated to constant euros, with 2013 as the base year.

The WACC for each project has been estimated using the long-term loans to non-financial corporations provided by the Bank of Spain (2015) as the cost of the external capital. Regarding the financial conditions, we assume that all debt is structured as amortized loans in which there are equal payments over the maturity of the loan. We assume that the equity cost is 8 per cent, following IRENA (2018). Given that our dataset includes projects commissioned in different years, the cost of equity and the long-term bank loans are in real terms.

A critical variable for our analysis is the LCOE, since we explore if there are differences in the financial drivers for leverage between projects with low and high LCOE. This metric reflects the total average cost, including operating and capital costs, per kilowatt hours (kWh) produced during the lifespan of the project.

As mentioned before, a critical value in the analysis of the LCOE is the discount rate. To illustrate this point, we calculate the LCOE for a standard Spanish wind project using different discount rates. Figure 4 shows this relationship. Though this relationship is well known, the role of external financing has usually been ignored. The standard metric used to discount future costs in energy projects is the WACC. Figure 4 shows that the higher the WACC, the higher the LCOE of a project.

Figure 4: LCOE vs discount rate



Source: Authors.

Table 1 presents some descriptive statistics. The leverage is, on average, equal to 47 per cent, but it ranges from a minimum of 10 per cent to a maximum of 85 per cent. The average size of the project is 34 MW, ranging from 16 MW to 94 MW. Capital costs are on average €1.5 million/MW, with a limited range of variability across projects, while operating costs are €18/MWh with more pronounced variability. The WACC is 6 per cent on average, while the capacity factor ranges from 6 per cent to 40 per cent.

Table 1: Descriptive statistics

	Units	Mean	Standard deviation	Maximum	Minimum
Capital cost	€/MW	1,490,700	93,358	1,691,939	1,214,400
Operating cost	€/MWh	18	5	42	10
Size	MW	34	12	94	16
Leverage	%	47	16	85	9.9
LCOE	€/MWh	84	26	193	36
WACC	%	6	1	8	4
Capacity factor	%	19	6	40	6

Source: Authors.

Table 2 shows that the correlation between leverage and all other listed variables is negative, whereas it is positive with the capacity factor. Of course, the figures shown refer to pairwise correlations and provide only a preliminary indication of the factors affecting leverage. A more comprehensive approach is one that considers multiple correlations, entailing the estimation of multiple regression models, a task which we carry out in the next section.

Table 2: Correlation matrix

	LEV	CAPEX	OPEX	SIZE	LCOE	WACC	CAPF
Number of projects: 318							
LEV	1.00						
CAPEX	–0.13	1.00					
OPEX	–0.88	–0.05	1.00				
SIZE	–0.13	0.01	0.14	1.00			
LCOE	–0.93	0.09	0.98	0.15	1.00		
WACC	–0.91	–0.06	0.82	0.11	0.87	1.00	
CAPF	0.94	0.06	–0.89	–0.15	–0.92	–0.90	1.00

Note: CAPEX = Capital cost; OPEX = Operating costs

Source: Authors.

In this study we also ask if there are differences in the financial drivers of leverage between projects with low and high LCOE. In this database we can use €83/MWh as a threshold to differentiate 'economic' from 'uneconomic' projects. This number, €83/MWh, is the average feed-in tariff in 2006–2013 and it is also the average LCOE for Spanish wind projects commissioned in that period. On this basis, we obtain two subsamples: one with projects with a LCOE below €83/MWh and the other with projects with a LCOE above 83€/MWh, including 186 economic projects and 132 uneconomic projects, respectively. To explore whether the financial drivers that determine the leverage of a project changed during the financial crisis, two additional subsamples are defined: one with projects commissioned during 2006–08 and other with projects commissioned during the recession, 2009–2013. There are 191 and 127 projects in the two subsamples, respectively. Table 3 reports descriptive statistics of projects with a LCOE above and below 83€/MWh, and those initiated before and during the recessionary period.

