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How do Climate and Macroeconomic Factors Affect the Profitability of the Energy Sector?

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ABSTRACT

This research identifies the significant relationships between climate and macroeconomic variables with the financial profitability (ROA) of energy sector companies in Germany, Norway, France and Spain. We work under the hypothesis of the existence of non-linear relationships for which we fit a Generalized Additive Model (GAM) for each country. We find that macroeconomic variables are often considered more important for modeling profitability than climate variables. This is because general economic conditions, such as interest rates and commodity prices, can have a broader and deeper impact on a firm's financial performance than local climate variations. However, climatic conditions are relevant if the specific industry consists of renewable energy companies. The results of this study can be very useful for financial analysts and investors, as they can adjust their business strategies to improve their financial performance.

Keywords: Asset-liability Management, Generalized Additive Model, Macroeconomics, Renewable Energy, Weather Conditions
JEL Classifications: Q42, Q43, Q54

1. INTRODUCTION

The financial profitability of energy sector companies has been an area of interest for financial analysts and investors. Financial profitability is a key measure of a company's performance, and is influenced by a variety of factors, both internal and external. In addition to financial factors, such as operational efficiency and the efficient use of financial resources, energy sector companies are also influenced by climate and macroeconomic conditions (Jaraite and Di Maria, 2012; Jiranyakul, 2016).

In the energy sector, financial profitability is an even more important indicator, as the sector is highly regulated and investment costs are extremely high. The ability to generate profits is essential for the growth and sustainability of companies in this sector, where, in a developing world, energy is the foundation that sustains and integrates all existing forms of life and also produces the well-being of the population (IEA, 2019). Generation, distribution and marketing depend on supply and demand, which means that external factors can influence the profitability of companies in the sector.

In recent years, there has been a growing interest in the relationship between climate variables and the financial profitability of companies in the energy sector (Cao et al., 2022; Jaraite and Kažukauskas, 2013). Climate variables can have a significant impact on energy production and distribution, which in turn can affect the financial profitability of companies in the energy sector. For example, temperature can affect energy demand (Anton, 2021; Auffhammer and Mansur, 2014), while precipitation and wind speed can affect renewable energy production. As time goes by, new forms of electricity generation are presented, which are categorized into two groups: Renewable and non-renewable energies. Renewable energies are those that come from unlimited resources or whose raw material is quickly recoverable, contributing to cutting-edge issues regarding the environment, while non-renewable energies are those whose origin comes from the exploitation of fossil hydrocarbons such as oil, natural gas and coal, as well as some minerals such as uranium, copper and gold. Because these natural resources are limited or have generation cycles far below the rate of extraction and exploitation, the generation of electricity by this means is becoming increasingly critical and inefficient (Furlan and Mortarino, 2018).

In addition to climatic variables, macroeconomic variables can also have a significant impact on the financial profitability of companies in the energy sector. For example, electricity prices can be affected by oil and gas prices (Mosquera-López et al., 2017; Uribe et al., 2022), which can affect the financial profitability of fossil energy companies, while interest rates and GDP can affect the financial profitability of renewable energy companies.

Therefore, understanding the relationship between macroeconomic and climate variables and financial profitability is essential for making informed investment decisions and for the sustainable growth of companies in the energy sector (Eboli et al., 2010; Huang et al., 2021).

Europe is a clear example of the current external issues affecting the generation, distribution, and commercialization of energy. For example, due to the constant changes in the climate in Europe, the market has been affected for the production of electricity; this is because it is a priority to use renewable sources for electricity generation, helping to reduce the extreme climate changes (Chen et al., 2021). However, the problem with renewable energy sources is that there is a major infrastructure for effective production, Therefore, when strong climate changes occur, such as severe winter storms, countries find it impossible or very scarce to produce electricity through these sources and are forced to produce energy with non-renewable sources (Dowling, 2013). Europe must look to non-renewable energy sources, which come from elements such as oil, natural gas, nuclear energy, among others.

The review of the existing literature on the subject shows that there are previous studies that have evaluated the effect of climate variables on the financial profitability of energy sector companies (Errebai et al., 2022; Jalilzadehazhari et al., 2020). For example, some studies have evaluated the impact of temperature on wind and solar energy production. Other studies have evaluated the impact of precipitation on hydroelectric power production (Addoum et al., 2020; Anton, 2021; Tzouvanas et al., 2019; Wieczorek-Kosmala, 2020). There are also studies that have evaluated the effect of macroeconomic variables on the financial profitability of companies in the energy sector. For example, some studies have evaluated the impact of interest rates on investment in renewable energy projects. Other studies have evaluated the impact of the price of oil, gas or economic growth on the financial profitability of energy companies (Asafu-Adjaye, 2000; Troster et al., 2018).

However, it is important to note that the relationship between these variables is not linear. For example, an increase in temperature may have a positive impact on the financial profitability of energy sector companies up to a certain point, but a further increase in temperature may have a negative impact on the financial profitability of energy sector companies at a certain point, but a further increase in temperature may have a negative impact on the financial profitability of energy companies at a certain point (Anton, 2021). In addition, most of these studies have evaluated the impact of these variables in isolation, without considering their interaction (Cao et al., 2022). Therefore, this research proposes a non-linear methodology that allows for the identification of the relationship between climatic and macroeconomic variables on the financial profitability of energy sector companies.

To develop the empirical approach, a sample of energy sector companies from Germany, Norway, France and Spain will be used. As mentioned earlier, there are multiple factors that can influence the financial profitability of energy sector companies, in this case approximated from the ROA, so the objective of this research is to evaluate the effect of climatic and macroeconomic variables on said profitability. In the climatic variables, temperature, precipitation, solar irradiation and wind speed will be taken into account, and as for the macroeconomic variables, the interest rate, GDP, oil price and gas price will be taken into account.

The results of this study can be very useful for financial analysts and investors. If significant correlations are identified between climate and macroeconomic variables and the financial profitability (ROA) of energy sector companies, investors may be able to adjust their investment decisions accordingly. In addition, managers of energy sector companies can also benefit from the findings of this study. By gaining a better understanding of how climate and macroeconomic variables impact their company's financial profitability (ROA), they can adjust their business strategies to improve their financial performance. For example, if fluctuations in the price of oil and gas are found to have a significant impact on the financial profitability of energy companies, managers can consider diversifying their portfolio of products and services in order to reduce their exposure to these commodity price changes.

Likewise, energy companies can use the information obtained from this study to take measures that mitigate climate risks and increase energy efficiency. For example, if it is found that an increase in ambient temperature has a negative impact on the financial profitability of energy companies, they could implement measures to reduce their energy consumption and minimize their carbon footprint. In this way, not only is the environment protected, but the financial position of the company is also improved.

