UNIVERSIDAD DE CANTABRIA

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ELECTRICITY AS KEY TO ECONOMIC REGENERATION

LA ELECTRICIDAD COMO CLAVE DE LA REGENERACIÓN ECONÓMICA

En un contexto de diferentes subidas en el precio de la electricidad, vamos a analizar que repercusiones económicas tendría una bajada en el precio de la electricidad a través de reducciones impositivas asociadas.

In a context of different increases in the price of electricity, we are going to analyze what economic repercussions would have a drop in the price of electricity through associated tax reductions.

GRADO EN CIENCIAS ECONÓMICAS

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1. INDEX

2. SUMMARY

En un contexto en el que en España está incrementando el precio que el consumidor medio de electricidad paga por este recurso, en una situación de incertidumbre en los mercados acompañado de una recesión económica ocasionada por una crisis sanitaria, en este ensayo vamos a analizar qué consecuencias económicas tendría una disminución del tipo impositivo asociados al consumo energético. Además, se contextualizará la situación del sector eléctrico en el conjunto de la comunidad europea, comparándolo con los principales países europeos.

In a context in which in Spain the price paid by the average electricity consumer is increasing, in a situation of uncertainty of the markets accompanied by an economic recession caused by a health crisis, we are going to analyze what economic consequences would have a decrease in the tax rate associated with energy consumption. In addition, the situation of the electricity sector in the European community as a whole will be contextualized and compared with the main European countries.

3. INTRODUCTION TO THE ELECTRICITY

In Spain electricity arrived in 1852 in Barcelona and, as in many other European countries, it served for the primary use of lighting people's homes and cities[1]. This way, the most important streets and avenues of the big cities had lighting, as well as different wealthy houses, and this is what began to familiarize the population of Spain with this new form of energy. In time it gradually developed, while power producing companies were also developing.

In 1881 the Spanish Electricity Society was established, and this amenity began to be industrially exploited[2]. It all started with the creation of small thermal power plants, very limited in the beginning, but which over the years allowed the introduction of electricity into the production process, and with the implementation of trams in order to improve transport in the cities[3]. The production of electricity continued to develop and, in the 20th century, between the mid 70s and the early 80s, the main way to obtain electricity was through hydraulic power[4]. This improvement facilitated the development of electricity companies. Among them, there was the Lebon Gas and Electricity Company, which obtained control of much of eastern Spain through different pacts and agreements between companies. All this expansion of the electricity sector was halted in 1936 with the outbreak of the Spanish Civil War, which increased the price of coal, the main resource for both electric and gas thermal power plants, and many of them closed due to the competition from large hydroelectric plants. After the outbreak of the war, many of these power plants were seized, either by the Republican side or by the nationalist side[5].

So, based on the above information, we can find three major stages in the production process. At its beginnings in 1852, there was a first stage in which the electricity was placed in the hands of the private sector, small companies were in charge of its

[1] Cayón García F. Universidad Autónoma de Madrid, *Electricidad e Historia la perspectiva de un siglo,* 15 May 2014, 113-120

[2] Maluquer de Mortes J. Universidad Autónoma de Barcelona, In: *Los pioneros de la segunda revolución industrial en España: La Sociedad Española de Electricidad*, 1992, 124-130.

[3] García Marín R. and Espejo Marín C. Universidad de Alicante, In: Agua y Energía: Producción hidroeléctrica en España, March 2010, 107-113.

[4] Frolova Ignatieva M. and Pérez Pérez B. Universidad de Granada, In: El desarrollo de las energías renovables y el paisaje: algunas bases para la implementación de la convención europea del paisaje en la política energética española, December 2008, 290-294.

[5] Fernández Paradas M. Universidad de Málaga, In: La compañía española de electricidad y Gas Lebon en la Guerra Civil Española, October 2020, 618-623.

production, e.g. the initial thermal power plants. Later, the interwar period (1918 to 1939) brought the nationalization of energy services and of other services of general interest, including electricity. This is how a state monopoly of this sector was established after the victory of the nationalist side after the Spanish Civil War.

After these stages, we encounter the liberalization of the energy sector in search of a greater competition, which in Spain began in 1997 with the enactment of the Electricity Sector Law, that established a regulation on the Spanish electricity sector in order to guarantee a supply of quality electricity at a minimum cost. This stage is characterized by different laws in favor of the defense of the consumers and is currently in practice, e.g. the law 24/2013 of the electricity sector that establishes a quality service, as well as the right to claims of the consumer. Environmental protection measures are also added, which had not been considered in previous years[6].

After the liberalization of the electricity sector, we have, on the one hand, the companies, which achieved greater decision-making and price setting power, regulated with the free market, setting a price that is the result of competition - taking into account the small number of competitors it resembles more of an oligopoly. On the other hand, we have the state (the PVPC - Voluntary Price for the small Consumer), which through the law of supply and demand sets a price per hour for each hour of a day, also including different costs of access tolls and a small benefit for the electricity seller. In this way, the consumer has the possibility to choose whether they want to pay the state prices or the companies' free market prices for their electricity consumption.

Electricity billing is separated into two large subdivisions, on the one hand, there is the capacity quota, which is obtained from the contracted capacity and the price set for that capacity, and obviously the days of the contract, and on the other hand, there is the energy quota, which depends on the electricity consumption of the invoiced period and the price set per kilowatt-hour. Once this amount has been obtained, taxes are applied, first the electricity tax and then the VAT is added.