Table 3: Descriptive statistics of subsamples–mean values

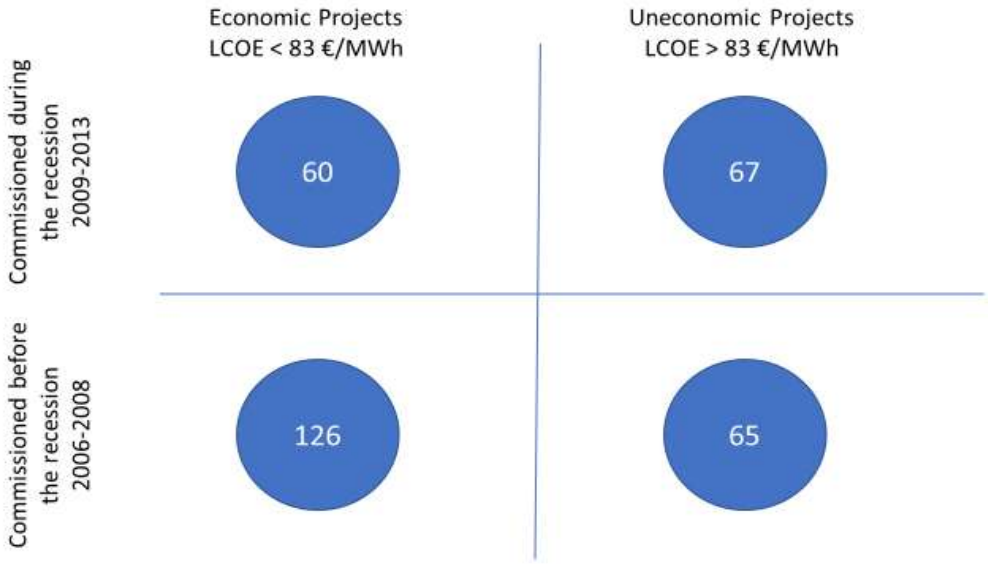
	Whole sample	LCOE below €83/MWh	LCOE above €83/MWh	Before recession 2006–08	Recession 2009–2013
Projects	Number	186	132	191	127
Capital cost	€/MW	1,485,341	1,498,252	1,470,481	1,521,108
Operational cost	€/MWh	15	22	17	18
Size	MW	33	35	32	36
Leverage	%	57	33	48	46
LCOE	€/MWh	67	108	81	88
WACC	%	5	7	6	6
Capacity factor	%	23	14	20	18

Source: Authors.

While there are differences between 'economic' and 'uneconomic' projects, we do not see big changes in projects' characteristics before and during the recession. In the latter, the main difference is in mean LCOE, whereas in the former, mean leverage and capacity factors are higher in 'economic' projects,

and operating costs and LCOE are lower than in ‘uneconomic’ projects. Figure 5 examines the four different types of project that we study.

Figure 5: Types of project



Source: Authors.

4. Methodology

We use a multiple regression method to empirically assess the relationships between the dependent and independent variables for our sample. Recall that our database is comprised of a set of 318 individual projects commissioned in different years and that there is only one observation per project. The dataset is thus not a proper panel, so we cannot use panel econometric methods.

We estimate a set of leverage equations by ordinary least squares. To allow for the possibility of heteroscedasticity, which is likely given the nature of our data, we compute heteroscedasticity-robust standard errors. The regression model is the following:

$$LEV_i = \beta_0 + \beta_1 SIZE_i + \beta_2 CAPF_i + \beta_3 OPEX_i + \beta_4 CAPEX_i + u_i \qquad (1)$$

for i = 1, … , 318 and where u is the error term. The β coefficients account for the partial effect of the explanatory variable considered on leverage. The ratio between estimated coefficient and its standard error informs us about the statistical significance of such an effect: if the t-statistic is above 2, as a rule of thumb we can say that the regressor is a significant explanator of leverage, other factors held constant. In addition to considering the statistical significance of individual explanatory variables, we would like to check the overall statistical performance of the regression. This is typically done by means of the R^2 indicator, adjusted for the presence of an intercept in the model: the closer the index is to 1, the better the overall performance. More rigorously, we can carry out a formal test of significance of all β coefficients (except for the intercept): if we cannot reject the hypothesis that they are jointly equal to zero, then the overall regression is statistically meaningless. This is the F-test and Table 4 shows the F statistics together with the P-value. If this value is smaller than 0.05 (the confidence level α is taken to be equal to 5 per cent), then the null hypothesis is rejected, and the regression is statistically meaningful. We provide the outcome of a few additional tests on the goodness of fit with regard to the specification of the model: (i) the Ramsey's RESET test, which is a general test of model misspecification; (ii) the Lagrange Multiplier (LM) test of residual heteroscedasticity; (iii) the Bera-Jarque test of normality of residuals.

