Energy and Industry 4.0 Nexus in Spain

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Technological development has profoundly marked the evolution of the economy. The constant changes brought about by scientific and technological advances have been decisive in the transition from an analogue to a digital world. In this context, the impact of the fourth industrial revolution (or Industry 4.0) manifests itself in many ways. Environmental impact is one of these. The energy sector has been evolving and changing just like the economy and society.

Industry 4.0 technology green taxes green energy

1. Introduction

Energy is a key factor in Industry 4.0, as it is necessary to drive the production processes and technologies used in it [1]. Industry 4.0 is characterized by increased automation and digitalization of industrial processes, which requires a higher demand for electricity [2]. In general terms, 4.0 should aim to reduce energy consumption and increase energy efficiency in industrial processes. To this end, technologies such as sensors and energy control systems are used to monitor and optimize energy consumption in real time [3][4].

In Industry 4.0, the utilization of renewable energy sources, such as solar, wind, and hydropower, represents a noteworthy facet concerning energy. These renewable sources are assuming growing significance within the context of Industry 4.0, offering the potential to diminish energy expenses and enhance the environmental sustainability of production processes.

Globally, the energy sector is in a process of transition toward Industry 4.0. In Europe, various initiatives and strategies are being implemented to drive the digital transformation of the energy sector. For example, the European Union has established the Horizon 2020 program, which funds research and innovation projects in energy and technology. Initiatives such as the European Green Pact, which seeks to achieve climate neutrality in Europe by 2050, have also been launched.

In the case of Spain, the energy sector is also undergoing a transformation toward Industry 4.0. In 2019, the Just Transition Strategy was approved, which lays the foundation for a sustainable and just energy transition in Spain. In addition, initiatives such as the National Integrated Energy and Climate Plan 2021–2030 have been implemented, which sets out the objectives and measures needed to achieve a low-carbon economy. On the business side, several Spanish energy companies are implementing digital technologies in their production processes. For example, the Spanish company Endesa has developed digitalization projects in its power plants and in the management of smart grids. Another Spanish company, Acciona, has implemented technologies such as virtual and augmented reality in the construction of wind farms.

In Spain, the arrival of 4.0 could be marked in 2015, when the "Industria conectada 4.0" (Connected Industry 4.0) initiative was launched at the state level, with the collaboration of private entities such as Telefónica. In this year, the platform published the report "The Digital Transformation of the Spanish Manufacturing Sector", which sought to highlight the importance of industry for the growth of the entire Spanish economy. Already in this report [5], the concept of guaranteeing the sustainability of the production process only appears in the appendix and in any case not in a long-term projection.

Furthermore, it can be observed the following trend when comparing the final energy consumption data for Spain to the total consumption of the Spanish industrial sector since the beginning of 4.0 (**Figure 1**, based on data from Energia.gob.es, accessed on 20 March 2023).

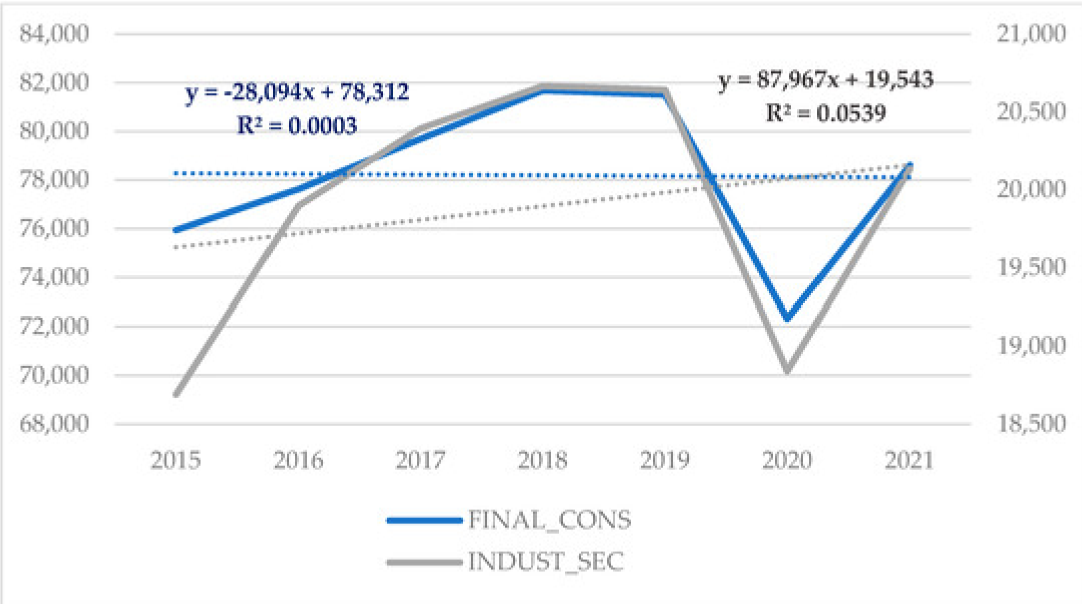

Figure 1. Final energy consumption in Spain (2015–2021).