The problem appears when it comes to obtaining the final amount after taxes, because instead of adding the two amounts and calculating the tax on the total, it is first calculated with respect to the electricity tax, and from the result the VAT is obtained, then in this way not only the electricity consumption is being taxed, but also the electricity tax, thus paying a tax on another tax, which violates the General Tax Law that prevents charging a tax on another tax. In this case electricity is another of the exceptions such as alcohol and tobacco, but due to the importance of electricity for daily life it could be corrected. This way, just by correcting this imbalance, it would already mean a reduction in the tax

[6] Jiménez J. C. Comisión Nacional de Energía, In: Una nota sobre los efectos de la liberalización del sector energético español, November 2008, 1-7.

burden associated with electricity, but to make the conclusions even clearer, we will also add an additional decrease in the VAT associated with electricity.

4. EUROPEAN ELECTRICAL SITUATION

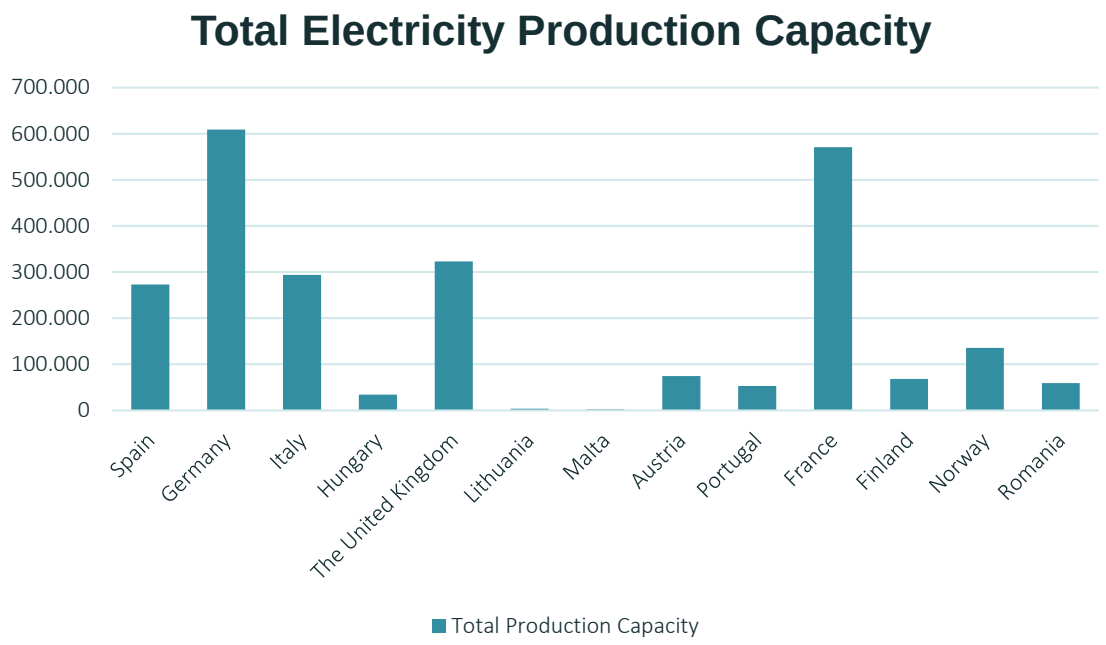
In this section we are going to analyze the main indicators of the Spanish energy sector in relation to the main European countries, in order to obtain a more accurate picture of the situation of the sector.

Among the indicators to be used for this purpose there are: electricity production capacity, the share of renewable energies from the total produced, the balance of physical exchanges of electrical energy between countries, electricity prices, market share of the largest generator of the electricity market, general satisfaction with the quality of the electricity service and the reliability of the electricity service by country.

The countries analyzed have been selected according to a diversity criterion, so that there are poor countries, rich countries, Northern, Eastern, Western and Central European countries, in order to get a real image of the European electricity sector. For this purpose, the following countries will be analyzed: Spain, Germany, Italy, Hungary, the United Kingdom, Lithuania, Malta, Austria, Portugal, France, Finland, Norway, and Romania.

4.1. TOTAL ELECTRICITY PRODUCTION CAPACITY

The first indicator that we are going to analyze is the electricity production capacity of the selected countries. This way we can get an idea of the situation that each country has in its annual electricity production. This production is measured in gigawatt-hours of electricity and the sample is for the year 2020, with the following results:

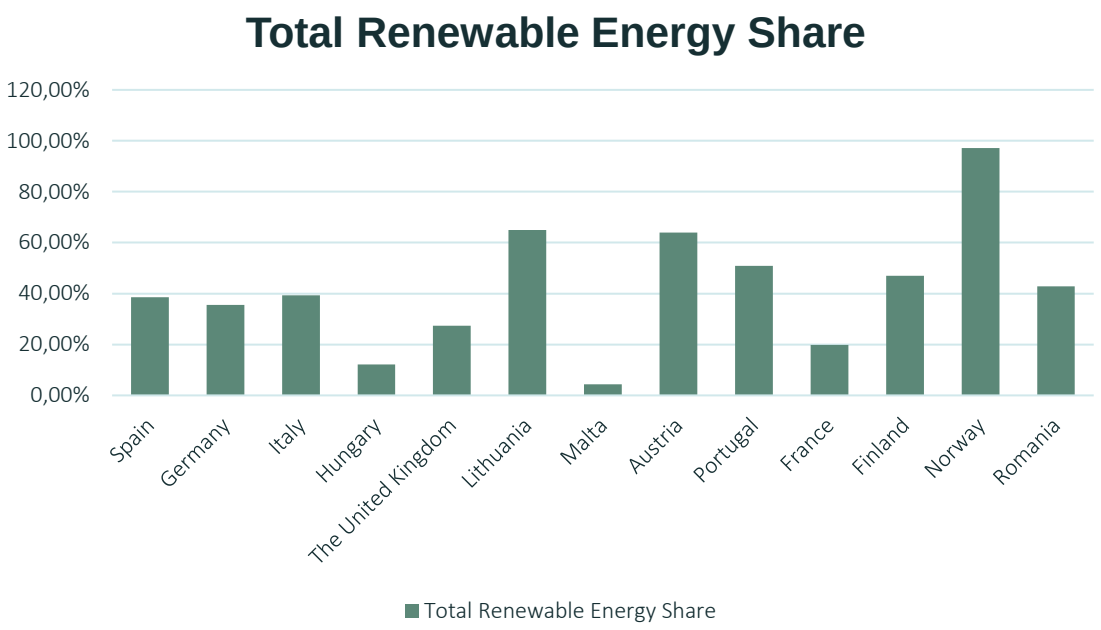


Personal contribution based on EUROSTAT, Gross and net production of electricity and derived heat, 2020.

We find that the country with the highest electricity production of our selection is Germany, evidently due to its high industrial demand for electricity, followed by France, the United Kingdom, Italy and Spain. On the contrary, the countries with the least production of electricity are Malta, due to its tiny national territory, followed by Lithuania, which, although is similar to Austria in size, has a reduced capacity of electricity production due to its low industrial development and infrastructure.

4.2. RENEWABLE ENERGY SHARE FROM THE TOTAL PRODUCED

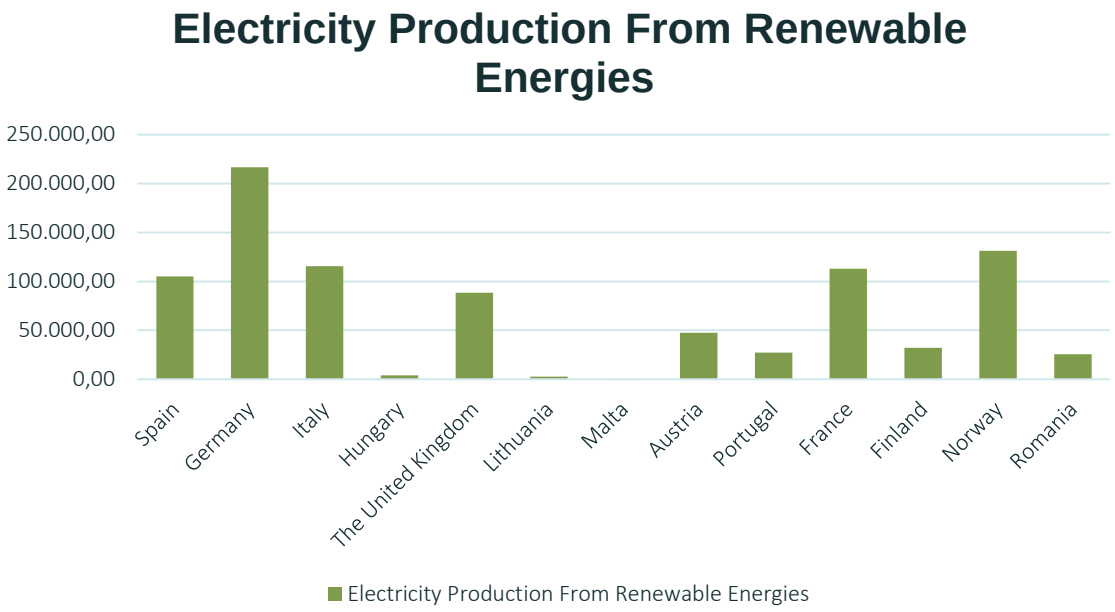
Nowadays a growing concern about environmental emissions could be observed as a trend. Therefore, many countries have increased the implementation of renewable energies in obtaining electricity. To analyze this implementation of renewable energies we rely on data on the percentage of participation in the total electricity production of these new technologies, for the year 2018.



Personal contribution based on ENTSO-E Data Portal 2018, Spain REE.

The country with the highest impact of renewable energy is Norway, with 97.10% of its total electricity production, followed by Lithuania (65%) and Austria (64%). This does not mean that these countries have the highest electricity production from renewable energies, for we have seen in the indicator of productive capacity that these three countries are among those with the lowest electricity production of our selection.

On the other hand, Germany, with only 35.36% renewable energy, produces 216,827.14 gigawatt-hours compared to the 131,368.53 gigawatt-hours produced by Norway with its 97.10%. Therefore, this first percentage is not significant to highlight this indicator, but we can use the total amount produced from renewable energies measured in gigawatt-hours, obtaining the following results:



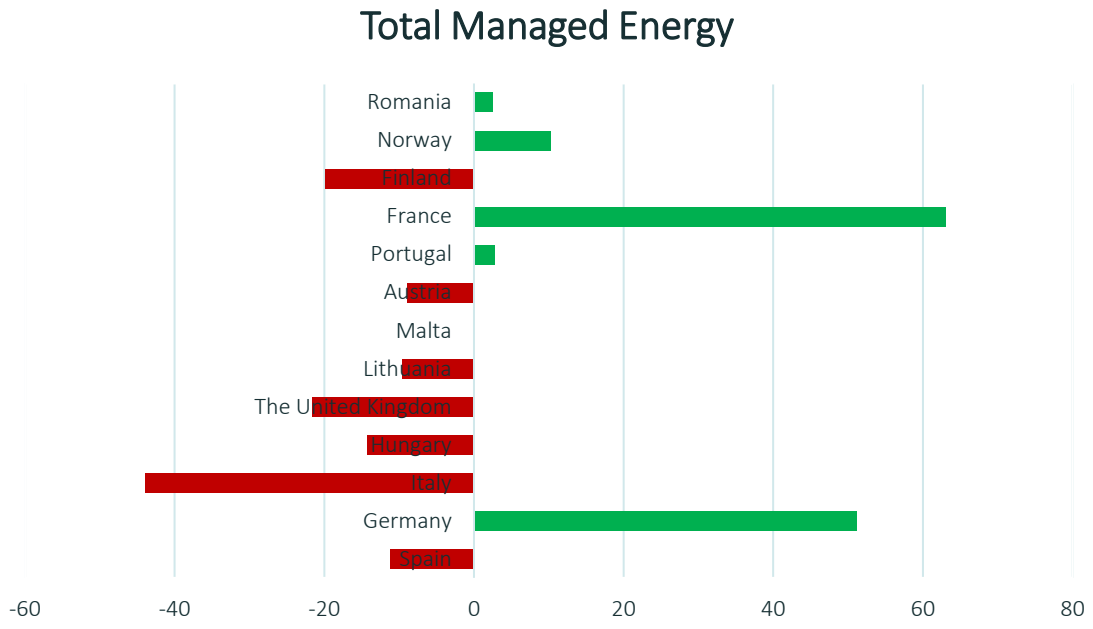
Personal contribution based on ENTSO-E Data Portal 2018, Spain REE and Eurostat, Gross and net production of electricity and derived heat, 2020.

Therefore, if we look at the percentage of renewable energy production with respect to national electricity production, the countries with the highest participation would be Norway, Lithuania and Austria, but these three countries are not the ones with the highest production of renewable energy , since if we analyze the production in gigawatt-hours of these renewable energies, which would be more significant for this variable, we obtain that the countries with the highest production in renewable energies are Germany, Norway and Italy, and those with the least production from renewable sources are, despite their large share in the production of these energies, Malta, Lithuania and Hungary.

4.3. BALANCE OF PHYSICAL EXCHANGES OF ELECTRICAL ENERGY BETWEEN COUNTRIES

Previously, the electricity production was determined by the national electricity demand, but that has already changed, since many countries have a higher demand than their national electricity production, requesting an electricity import from a contiguous country. The opposite situation exists as well, namely countries that have a very low demand and produce more to supply neighboring countries, therefore, there are importers and exporters of electricity.

Next, with this new indicator we are going to analyze whether the country is an exporter or importer of electricity, depending on whether the TWH, the total managed energy, is positive (exporter) or negative (importer) for the year 2018.

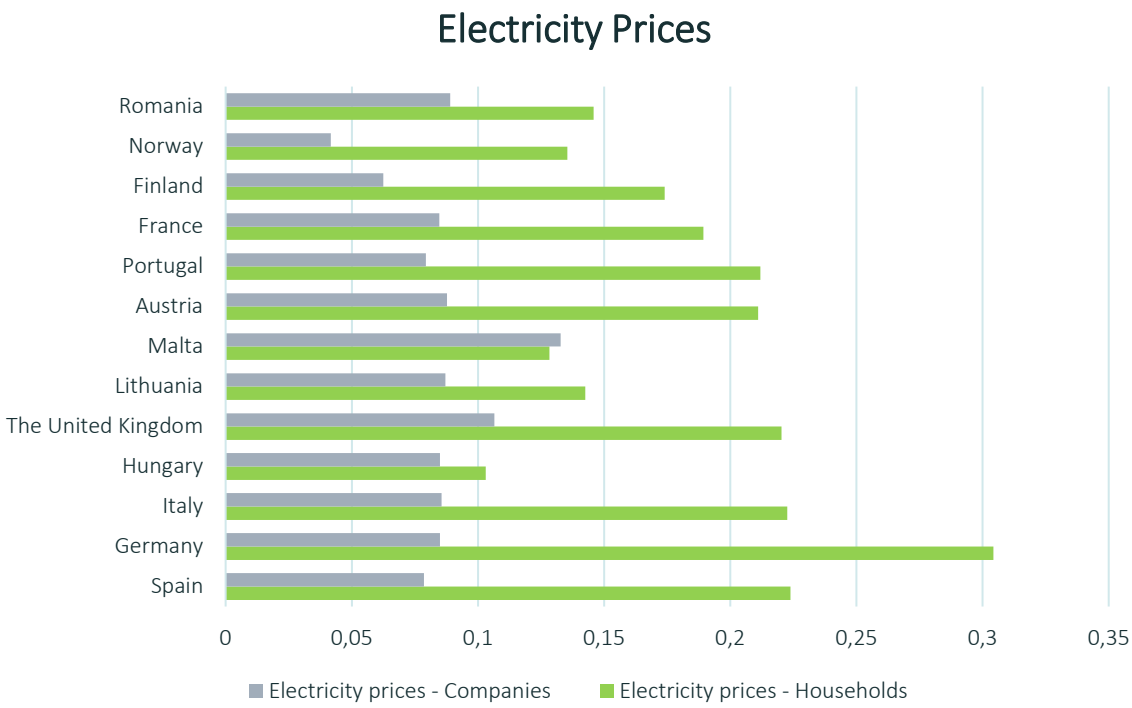


Personal contribution based on ENTSO-E Data Portal 2018, Spain REE.

We see that France, Germany, Norway, Portugal, and Romania, due to their high production, provide electricity to other nearby countries, while Italy, the United Kingdom, Finland, Spain, Hungary, Lithuania, and Austria need a greater contribution of electricity from abroad, due to their insufficient electricity production.