1.1. Weather Conditions

Temperature is an important climate variable that can affect energy production and consumption. For example, in countries with high temperatures, the use of air conditioning and ventilation systems can increase, which translates into an increase in electricity demand (Dell et al., 2012). On the other hand, in countries with low temperatures, the use of heating systems may increase, which may also increase energy demand (Errebai et al., 2022). In this regard, it could be thought that an increase in temperature could have a positive impact on the financial profitability of companies in the energy sector, as it could increase the demand for energy and, therefore, increase the profits of these companies. However, it should also be noted that the increase in temperature may have negative effects on energy production, especially in the production of hydropower and solar energy. In the case of hydropower, an increase in temperature can reduce rivers flow, which can decrease energy production. In the case of solar power, an increase in temperature can decrease the efficiency of solar panels, which can also decrease energy production. Therefore, the relationship between temperature and the financial profitability of companies in the energy sector is not necessarily linear and may depend on the type of energy being produced and the country in question.

Precipitation is another climate variable that can have an impact on the financial profitability of companies in the energy sector. In the case of hydropower, precipitation is a critical variable as it determines the amount of water available for power generation (Ugurlu et al., 2018). Therefore, an increase in precipitation can increase hydropower energy production and thus increase the financial profitability of companies in the energy sector in this field. However, in the case of solar energy, precipitation can have a negative effect on energy production as it can reduce the amount of solar irradiation available. Similarly, in the case of wind energy, precipitation can affect wind speed, which can decrease energy production. Therefore, as with temperature, the relationship between precipitation and the financial profitability of companies in the energy sector is not necessarily linear and may depend on the type of energy being produced and the country in question.

Wind speed is an important climate variable that can significantly influence the financial profitability of energy companies, especially those involved in wind power generation (Gómez-Quiles and Gil, 2011). Wind power is a renewable form of energy that is directly dependent on wind speed for its generation. As wind speed increases, so does the amount of energy generated by windmills. Therefore, if the wind speed decreases, the amount of power generated will also decrease, which can have a significant impact on the financial profitability of wind energy companies. Companies may be forced to invest in additional technology to increase the amount of power generated during periods of low wind speed. This can have a significant cost and affect the financial profitability of the company. In addition, fluctuations in wind speed can influence the stability of power supply and can affect the company's ability to meet long-term power supply contracts. This can impact investor perception and confidence in the company's ability to generate stable and sustainable revenues.

The ability to generate energy from sunlight is a key feature that defines the profitability of a solar energy company. The amount of energy that can be produced depends on the amount of sunlight that reaches the solar panels. The greater the solar irradiance, the higher the energy production and, therefore, the higher the financial profitability of the company. The profitability of a solar energy company is affected not only by the amount of energy it can produce, but also by the price at which it can sell that energy (Russo et al., 2022).

1.2. Macroeconomic Conditions

Another important factor that influences the financial profitability of companies in the energy sector is the interest rate (Gupta, 2017; Gupta and Krishnamurti, 2018; Wieczorek-Kosmala et al., 2021). When the interest rate is high, companies have higher financial costs to finance their investment projects. This can decrease the financial profitability of the company, since the money used to pay interest cannot be used to finance new projects. On the contrary, when the interest rate is low, companies have lower financial costs, which allows them to finance more investment projects and increase their financial profitability. As for GDP, if it is high, it can be an indicator of a growing economy (Narayan et al., 2010), and, therefore, of a higher energy demand. This can lead to an increase in the financial profitability of energy companies due to higher demand and thus higher revenues. In contrast, a low GDP can be an indicator of a recessionary economy, which can lead to a decrease in energy demand. This can lead to a decrease in the financial profitability of energy companies due to a decrease in revenues.

On the other hand, the price of oil is a factor that can influence the financial profitability of companies in the energy sector. Many companies in the energy sector produce oil and gas, and the prices of these products are highly volatile (Shah et al., 2018; Soroush et al., 2021). When oil prices are low, companies may find it difficult to maintain their financial profitability as their revenues decline. Conversely, when oil prices are high, companies may increase their financial profitability as their revenues increase.

Lastly, gas prices can also have an impact on the financial profitability of companies in the energy sector. Gas is an increasingly used source of energy worldwide, and many companies in the energy sector produce and sell gas (Uribe et al., 2022). When gas prices are high, companies can increase their financial profitability, as their revenues increase. Conversely, when gas prices are low, companies may struggle to maintain their financial profitability.

2. METHODOLOGY

2.1. Generalized Additive Model - GAM

From the statistical perspective, advanced techniques are emerging that allow dealing with non-linear relationships. It is suggested to use a Generalized Additive Model (GAM) which would be ideal under the conditions of the problem because it would provide better predictions since the interaction of factors with profitability does not present a linear relationship (Rigby et al., 2005).

Capa et al. (2014) found that in generalized additive models, the relationship between the response and explanatory variables does not have a similar parametric structure, but is locally adjusted through graphical functions. That is, there is no equation that represents the relationship between variables in a constant way, but rather such equation varies according to the environment of the response values of interest, in this occasion parameters are not estimated, but rather functions are calculated that will be in charge of making a better prediction by means of smoothing the regression. The advantage of this analytical approach is its great flexibility to model complex relationships between response and predictor variables. Its disadvantage is precisely the need for graphical elements for its interpretation, which also makes it difficult to implement (Hastie and Tibshirani, 1987).

The variable Y is then assumed to have a distribution conditional on $X = (x_1, x_2, \cdots, x_p) \in R^p$ given by Hastie and Tibshirani (1987) in equation 1.

$$(Y|X = (x_1, x_2, \cdots, x_p) \sim f(y|\theta(x_1, x_2, \cdots, x_p)) \quad (1)$$

Where $\theta(x_1, x_2, \cdots, x_p)$ is a smooth function of $x = (x_1, x_2, \cdots, x_p)$. To solve the dimensionality problem a simplification of the above model (Multivariate Local Likelihood Model) is proposed. Taking into account the above, the generalized additive model is defined according to equation 2.

$$(Y \mid X = (x_1, x_2, \cdots, x_p)) = \alpha + g_1(x_1) + \cdots + g_p(x_p) + \varepsilon \quad (2)$$

The regression function is represented as $\sum_{j=1}^{p} g_j(x_j)$. Where *gj (xj)* is defined as the smooth unspecified functions (nonparametric in the sense that they will be estimated by nonparametric procedures). A generalized additive model differs from a generalized linear model in that an additive predictor replaces the linear predictor. Specifically, the response Y is assumed to have a given distribution with the mean μ = E (Y|X = (x1, x2,⋯,xp) linked across predictors $\sum_{j=1}^{p} g_j(x_j)$.

The estimation of α and *g1,…gp* is carried out by replacing the weighted linear regression in which the dependent variable is fitted by an algorithm appropriate for fitting a weighted additive model (This product is described in Algorithm 6.1 [Hastie and Tibshirani, 1987]).