Since the introduction of 4.0, the trend in energy consumption by both the Spanish economy as a whole and the industrial sector has shown a rise to 2020, a cause attributed, among others, to the impact of the health crisis COVID-19. A closer examination of Spain's economic growth reveals a startling reality.

Regarding the country's economic growth, the health crisis caused by COVID-19 initially did not lead to a decrease in growth levels. By observing the linear correlation coefficient (LCC) between the GDP variable at constant prices and analyzing its correlation with respect to final energy expenditure, as well as with the final energy expenditure of the industrial sector, two models emerge, which are described below.

$$LCC\ (GDP\text{-}final\ energy\ consumption) = -0.05\ [R^2]\ (1)$$

This expression is likely from a study that examines the relationship between the levelized cost of energy (LCC), gross domestic product (GDP, constant prices), and final energy consumption. The value of −0.05 indicates that there is a negative correlation between LCC and GDP (constant prices)-final energy consumption, which means that as the LCC decreases, GDP (constant prices) and final energy consumption tend to increase. The value in brackets, [R^2], indicates the coefficient of determination, which measures how well the model fits the data. In this case, an R^2 of 0.05 means that the model explains only 5% of the variance in the data.

$$LCC\ (GDP\text{-}final\ energy\ consumption\ industry) = 0.16\ [R^2]\ (2)$$

This expression is like the first one, but it focuses specifically on the relationship between LCC, GDP (constant prices), final energy consumption, and the industrial sector. The value of 0.16 indicates a positive correlation between LCC and GDP (constant prices)-final energy consumption industry, which means that as the LCC increases, GDP (constant prices) and final energy consumption in the industrial sector tend to increase as well. The value in brackets, [R^2], represents the coefficient of determination, which, in this case, is 0.16, meaning that the model explains 16% of the variance in the data.

The research examined the correlation between the levelized cost of energy (LCC), gross domestic product (GDP, constant prices), and final energy consumption, with a specific focus on the industrial sector. The outcomes of our analysis revealed that LCC and GDP were positively correlated with the final energy consumption in the industrial sector (LCC (GDP-final energy consumption industry) = 0.16 [R^2]). This result implies that an increase in LCC would lead to an increase in GDP and final energy consumption in the industrial sector. Nonetheless, a negative relationship was also detected between LCC and GDP (constant prices)-final energy consumption in all sectors (LCC (GDP-final energy consumption) = −0.05 [R^2]), suggesting that a decrease in LCC would lead to an increase in GDP and final energy consumption across all industries. In summary, the findings indicate that a reduction in LCC could have significant implications in promoting economic growth and decreasing energy consumption in diverse sectors.

Thus, initially, energy consumption and growth do not seem to have a satisfactory level of relationship. This may have an impact on policies and measures to be taken in the energy sector as what happens will not result in further growth of the economy. This may discourage the development of new and better energy policies and energy consumption.

2. Sustainability 4.0: Types of Energy Used in Spain

Globally, there is a trend from high to low carbon emissions, just as there is a trend from fossil to non-fossil energy [6]. The application of technology also enables energy to be harnessed and energy-efficient and low-emission production methods to be generated. Thanks to this 4.0 technology, among other benefits, there are better safety protocols [7] that seek to prevent incidents affecting the environment [8]. However, due to the production activity itself, the probability of suffering these incidents is still high. Therefore, the consumption of this non-green energy will perpetuate a problem of industrial sustainability.

Energy consumption in Spain is high compared to other EU countries. According to data from the European Environment Agency, energy consumption per capita in Spain is about 10%, according to the data published by eea.europa.eu on the energy consumption of the EU—higher than the European average. The transport and residential sectors are the largest consumers of energy in Spain, followed by industry and the services sector. In terms of the source of energy used, oil and its derivatives are the most widely used in the country, followed by electricity and natural gas.

The study of the data relating to the several types of energy currently used by Spanish industry provides a snapshot of the state of this issue and the level of progress made since the advent of the 4.0 concept.

There is a subtle trend toward reducing the presence of fossil fuels in Spanish industry. However, the percentage of fossil fuels is extremely high and is still a long way from sustainability standards, as it is still 2021, six years after the start of 4.0 and practically two decades since the changes in the consumption of these energies began to be considered.

It is evident that a truly effective economic and political plan is necessary for the gradual elimination of the use of fossil fuels, as was done in Germany with the Energiewende initiative [9], and periodic monitoring of data is necessary to evaluate whether this transition is taking place.

3. Policies on Renewable Energies: Green Taxes

The features of the industries and companies in Spain should be considered. Thus, there is a high presence of small and medium-sized enterprises, so policies should focus on innovation and promotion of cleaner technologies, considering the size, knowledge intensity, and inter-company cooperation of the Spanish fabric [10].

The objective of sustainable development is to achieve a harmonious equilibrium between economic advancement, environmental preservation, and social well-being, with the goal of ensuring that future generations can meet their needs [11]. Other scholars emphasize the significance of conducting meticulous assessments of energy sectors to inform the planning and decision-making processes associated with energy policies [12].