5. Empirical results

The purpose of this study is to understand the economic and technical variables that make a project attractive for banks or lenders using an econometric approach. We estimate a set of equations like expression (1[1]). As discussed in Section 2, there are several potential determinants of a company's leverage, in addition to those considered here. We note that the focus here is on individual projects and not on companies, and that the data available are limited to those of the variables used here.

Table 4: Estimation of determinants of leverage in Spanish wind projects

	(1)	(2)	(3)	(4)	(5)
	Whole sample	LCOE below €83/MWh	LCOE above €83/MWh	Before recession 2006–08	Recession 2009–2013
C	15.36	15.79	14.45	–2.54	19.75
	(11.82)	(9.66)	(6.04)	(–0.86)	(9.04)
SIZE	0.01	0.01	0.01	0.01	0.00
	(1.04)	(1.35)	(0.19)	(1.06)	(–0.10)
CAPF	0.03	0.25	–0.40	0.19	1.13
	(0.18)	(0.98)	(–2.71)	(1.36)	(1.49)
OPEX	–1.44	–1.10	–1.98	–1.27	–0.09
	(–6.13)	(–3.35)	(–12.11)	(–7.24)	(–0.10)
CAPEX	–0.85	–0.92	-0.73	0.40	–1.29
	(–10.76)	(–11.21)	(–4.28)	(2.04)	(–5.56)
Adjusted R^2	0.96	0.91	0.91	0.99	0.94
F test	2056.83	471.54	340.57	5703.66	488.25
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Reset test	9.73	7.05	4.54	171.82	3.57
	[0.00]	[0.01]	[0.03]	[0.00]	[0.00]
LM test for heteroskedasticity	5.65	0.77	2.11	12.654	5.61
	[0.02]	[0.38]	[0.15]	[0.00]	[0.02]
Bera-Jarque test	93987.6	30382.1	28642.2	323.853	13156.6
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
No. obs.	318	186	132	191	127

Note: Robust standard errors in round brackets. P-values in square brackets.
Source: Authors.

[1] We have estimated a set of alternative regressions, but we opted for this set of independent variables because they provide an economic interpretation to the econometric results.

Table 4 presents the estimation results of the three different sets of regressions we ran. The first regression (column 1) uses the entire dataset, which is data from 318 projects. The second set of regressions (columns 2 and 3) differentiates projects with LCOE below and above 83€/MW (that is, between economic and uneconomic projects). Finally, the third set of regressions (columns 4 and 5) distinguishes between two time periods: 2006–08 and 2009–2013.

We highlight that all statistical tests almost unanimously suggest that the regression models are not misspecified and that the overall performance, judged by the adjusted R^2, is very satisfactory.

Before turning to the results, it is important to highlight that the debt is the final output of a negotiation process between the bank (or the lender) and the developer of the project (or the borrower). Banks try to minimize risks, offering debt to 'good' projects (that is, projects with low capital and low costs and, potentially, high revenues). In the case of 'bad' projects, developers try to minimize the equity and maximize the level of debt to reduce their own risk. This suggests that the signs of the coefficients in the regression are not necessarily predetermined by economic theory.

The first regression (column 1) suggests that the leverage of a renewable energy project is explained by its cost. The higher the cost, the lower the debt and leverage. This finding has two implications. The first is that the relationship between leverage and costs is driven by supply, not by the demand for funds. The second is that banks – the supply side – want to minimize risk and, for this reason, are more prone to lend money to 'good' projects.

The size of the project and capacity factor are not significant. The capacity factor is the variable that measures the productivity of the project in terms of electricity generation. According to these results, more productive projects do not seem to have a higher debt leverage. A potential explanation is that future revenues are subject to regulatory changes and, therefore, they are uncertain. Another explanation would be that financiers understand the relevant costs but are not that familiar with capacity factors. In addition, there could be a huge variance between projected capacity factors and outturns, for a variety of reasons. For this reason, banks would focus mostly on costs to determine the risk of a project.