The method for estimating a generalized additive model combines the backfitting algorithm (Algorithm 9.2 [Hastie et al., 2009]) with some likelihood maximization algorithm used in fitting generalized linear model. Specifically, a commonly used algorithm for estimating generalized linear models is the one based on iteration of reweighted least squares fits. In this type of algorithm, each adjustment of a weighted least squares multiple regression is replaced by the adjustment of a weighted additive model by backfitting. In this way, the generalized additive model is fitted instead of the corresponding generalized linear model.

GAM is a modern statistical technique that does not require compliance with the assumptions of parametric statistics and allows the fitting of statistical models in accordance with ecological theory (Katsanevakis and Maravelias, 2009).

2.2. Functional Principal Component Analysis

Yao et al. (2005) suggest a method called Principal Component Analysis through Conditional Expectation (PACE) for determining FPC (Functional Principal Component) scores for longitudinal data. Unlike traditional methods, PACE does not individually smooth the underlying common curves that dictate the system dynamics. Instead, it calculates FPC scores from the entire dataset. As explained by Yao et al. (2003), PACE uses the first K eigenfunctions to forecast the path of $X_i(t)$ for the *i-th* energy company given by equation 3:

$$\hat{X}_i^K(t) = \hat{\mu}(t) + \sum_{k=1}^{K} \hat{\xi}_{ik} \hat{\varphi}_k(t) \quad (3)$$

The entire data set is used to estimate the eigenvalues and the eigenfunctions in the following way (equation 4):

$$\hat{\xi}_{ik} = E\left[\xi_{ik} \mid \tilde{Y}_i\right] = \hat{\lambda}_k \hat{\varphi}_{ik}^T \hat{\Sigma}_i^{-1}\left(\tilde{Y}_i - \hat{\mu}_i\right) \quad (4)$$

Where $\hat{\Sigma}_i = \hat{G}_i + \sigma^2 I$, and $\tilde{Y}_i = \left(Y_{i1}, \ldots, Y_{iN_i}\right)^T$.

3. DATA

To approximate our empirical exercise, we used information from 56 energy sector companies within the countries of Germany, Norway, France and Spain. Of which, there are Oil and Gas, Oil and Gas Related Equipment and Services, Renewable Energy companies. Table 1 shows the number of companies in the sample by country and industry type. The selection of the sample for the empirical exercise was generated by the availability of information within the Refinitiv platform. We used the historical series of the ROA indicator for each of the companies on a quarterly basis from the last quarter of 2002 (2002-Q4) to the last quarter of 2022 (2022-Q4) for a total of 81 periods. The source of this information is REFINITIV.

Since there was some missing data in the time series, the FPCA was used to find the smooth functions of the profitability of each of the companies, and an average function per country was generated to represent the profitability of the energy companies. Figure 1 shows the smoothed profitability functions in gray, and in addition, the average profitability function in green for each country in the sample.

As for the climate information, georeferenced information for the countries was used from The Prediction of Worldwide Energy Resources (POWER) project by NASA'; likewise, the time period was quarterly from 2002-Q2 to 2022-Q2. The selected climatic variables are related to energy generation and demand, for each of the four countries we observe in Figures 2-5 the variations in temperature, precipitation, wind speed and solar irradiation.

The macroeconomic information comprises variables such as short-term interest rate, Gross Domestic Product (GDP), oil price (Brent) and gas price (TTF), the latter specifically from the period 2005-Q1. These macroeconomic variables were extracted from the OECD database.

Table 1: Distribution of companies in each country and industry

Country	Industry	Subtotal	Total
Germany	Oil and gas related equipment and services	1	9
	Renewable energy	8	
Norway	Oil and gas	9	37
	Oil and gas related equipment and services	26	
	Renewable energy	2	
France	Oil and gas	1	3
	Oil and gas related equipment and services	2	
Spain	Oil and gas	1	3
	Oil and gas related equipment and services	2	