However, economic growth has led to the exploitation of natural resources and pollution, which is a challenge for sustainable development. Environmental taxes can contribute to sustainable development by internalizing environmental costs in the price of goods and services, encouraging the adoption of more sustainable practices, and generating revenue for environmental protection policies and sustainable development programs [11]. Related to the above is a change in business culture, as well as a need for investment in resources and infrastructure [13].

By way of illustration, the case of European small and medium-sized enterprises in terms of the adoption of clean technologies and recycling is discussed. Studies indicate that energy prices have a strong influence on the adoption of clean technologies and recycling by SMEs. In addition, the capacity of SMEs to innovate and the existence of supportive policies also influence their adoption of clean technologies and recycling [14].

This indicates that EU energy and environmental policy must be coherent and coordinated to support sustainable development and the adoption of clean technologies by SMEs.

Thus, it is argued that environmental taxes can be an effective tool for tackling climate change and promoting sustainable development, as they allow environmental costs to be included in the price of goods and services, providing incentives for the adoption of more sustainable practices [15]. In addition, revenues generated by environmental taxes can be used to finance environmental protection policies and sustainable development programs.

The implementation of environmental fiscal policies should be accompanied by measures to support and promote sustainable practices and technologies, as well as environmental education and awareness programs [16].

However, the definition of environmental taxes and their application, specifying their objectives and design criteria (such as their tax base), as well as the relationship between environmental taxes and other environmental policy instruments, need to be properly studied and precisely defined [16].

In this context, the reality is that Spanish industry, despite adapting changes in terms of technology, connectivity, and managing increasingly smart factory units, has not applied protocols for switching from traditional energy sources.

One of the causes may be the lack of economic return in the short and medium term of applying these changes. On the contrary, they imply economic and human costs that make companies decide not to implement the changes. National expenditure on environmental protection applied to the industrial sector in Spain in 2010 amounted to EUR 18,636.50 million, according to the data published by the OECD (about environmental protection expenditure accounts).

It is true that since the implementation of 4.0 in Spain, there has been an increase in this type of expenditure, rising by more than 13.00%. The use of modern technologies together with European environmental policies can therefore justify this.

On the other hand, it shows the data corresponding to pollution and resource taxes. There is no change in the taxes paid for pollution. This indicates that, on the one hand, the industry has not changed its attitude and way of production. On the other hand, it seems that all the effort to generate an environmental culture among the agents involved in the industry is not yielding results.

The use of taxation tools comes to tax certain behaviors. Already in the neoclassical approach to growth, with authors such as Solow in 1956 [17] or later visions of endogenous growth with authors such as Romer [18][19], the intervention of the public sector is the object of study.

Historically, public intervention has had the objective of stable economic growth (in addition to others such as the correct distribution of income or equity) [20]. However, when it comes to environmental taxes (green taxes), the focus is on the behavior of the agents. The presence of both positive and negative externalities must be analyzed, as far as it marks the existence of both economic and non-economic (or extra-economic) consequences. In the case of environmental externalities, public intervention is a political decision, not an economic one.

As these externalities are not measured in terms of costs and benefits for market actors, other issues must be addressed. One option is to apply the Polluter Pays Principle (PPP) [21], which has been widely applied by the European community in cases such as A. Stanley [22]; the case deals with Directive 91/676/EEC, which aims to protect waters from pollution caused by nitrates from agricultural sources. The case focuses on the identification and designation of vulnerable zones to pollution and their validity in relation to principles such as the PPP, the principle of rectification of environmental damage at the source, and the principle of proportionality. This case has been used as a basis for subsequent decisions, but difficulties in its application have been noted due to problems of identification and proportionality in the risk relationship.

Although this method suffers from problems such as the proportionality of the sanction, the standards of liability for both the risks of pollution and the damage caused must be very well defined. The limitations of the PPP approach have led to the exploration of new options. These include the use of market-based instruments such as subsidies or taxes. In the case of environmental taxes, their objective is to penalize negative externalities. The purpose of this type of tax is to modify behavior, to correct the negative externalities of the activity.

It is true that despite the above, Spain is making efforts to adjust the tax system—for example, the “Libro Blanco para la Reforma del Sistema Tributario” (White Paper for Tax System Reform) [23], in which a diagnosis of the Spanish tax system is made, by which a series of recommendations are articulated; the text also offers different proposals on several areas, among which is environmental taxation, with proposals such as the abolition of the Tax on the Value of Electricity Production, or the reform of the special tax on electricity to promote electrification and energy efficiency.

In the same sense, attention must be paid to the situation of Spanish fiscal decentralization, as it has usually had a negative impact on environmental taxation (e.g., in the case of water taxes [24]) and has resulted in a lack of coordination between the different public administrations involved in management and a lack of coherence in the related tax policies.

Considering the structure of the tax itself, and the percentage of impact that this type of tax has, the conclusion is that it is inefficient. It does not incentivize behavioral change because it treats all products in an excessively generic way.

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