4.4. ELECTRICITY PRICES

Next, once the electrical structure of the selection of countries has been analyzed, we will analyze the situation of the average electricity consumer for these countries. In the price of electricity, we are going to divide this indicator for domestic and non-domestic consumers, to study if there is any difference in relation to the type of consumer and the price. For this we have data on the average electricity prices for 2020 expressed in euros per kilowatt-hour, with taxes included for domestic consumers and without applicable taxes during the first half of each year for non-domestic consumers.

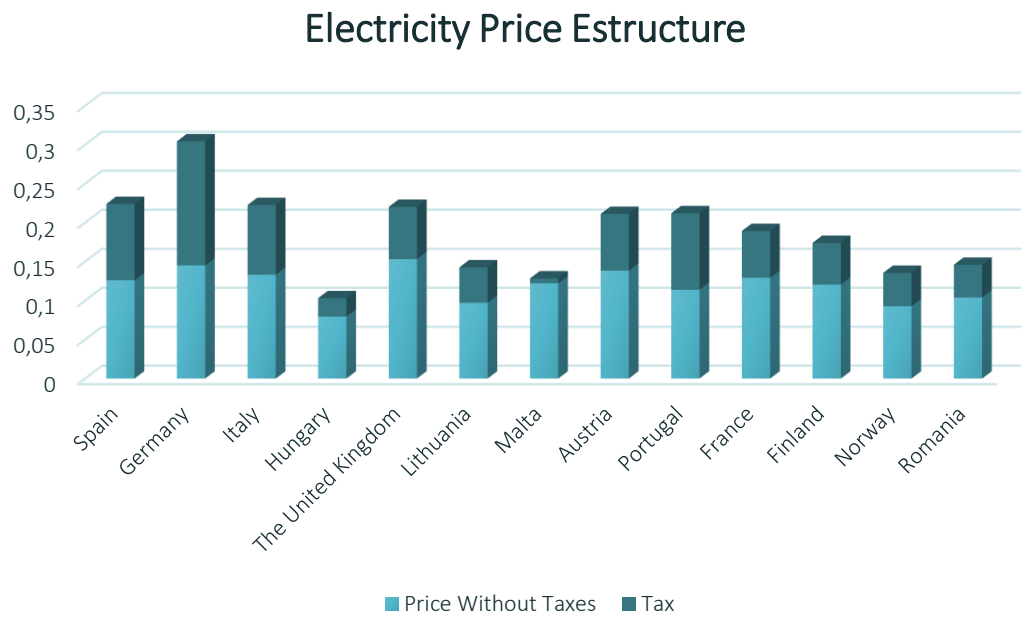


Personal contribution based on EUROSTAT, Electricity prices by type of user, 2020.

Once the data is represented, the main difference is that the electricity prices of domestic consumers are higher, regardless of the country of reference, in relation to the prices of the companies. This is understandable since the companies do not include the first semester of VAT. The country with the highest electricity prices for domestic consumers is Germany, understandable due to the high demand for electricity in this country, as well as the infrastructure to supply this demand, followed by Spain, which is a country with a very reduced demand, compared to Germany or France, the latter with a lower price per kilowatt. Italy has similar electricity prices to Spain, but with a much higher demand for electricity than Spain. The lowest price for electricity for domestic households is to be found in Hungary and Malta. The behavior of electricity prices for households is directly related to the demand for electricity of the country in question, as well as its degree of development.

Regarding the price of non-domestic consumers, or companies, we observe that the prices of the selection of countries are very similar, around 0.08 euro per kilowatt-hour, although we find countries like Norway, where the price is very low, 0 .04 euros per kilowatt-hour, understandable due to its high electrical efficiency. Germany, which in the household electricity market was the most expensive country, in the business market has much lower prices. In this market, Spain also lowers its prices considerably compared to the price for households, being the third country with a lower electricity price for companies, next to Portugal.

This difference between the electricity market of households and companies raises the questions whether this change in prices is due to taxes or is it just that prices are lower for companies than for households. In order to further investigate on this, we realized a separation of the electricity prices expressed in euros per kilowatt-hour for the price without taxes included on the one hand, and the taxes on the other hand.



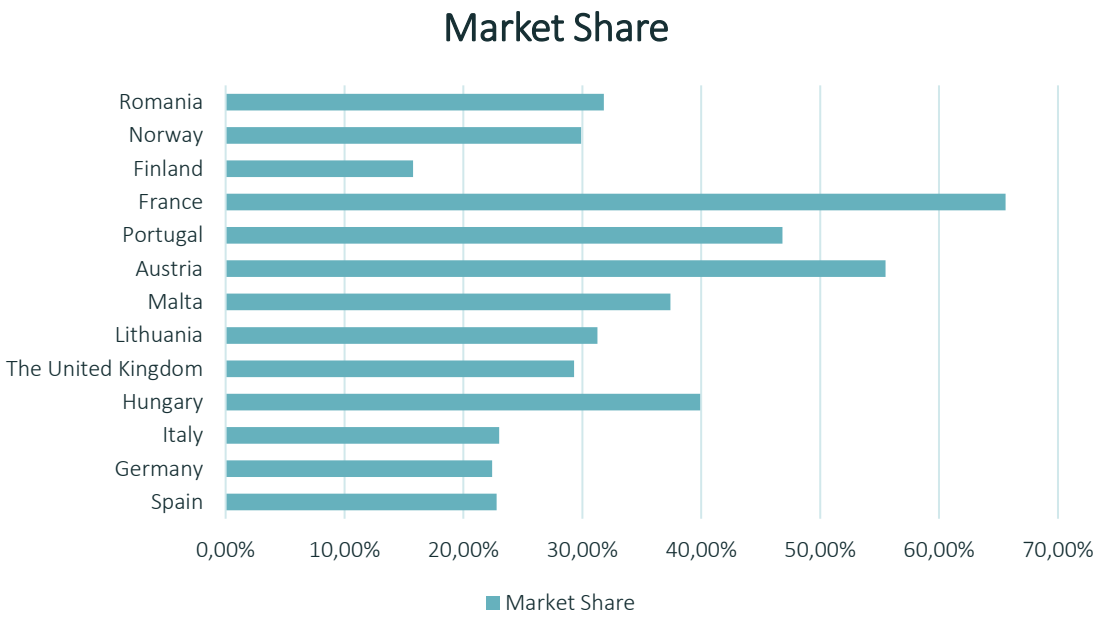
Personal contribution based on EUROSTAT, Electricity prices by type of user, 2020.