Figure 1: Smoothed average profitability functions

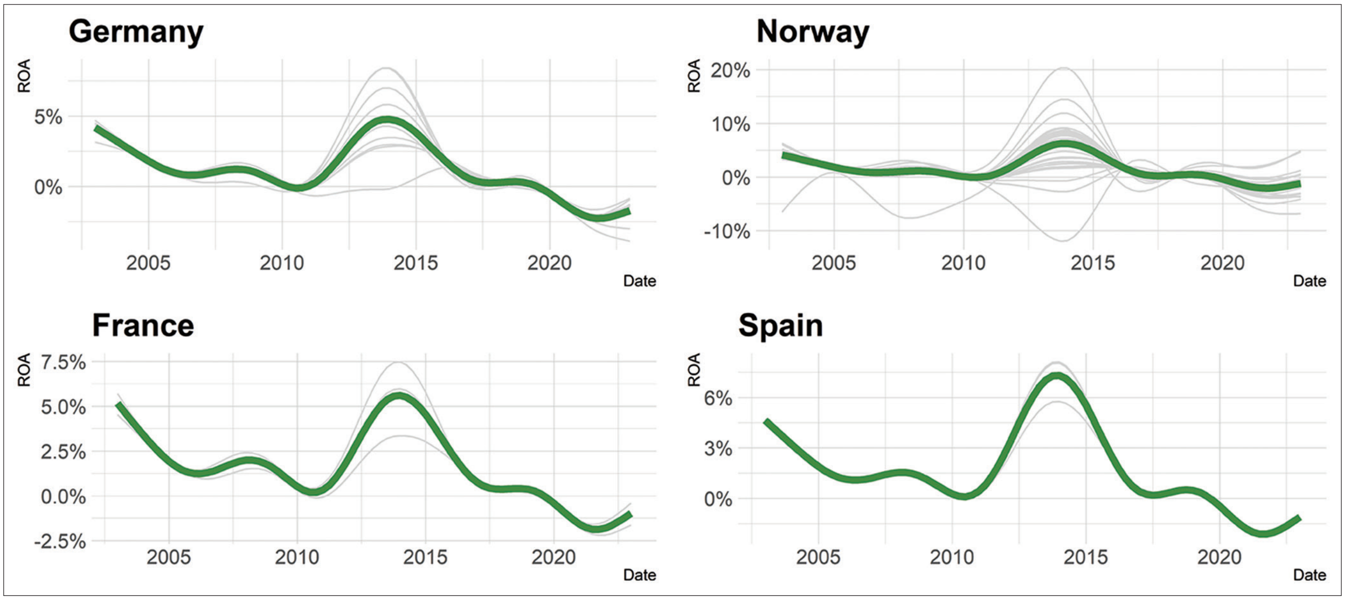


Figure 2: Climate variation in Germany

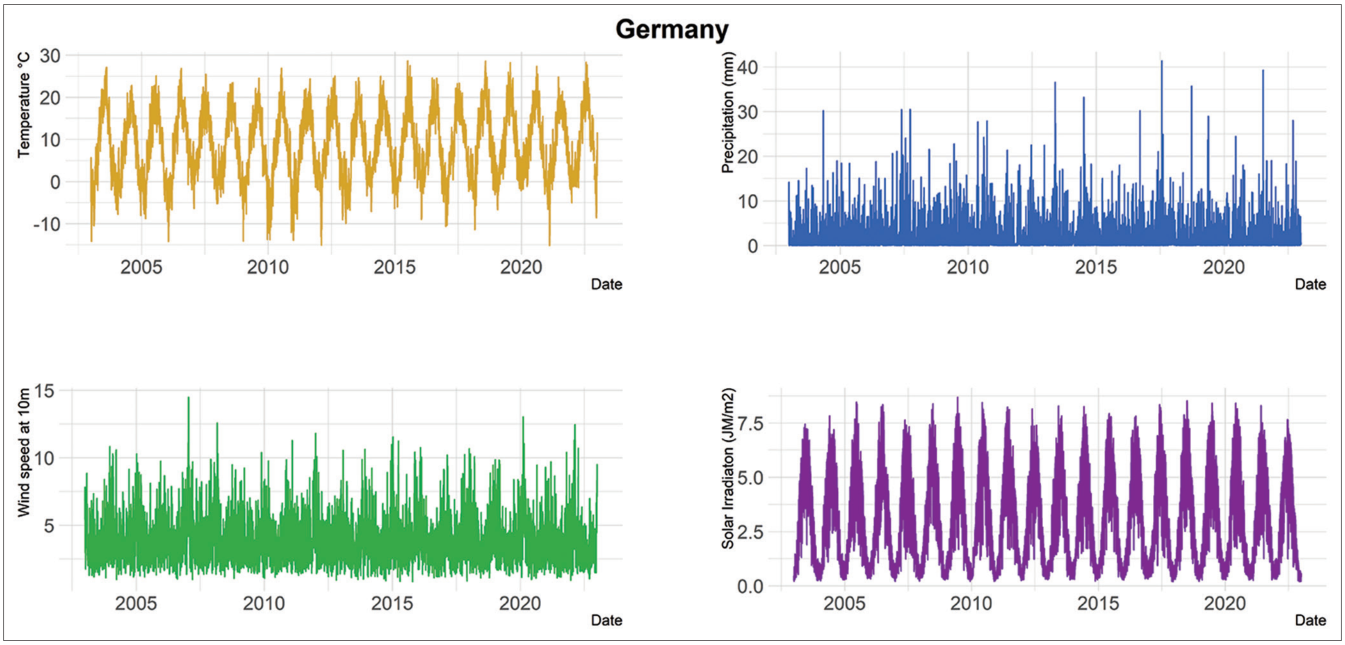


Figure 1 shows a decreasing trend over time for each of the countries. All four countries show a increase in profitability around 2014 followed by a noticeable decrease up to the present date.

In terms of climatic information, the seasonal variations that affect these countries, in addition to the cold temperatures in Norway, are clearly perceived. In contrast, Spain has had a warmer behavior over time. France presents in the last period higher precipitation levels than the historical average. Regarding wind speed, countries such as Germany and France have historically presented higher levels of wind speed. Table 2 summarizes the descriptive statistics for each of the variables in each country.

4. EMPIRICAL RESULTS AND DISCUSSION

The different estimates of our GAM model for each of the countries are shown in Table 3. This table covers the smoothed terms of the model, it should be noted that we do not include any linear terms for the model. The smoothed coefficients are not printed since each smoothing has several coefficients, one for each basis function. Instead, the first column *edf*, which stands for effective degrees of freedom, represents the complexity of the smoothing. An *edf* of 1 is equivalent to a straight line. An *edf* of 2 is equivalent to a quadratic curve and so on, with higher *edf* describing more wavy curves. Figures 6-9 one can observe the plot that shows the different degree of smoothness of the estimate.

Figure 3: Climate variation in Norway

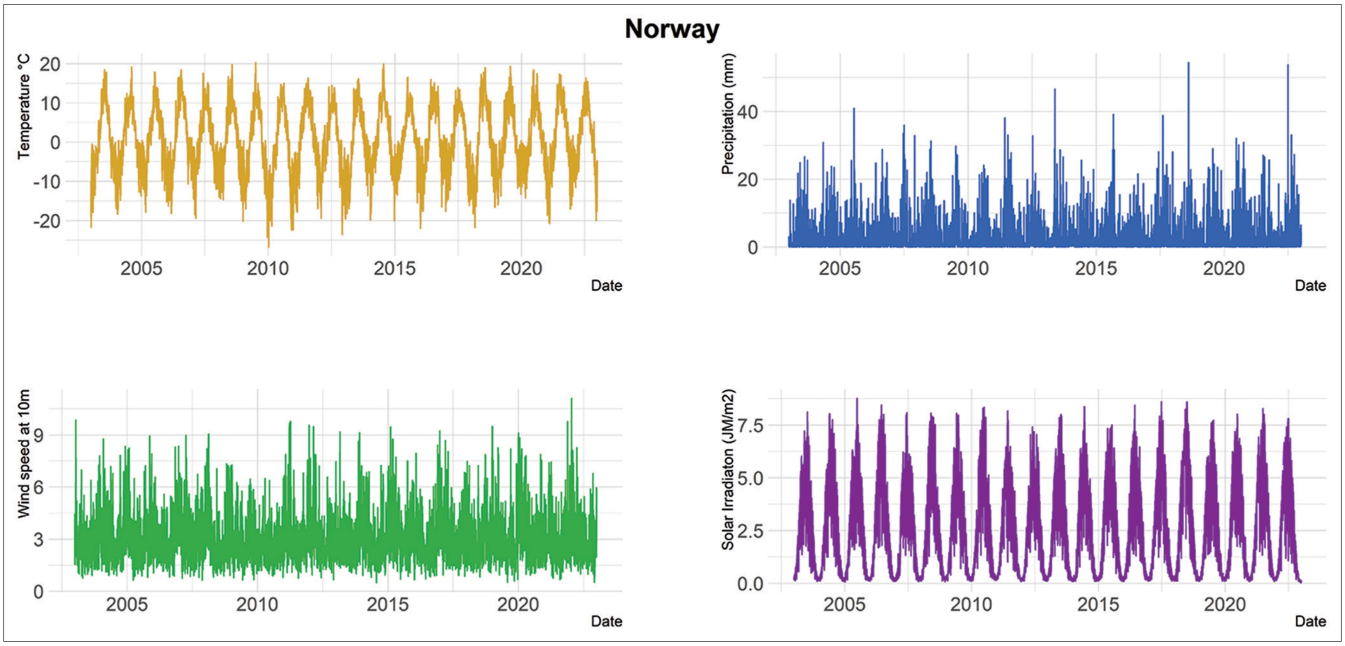
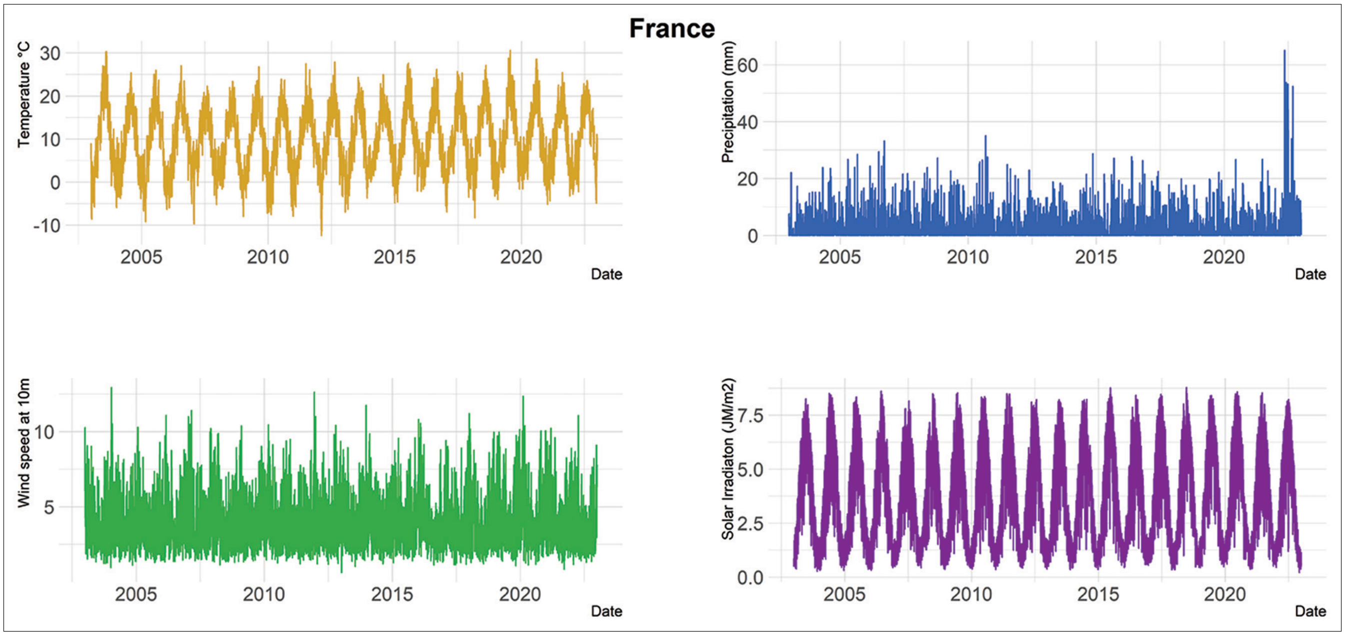