Regressions in columns 2 and 3 explore whether there are differences between 'economic' and 'uneconomic' projects. In both regressions the operating and capital expenses have a negative and significant coefficient, suggesting that projects with lower costs have access to a higher level of debt. The main difference between the two types of project is the role of capacity factor. In the case of uneconomic projects, the capacity factor has a negative and significant coefficient. This implies that less productive projects tend to have access to a lower level of debt. In the case of economic projects, this variable does not seem to be statistically relevant.

Finally, columns 4 and 5 analyse the potential differences before and after the financial crisis. The financial crisis of 2008–09 had a devastating impact on the Spanish financial system and on credit to the private sector. Despite the easing of the financial conditions by the European Central Bank, the sovereign risk premium increased massively, increasing the cost of debt and reducing the financing to the private sector. Pianeselli and Zaghini (2014) find that in 2010–12 Italian, Spanish and Portuguese firms paid on average between 70 and 120 basis points of additional premium due to the negative spill overs from the sovereign debt crisis, while German firms received a discount of 40 basis points. The Bank of Spain (2017) report shows that, outstanding lending to the private sector in Spain dropped by around 6 per cent between December 2008 and December 2011. Many financial institutions disappeared during the recession (Martin-Aceña, 2013). In 2007 Spain had 45 savings banks and by the end of 2012 the number had dropped to 13. The Bank of Spain and the Fund for the Orderly Restructuring of the Banking Sector bailed out seven savings banks, and four of them were nationalized.

Here the results show a relevant finding. There is a change in the parameter associated to capital cost. Before the crisis, the leverage and the capital cost had a positive and significant association. This implies that more expensive projects had access to higher debt. After the crisis, this parameter switches to a negative sign. This suggests that banks reduced substantially the access to financing and, as a result, more expensive projects tended to have a lower debt ratio.

6. Conclusions

There is a growing consensus among policymakers and practitioners on renewable financing: it is considered as the most relevant bottleneck to accelerate the deployment of this technology. Multilateral institutions such as the World Bank and IRENA are developing new instruments to facilitate the financing of these types of projects. Within this context, this study explores the relationship between financial leverage and the key characteristics of renewable energy projects, using data on Spanish wind farms for the period 2006–2013. We want to highlight that the conclusions of this study are limited by the data that we have. In particular, the policy, the market conditions, the cost of the technology, and regulation for renewable projects are changing constantly and differ between countries. These variables have an impact on our findings. However, the conclusions we have come to are consistent with the data and the econometric model used. We think they provide a potentially useful insight.

There are two findings that we consider relevant. Firstly, the capital and operational costs of a project are the main determinants of the level of debt of a renewable project. This is an expected result, since renewable energy is a capital-intensive industry. However, according to our results, the capacity factor of the project has a minor relevance, despite capacity factor is critical to determine electricity generation and the flow of revenues along the maturity of the project. The lack of statistical significance of the capacity factor is an unexpected result. A possible reason is that these projects have a very long period of maturity and future revenues are subject to regulatory changes. Under these conditions, there is a lot of uncertainty about future revenues. For this reason, banks would focus on capital and operational costs to assess the risk of the project and, therefore, to determine the level of debt. In any case, additional research on this aspect is needed. Secondly, the behaviour of Spanish banks towards renewable energy projects changed since the financial crisis of 2008 Before the crisis, more expensive projects tended to have a higher debt ratio. This would suggest a relative abundance of financial credit in the period 2006–09 or, alternatively, a relaxed attitude towards the risk of the projects. After the financial crisis, expensive projects were penalized in terms of access to external financing.

Finally, an interesting implication can be derived from this empirical study. The LCOE is not an adequate variable to understand the access to external financing. The reason is that the LCOE is a function of WACC. The higher the WACC, the higher the LCOE and vice versa. However, the WACC depends on the leverage of the project. For this reason, the LCOE and the cost competitiveness of a renewable project can be be evaluated only after the financial conditions of the project are set.

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