From this separation we can understand that in certain countries most of the price of the electricity is composed by taxes. The first one is Germany, which is currently the country of our selection with the highest electricity taxes paid by its consumers - understandable, due to its high demand and maintenance cost of the electrical infrastructure. It is followed by Spain, which with a lower demand pays higher prices, than for example France, which doubles the Spanish demand for electricity. The consumers paying the least in taxes for consuming electricity are in Malta, Hungary - which also pays a lower price for electricity, and Romania.

4.5. MARKET SHARE OF THE MAIN ELECTRIC GENERATOR

With this new indicator we are going to analyze the market share of the largest generator in the electricity market, and try to analyze in which country, from our selection, the electricity companies have greater market and decision-making power. For this we will

use data on the percentage of the participation that the main electricity generator has in each country, for the year 2019.



Personal contribution based on EUROSTAT, Market Share of the largest generator in the electricity market, 2019.

We observe that the country in which the largest market share is held by the main electricity generator is France, with 66% of the electricity market, followed by Austria and Portugal. If we analyze these countries in relation to the price they pay for electricity, expecting companies with a greater market share to act as monopolists and set higher prices than in those countries in which there is more than one generator and the market share is more divided, we observe that Portugal and Austria have higher prices for electricity compared to France - a country with a higher market share held by its electricity generating company. This only means that higher market shares are not necessarily related to higher electricity prices, due to the fact that the state is acting as the regulator of these prices set by companies and does not allow excessive price increases.

4.6. OVERALL SATISFACTION WITH THE QUALITY OF THE SERVICE

In relation to consumer satisfaction regarding the electricity, its price and quality, as well as their safety, we will compare data from the Eurostat consumer satisfaction surveys.

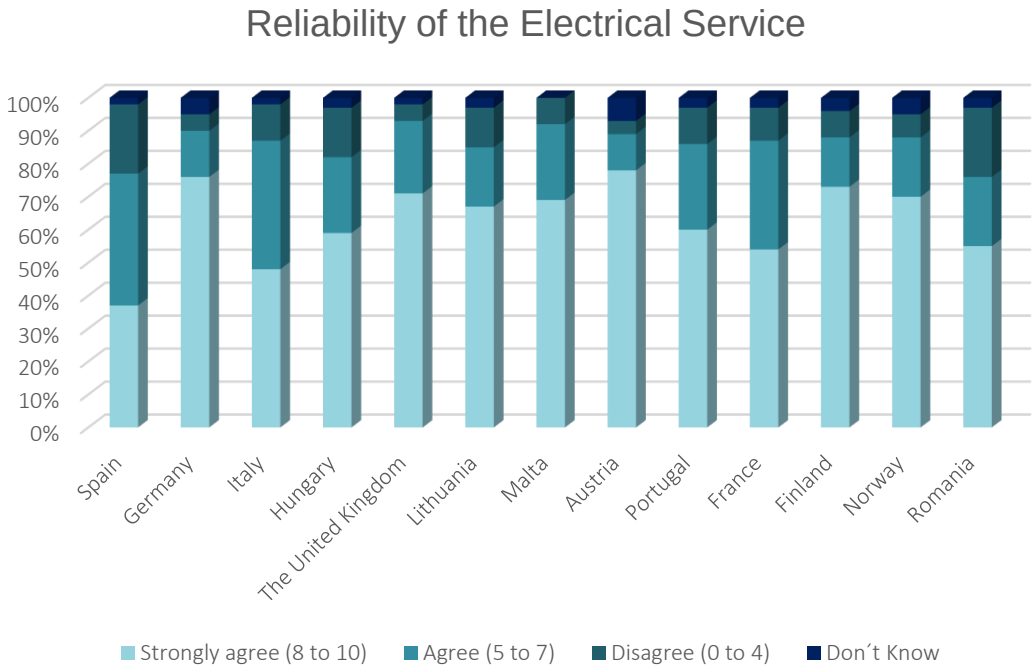
The surveys measure the degree of consumer satisfaction with the quality of the electricity service, analyzing their answer to the statement that: "electricity companies generally offer a high-quality service" (with a score from ten to eight meaning a complete agreement, from seven to five - agree, from four to zero - in disagreement. "I don't know" was also a potential answer).

Personal contribution based on EUROSTAT, Consumer Survey, "Electricity companies generally offer a high-quality service, 2016.

The country with the highest satisfaction rate on their electricity service is Austria, with 55% of consumers fully agreeing, followed by Malta and Germany. The country with the least satisfaction of the consumers, from our selection, is Spain, with only 2% of the consumers totally agreeing and 25% totally disagreeing - this is the worst data of all our selection, and it is partially understandable when analyzing the others indicators of the study - Spain is a country with a low productive capacity, with very high prices and paying high tax rates on electricity, which translates into low user satisfaction.