Figure 4: Climate variation in France



The terms to the right of the *edf* column have to do with significance tests for smoothing. The *Ref.df* and *F* columns are test statistics used in an ANOVA test to test the overall significance of smoothing. The result of this test is the P-value on the right. A good way to interpret the significance of smoothed terms in GAM is as follows: a significant smoothed term is one which no horizontal line can be drawn across the 95% confidence interval. Note that high *edf* does not necessarily mean significance or vice versa. A smoothing can be linear and significant, non-linear and non-significant, or one of each.

In the case of Germany (Figure 6), on the climatic variables side we find that there is a significant relationship between profitability with irradiance, and temperature at a significance level of 0.10. In the case of macroeconomic variables, we find that there is a significant effect with interest rate, oil price and gas price.

Our model for Germany specifically shows that, when the temperature increases above 20°C the profitability of the companies tends to increase, indicating a positive effect on the ROA of the companies. One possible reason for this could be that the increase in temperature may lead to an increase in demand for energy for refrigeration and air conditioning. This can increase the price of energy in the market and thus improve the profitability of energy-producing companies.

Figure 5: Climate variation in Spain

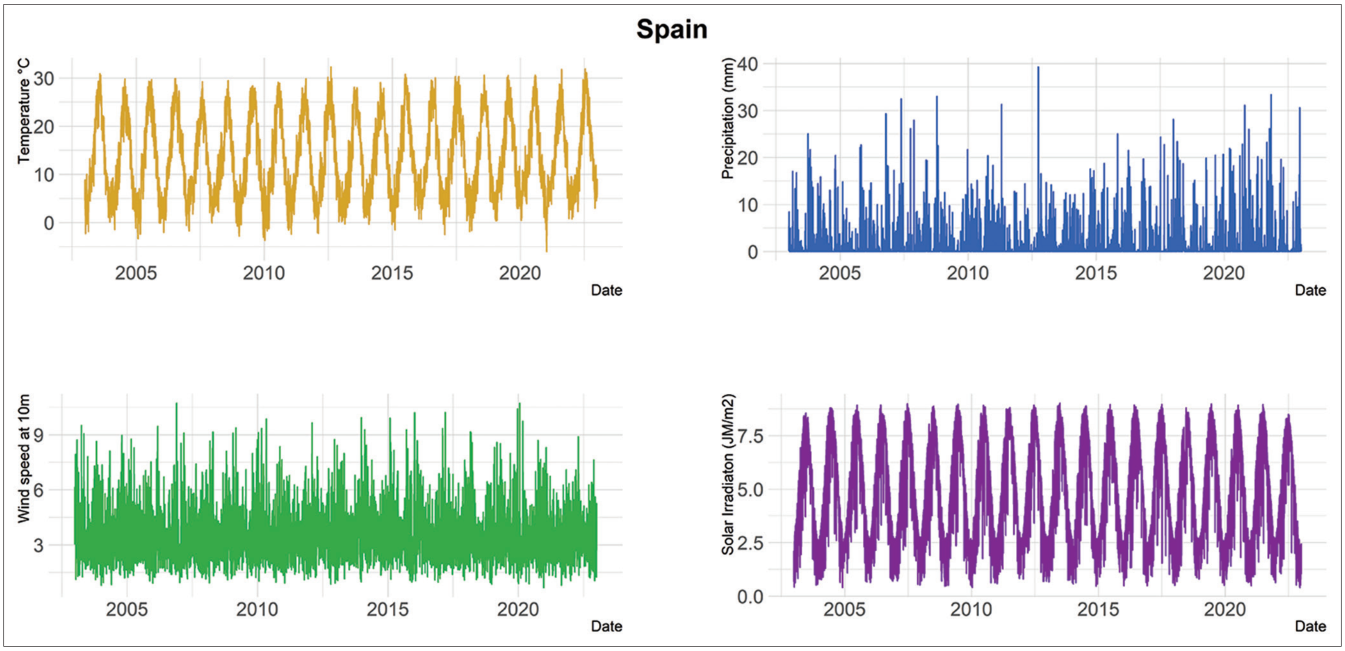


Table 2: Descriptive statistics of climate and macroeconomics variables in each country

Country	Indicator	Mean	SD	Min	Max
Germany	ROA (%)	1.14	1.88	−2.26	4.78
	Temperature (°C)	8.61	7.99	−15.17	28.62
	Precipitation (mm)	1.92	3.33	0.00	41.35
	Solar irradiation (W/m^2)	3.00	2.08	0.19	8.69
	Wind Speed at 10 m (m/s)	3.90	1.75	0.82	14.49
	Short-term interest rate (%)	1.08	1.58	−0.57	4.98
	GDP (%)	0.30	1.72	−9.48	9.00
Norway	ROA (%)	1.40	2.16	−2.08	6.24
	Temperature (°C)	0.53	8.44	−26.72	20.29
	Precipitation (mm)	2.67	4.52	0	54.48
	Solar irradiation (W/m^2)	2.58	2.14	0.03	8.76
	Wind speed at 10 m (m/s)	2.99	1.39	0.49	11.10
	Short-term interest rate (%)	2.32	1.57	0.25	6.94
	GDP (%)	0.41	1.32	−5.41	4.43
France	ROA (%)	1.58	2.02	−1.87	5.60
	Temperature (°C)	9.77	7.22	−12.40	30.62
	Precipitation (mm)	2.27	4.17	0	65.12
	Solar irradiation (W/m^2)	3.60	2.20	0.21	8.78
	Wind speed at 10 m (m/s)	3.98	1.73	0.62	12.94
	Short-term interest rate (%)	1.08	1.58	−0.57	4.98
	GDP (%)	0.31	2.68	−13.50	18.28
Spain	ROA (%)	1.67	2.44	−2.11	7.31
	Temperature (°C)	13.60	8.34	−5.99	32.28
	Precipitation (mm)	1.24	3.17	0	39.27
	Solar irradiation (W/m^2)	4.75	2.33	0.40	9.01
	Wind speed at 10 m (m/s)	3.47	1.41	0.67	10.72
	Short-term interest rate (%)	1.08	1.58	−0.57	4.98
	GDP (%)	0.33	2.91	−17.83	16.64

As for Irradiance, if it increases by around 7 W/m^2, profitability is expected to decrease slightly. A possible reason for this could be that, in the context of solar energy production, an increase in irradiance may lead to higher energy production, which could lower the price of energy in the market due to an increase in supply. This could, in turn negatively affect the profitability of solar energy companies, as they would have to sell their energy at a lower price.

The interest rate shows an oscillatory behavior, if it is below zero profitability decreases, while if it increases profitability begins to increase. This result goes against the hypothesis stated at the beginning. In general, an increase in the interest rate can have both positive and negative effects on the profitability of companies in the energy sector. On the one hand, an increase in the interest rate can reduce financing costs for energy companies in Germany, which can increase their profitability. If companies have short-term debts, an increase in the interest rate can decrease their financial burden, which can have a positive effect on their ROA. In this case, this can be explained by the fact that our interest rate is short term, for which, companies can take advantage of interest rate increases to renegotiate their short-term loans and obtain new, more favorable conditions. If companies renegotiate their loans at a higher interest rate, but with a longer term for repayment, they can reduce their financing costs in the short term. That is, the increase in the interest rate allows them to obtain a better interest rate for the next term of their loans and thus reduce their cost of financing. On the other hand, an increase in the interest rate can also have a negative impact on the overall economy, which in turn can affect energy companies. If the increase in the interest rate leads to a decrease in the demand for energy in the economy, energy companies may experience a decrease in their revenues and a decrease in their profitability. In addition, if energy companies have long-term debt, an increase in the interest rate may increase their cost of financing, which may reduce their profitability and decrease their ROA.

As for BRENT, if it rises above 100 USD, companies perceive positive effects on their profitability. Finally, as for the TTF, if the price of gas increases, the profitability of companies decreases. This could be explained by the fact that an increase in the price of natural gas would affect the energy production cost of energy companies in Germany, which could in turn reduce their profitability. If companies cannot increase their energy selling

Table 3: Estimates of the GAM model for each country

Smooths	Germany				Norway				France				Spain			
	edf	Ref.df	F	P-value	edf	Ref.df	F	P-value	edf	Ref.df	F	P-value	edf	Ref.df	F	P-value
s(Temp)	3.42	4.10	2.15	0.09.	1.00	1.00	1.98	0.17	1.00	1.00	0.00	0.99	1.00	1.00	0.16	0.69
s(Prec)	1.00	1.00	0.01	0.91	1.00	1.00	0.83	0.37	1.65	1.94	0.94	0.42	1.00	1.00	0.00	0.98
s(Wind)	1.00	1.00	0.89	0.35	1.00	1.00	6.02	0.02*	1.00	1.00	0.01	0.93	1.56	1.92	0.94	0.46
s(Irrad)	4.70	4.94	4.26	0.00**	3.14	3.71	1.80	0.17	1.02	1.04	0.00	0.98	3.37	3.95	1.32	0.34
s(IRShort)	4.96	5.00	37.09	0.00***	4.33	4.75	6.05	0.00***	4.93	4.99	33.78	0.00***	4.93	4.99	36.08	0.00***
s(GDP)	2.86	3.38	1.46	0.25	3.10	3.73	1.51	0.18	1.00	1.00	0.28	0.60	1.00	1.00	0.05	0.83
s(Brent)	3.57	4.22	3.92	0.01**	3.74	4.35	2.75	0.04*	3.92	4.51	5.48	0.00**	3.69	4.32	6.51	0.00***
s(TTF)	4.96	5.00	11.81	0.00***	3.65	4.19	8.05	0.00***	1.88	2.34	9.33	0.00***	1.95	2.41	9.71	0.00***
Deviance	91.9%				76.5%				85.2%				86.2%			

This table shows the significant associations according to the GAM model. Levels of significance are signaled by p-values (0.001=***, 0.01=**, 0.05=*, 0.1=.). s() indicates the smoothing function. Temp: Temperature. Prec: Precipitation. Wind: Wind speed. Irrad: Solar irradiation. IRShort: Interest rate (short-term). GDP: Gross Domestic Product. Brent: Brent oil prices. TTF: Gas prices