4.7. RELIABILITY OF THE ELECTRICAL SERVICE

Next, we will analyze the confidence that electricity users from the following countries have in the electricity supplies they use in their homes. This indicator is measured through a Eurostat survey, in which electricity consumers from different countries indicate, on a scale from zero to ten, their degree of conformity with the statement that "the electricity service is reliable, works well all the time". This is how we obtained the following results:



Personal contribution based on EUROSTAT, Consumer Survey, “The Electrical service is reliable”, 2016.

In this indicator we find Spain, once again, as the country with the least reliability of its electricity service, which justifies the low satisfaction in relation to this service. What is really significant about this indicator is that Eastern European countries, which do not have such developed infrastructures as central Europe, have greater satisfaction and reliability. According to this, countries such as Spain, France and Italy have a lower level of reliability of the electricity supply than Lithuania, Hungary and Romania. The country with the highest reliability rate of electricity consumers is Austria, followed by Germany and Finland - also reflected in the overall satisfaction previously analyzed.

5. ELECTRICITY CONSUMPTION, PRICE AND ECONOMIC GROWTH

In this section we are going to obtain the relationship between electricity consumption, the price of this consumed electricity and economic growth. For this we are going to use data from Spain on final electricity consumption in gigawatt-hours, the GDP expressed in current prices in thousands of euros and electricity prices in euros per consumed kilowatt-hour for the period from 1995 to 2020.

In order to visually represent the relationship between these three variables, we are going to use Pearson's correlation coefficient, which is a value that measures the relationship between two variables. It is bounded between 1 and -1 and has no units. A value close to 1 expresses a strong positive or direct correlation between the variables, between 0.3 and 0.5 a moderate correlation, between 0.29 and 0.10 a weak correlation between the variables, and close to 0 the relationship is practically non-existent. If the coefficient is negative, the scale is similar with the peculiarity that the relationship, instead of being positive, will be negative or inverse. It must be considered that when we use the term "relation" we refer to linear relations. If the relation between the variables is non-linear, this coefficient will not be able to measure it. Pearson's coefficient is represented by an “r” and is obtained from:

$$r = \frac{\sigma_{xy}}{\sigma_x \cdot \sigma_y}$$

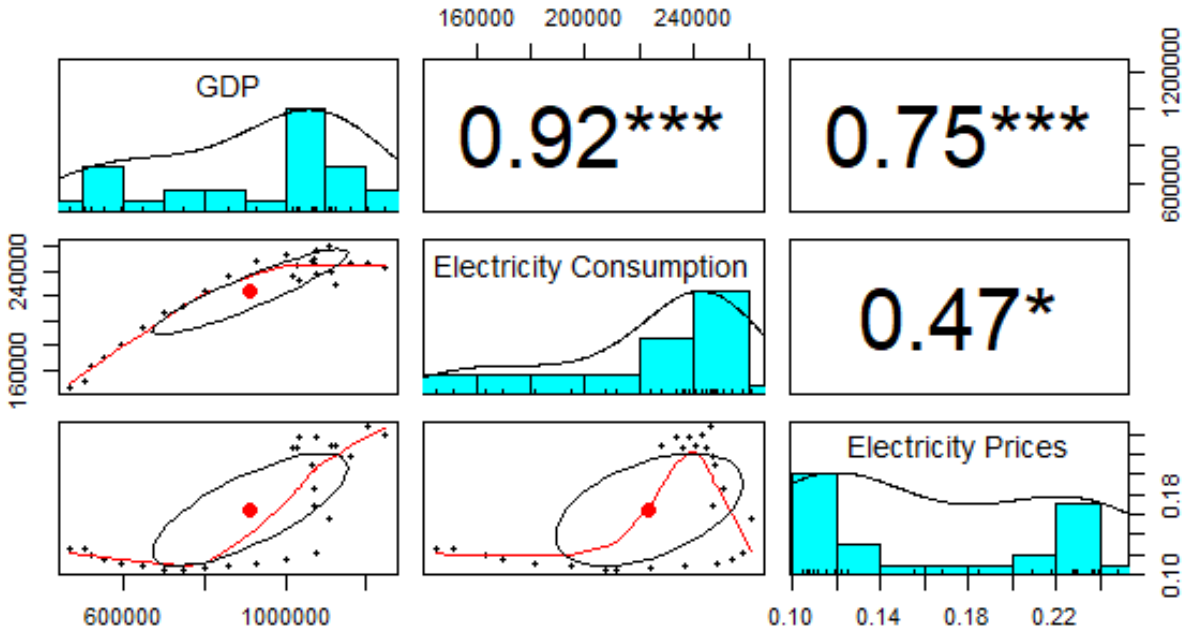
Where σ_{xy} represents the covariance between the two variables, and σ_x together with σ_y refers to the standard deviations of each of the variables. In this way, if we calculate the Pearson correlation coefficient between the GDP, electricity consumption and electricity prices, we obtain:

	GDP	Electricity Consumption	Electricity Prices
GDP	1,00	0, 9181601	0, 7452526
Electricity Consumption	0, 9181601	1,00	0, 4748909
Electricity Prices	0, 7452526	0, 4748909	1,00

The electricity consumption and the GDP have a correlation coefficient of 0.918. A correlation coefficient close to one represents a strong positive correlation, this implies a direct relationship between the variables - when electricity consumption increases, the GDP increases and when the GDP increases, electricity consumption increases too. Regarding the GDP and electricity prices, the correlation is also positive - when the GDP grows, electricity prices also grow. However, we see that the relationship between

electricity consumption and electricity prices is moderate - when electricity consumption increases, electricity prices also increase, which is reasonable because with an increase in electricity demand the offer remains unchanged, the demand is more volatile than the offer - because for the offer of electricity to vary, an improvement in the infrastructures is necessary, which is difficult to obtain on a short term, so the prices increase.