Figure 6: Estimated GAM model smoothing - Germany

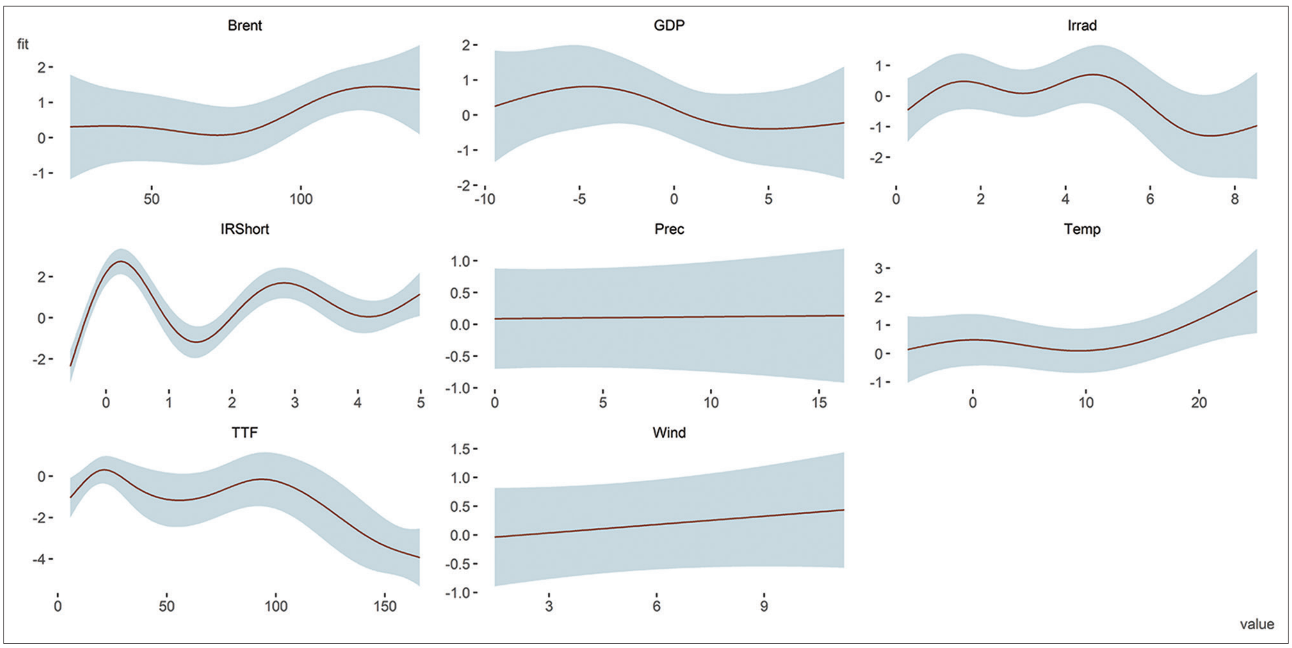


Figure 7: Estimated GAM model smoothing - Norway

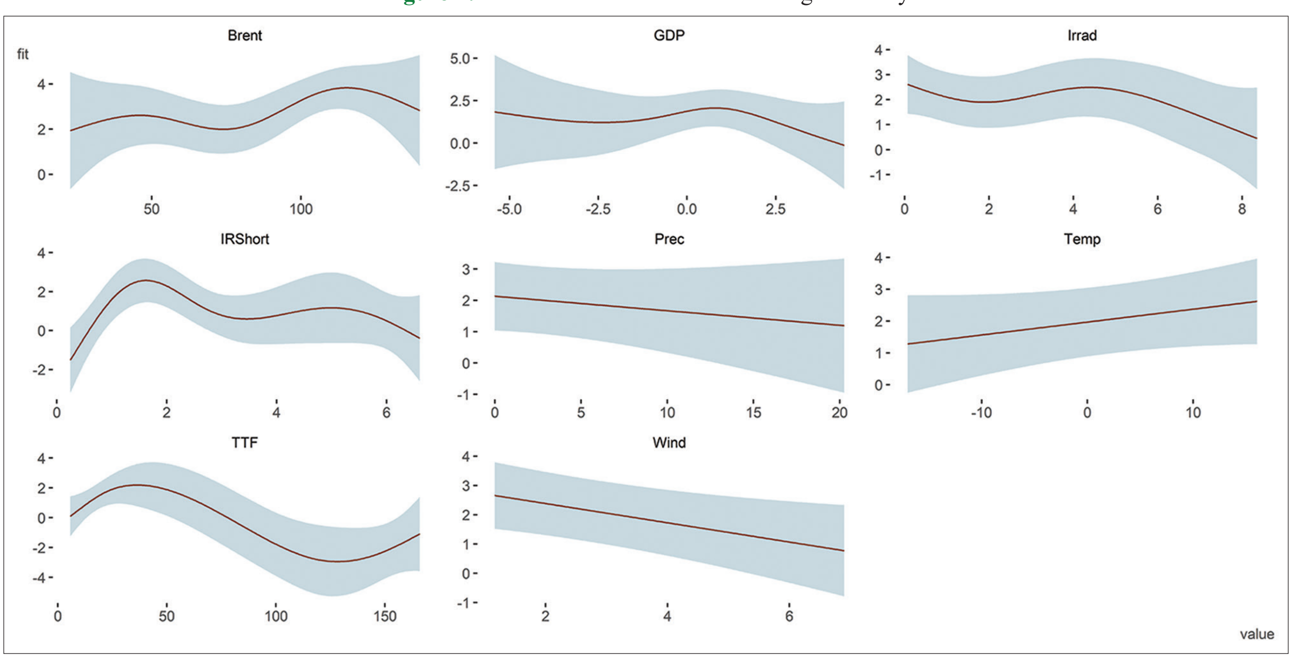


Figure 8: Estimated GAM model smoothing – France

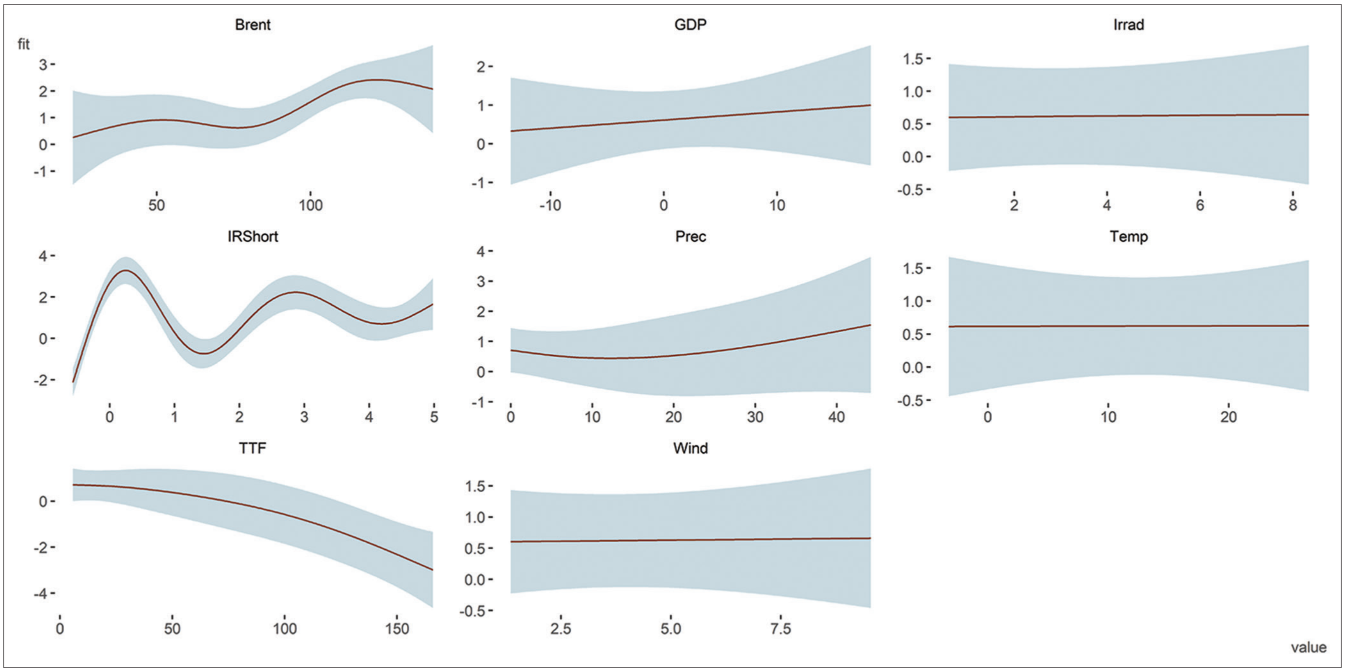
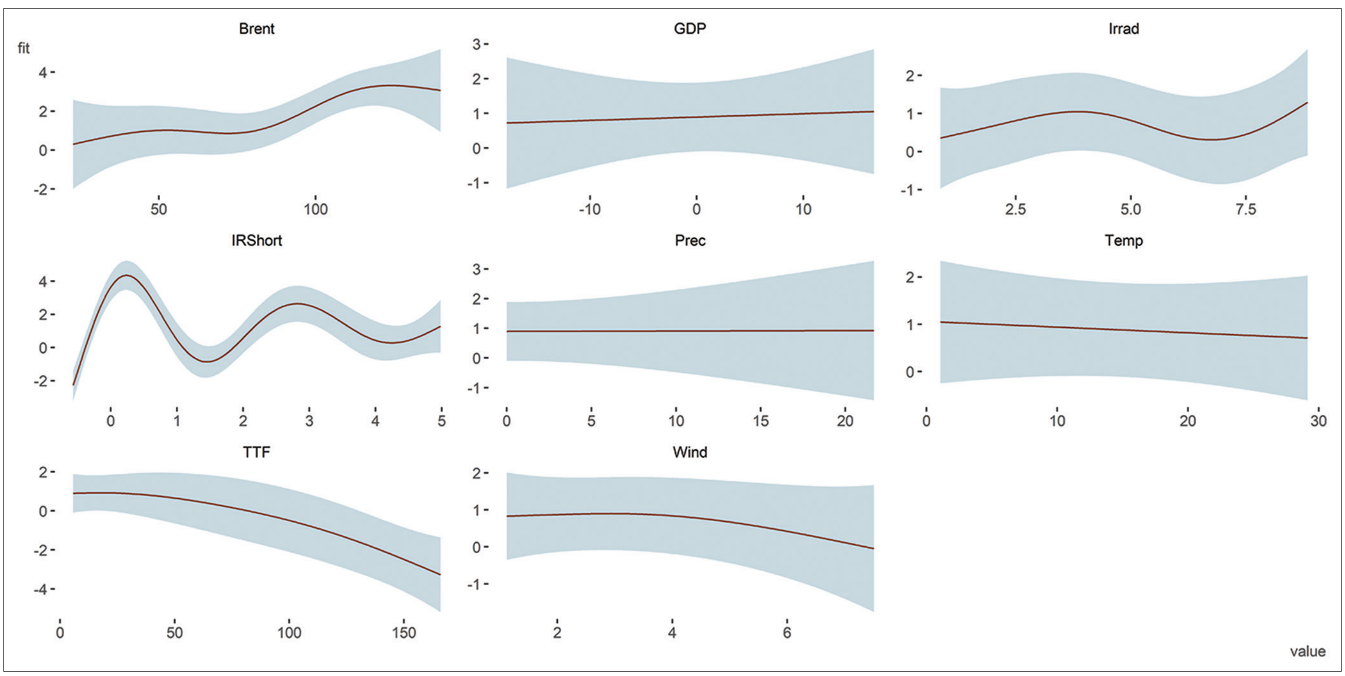


Figure 9: Estimated GAM model smoothing – Spain



prices in the same proportion as the increase in the gas price, their profit margin will decrease and their ROA will also decrease. In addition, an increase in the price of natural gas could increase the operating costs of energy companies in Germany, which could also reduce their ROA. As a result, companies may be forced to look for more profitable alternatives, such as renewable energy production, to maintain or improve their profitability in this scenario of rising natural gas prices.

Regarding Norway, in Figure 7 we find that the wind speed, interest rate, oil price and gas price are significant in explaining the profitability of energy sector companies. The effects of interest rate, oil price and gas price are similar to those presented in Germany. As for wind speed, the following behavior is shown: a positive effect is always perceived, but it decreases as wind speed increases. In general, as wind speed increases, wind power production increases, which increases the company revenues. However, as wind speed increases, the load on wind turbine components also increases, which can reduce turbine life and increase operation and maintenance costs. In addition, when the wind speed is too high, the turbine can be damaged or even stop working, which can result in additional costs for the company.

Therefore, if the wind speed is too high, company profitability may decrease due to additional repair and maintenance costs. In the specific case of Norway, most of the energy generated in the country comes from hydropower, which is a very cost-effective renewable energy source. Therefore, although wind energy is an important source of renewable energy in Norway, it may be more difficult for energy sector companies that generate wind energy to maintain high profitability compared to other European countries with less hydropower.

In the case of France and Spain (Figures 8 and 9) significant effects are found for the interest rate, oil price and gas price variables. These exhibit the same behavior described above for Germany and Norway. In this case, it is worth noting that in our sample for France and Spain we do not have companies classified in the renewable energy sector, therefore, it is to be expected that our model would not identify a climate factor as significant.

Finally, our models achieve a high goodness-of-fit measured by the deviance in Table 3, with Germany being the country with the best fit quality at 91.9%, followed by Spain at 86.2%, France at 85.2% and Norway at 76.5%.

5. CONCLUSIONS

The findings of this analysis indicate that there are significant relationships between climate and macroeconomic variables with the profitability of energy sector companies in Germany and Norway. In Germany, temperature has a positive effect on profitability when it exceeds 20°C, possibly due to an increase in energy demand for refrigeration and air conditioning. Solar irradiation has a negative effect on profitability when it increases, possibly due to an increase in solar energy production and a decrease in market prices. The interest rate has an oscillating effect on profitability, with positive and negative effects, depending on the financing conditions of the companies. The oil price has a positive effect on profitability above USD 100 per barrel, while the gas price has a negative effect on profitability. In Norway, wind speed has a positive effect on profitability, but this effect decreases as wind speed increases. Overall, these results indicate the importance of considering both climatic and macroeconomic variables when analyzing the profitability of energy sector companies in different geographical contexts.

We cannot conclude that climatic and macroeconomic factors are more important in explaining profitability, as the relative importance of climatic and macroeconomic variables in modeling profitability may vary depending on the industry sector and the specific company in question.

However, in general, macroeconomic variables are often considered more important for modeling profitability than weather variables. This is because general economic conditions, such as inflation, interest rates, fiscal and monetary policies, can have a broader and deeper impact on a company's financial performance than local weather variations.

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