Next, we are going to represent this data through histograms and scatter plots:



Personal contribution based on EUROSTAT, "Supply, transformation and consumption of electricity", "Electricity prices for household consumers", "GDP and main components", 1995-2020 (R Studio)

We observe that the variations in the consumed electricity and in the prices of electricity adjust to the variation of the GDP, and therefore we found such high correlation coefficients. In relation to the electricity consumption and electricity prices, the adjustment is not so remarkable with respect to the GDP, which is why we have such a moderate correlation coefficient (0.47).

Once the correlation between the variables has been analyzed, we are going to observe the p-values obtained, to study if there is a correlation between the GDP with the electricity consumption and the electricity prices. To do this, we will test the null hypothesis of no correlation between the variables with respect to the GDP. For both relationships - between the GDP and the electricity consumption (p-value = 3.90×10^{-11}) and between the GDP and the electricity prices (p-value = 1.25×10^{-5}) we obtain a p-value that is less than 0.05, a value assigned in the reference statistics related to the 5% probability. So, we can reject the null hypothesis and affirm that there is a correlation between the variables.

6. ECONOMIC PREDICTION

Next, we are going to define a linear regression model to try to predict how the "electricity consumption" variable will be affected by a drop in electricity prices, based on the reduction in the tax rate associated with electricity. For this we obtain the following model:

$$Electricity\ Consumption = 175511 + 291070\ Electricity\ Prices$$

As the p-value of electricity Prices (0.0142) is less than 0.05, we reject the null hypothesis of no significance and conclude that the "electricity prices" variable is significant. If we look at the F-statistic, it has a p-value of 0.01423, less than 0.05, then we reject the null hypothesis that the model is wrong and we can conclude that the model is correct, although according to the adjusted value of the squared "r", the model only explains 20% of the variability of electricity consumption. Therefore, if we assume a reduction in the tax rate, from 21% to 10%, the price of electricity for next year will go from 0.2298 to 0.1997, which gives us:

$$Electricity\ Consumption = 175511 + 291070\ (0{,}1997) = 233.637{,}679$$

With this new price of electricity, the predicted electricity consumption will be 233,638.1, in relation to 228,459 last year, assuming an increase in electricity consumption of 2.267%.

The next model that we are going to estimate is a multiple linear regression model, in order to predict the variation of the GDP caused by this decrease in VAT. We obtain the following model:

$$GDP = -511.258{,}4 + 5{,}106818\ Electricity\ Consumption + 1.715.389\ Electricity\ Prices$$

We observe that both variables are significant in the model, with a p-value of electricity consumption of 2.09 x 10^{-14} and a p-value of electricity price of 3,57 x 10^{-9}, both clearly under 0.05, thus rejecting the null hypothesis of no significance and concluding that the variables are statistically significant.

Regarding the F-statistic, it has a p-value of 2.2 x 10^{-16} less than 0.05, so we can affirm that the model is correct, furthermore if we look at the adjusted r-squared, our new model

explains a 96.36% variation in the GDP. If we replace the value of the new price for the next year and the estimated electricity consumption, we will obtain the following prediction for the GDP:

$$GDP = -511.258{,}4 + 5{,}106818\ (233.637{,}679) + 1.715.389\ (0{,}1997) = 1.024.452$$

Surprisingly for our expectations, this drop in the price of electricity produces a reduction in the GDP (the GDP for 2020 was 1,121,698), which represents a drop of 8.67% compared to the previous year. In this case, we observe that the increase in the amount of electricity consumed does not compensate for the drop in the price of electricity. Considering that both variables are directly correlated with the GDP, although an increase in electricity consumption translates into an increase in GDP, a fall of the price also implies a fall in the GDP, the fall in price being greater than the growth from the consumption, thus justifying the results obtained from the prediction.

7. CONCLUSION

Initially we have presented the image of the Spanish electricity sector in Europe as a whole - a country with a low productive capacity compared to countries with a similar development of infrastructures. This low productive capacity requires imports of electricity from neighboring countries in order to supply the entire demand for electricity in the country. Regarding renewable energies, it is the fifth country with the highest environmentally friendly production, evidently due to the characteristic hydroelectric energy of the country. The price that electricity consumers pay for this service is high in this European perspective, being the country with the second highest price and which pays the highest taxes, and this naturally translates into a low satisfaction of the electricity users. Only 23% of the population is satisfied with the quality of the electricity services. The reliability is also low, only 37% of those surveyed affirm without a doubt that the electricity service is reliable, which shows that Spain, both in overall satisfaction and in reliability, obtained the worst results of our selection.

Therefore, it seems reasonable to reduce the price of electricity, through the associated excessively high taxes. In the economic analysis that we carried out for the last 26 years, we concluded that a decrease in the price of electricity based on a reduction in taxes would cause an increase in the consumption of electricity, which we expected to translate into an increase in the GDP, as the two variables are directly related, but the decrease in prices was greater than the increase in electricity consumption, and based on this decrease we obtained a future decrease in the GDP.

Even though the model explained 93% of the variation in the GDP, it is obvious that it would be necessary to add more significant variables in order to obtain results that are closer to reality. This hypothetical reduction in the price of electricity would mainly affect households, which will have a higher disposable income, with a possible increase in consumption. Companies will also be able to produce more, since the production costs are decreasing, obtaining higher profits. On the other hand, the state has to reduce its tax revenues on the short term, but the increase in consumption and the profits of companies will bring higher tax revenues on the long term. Therefore, it seems logical to assume that this decrease in electricity taxes and in the price of electricity may improve the satisfaction of electricity users and also produce an increase in the GDP, improving at the same time the Spanish economic situation.

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