Does electricity production cause economic growth? An analysis of the Spanish case during the period 1958-2011

1. Introduction

Since the beginning of the industrial revolution, changes in production and the consumption of energy have been basic elements of successive transformations in the world economy. As is well known, electricity was swiftly adopted in western countries and activities related to it soon became economic sectors, leading to the modernization of the production system.

In Spain, this form of energy followed the same steps as in other developed countries, although with delays and peculiarities. In the early 1950s, Spain's energy consumption (and electricity consumption) was weak with an absolute pre-eminence of coal and a scarce external dependence. The low energy consumption was coherent with the backwardness of Spanish economy, which had a predominantly agricultural productive system and a still incipient industry.

Circumstances changed during the 1950s and the electricity sector became the engine of Spanish industrial expansion (Germán Zubero 1990). The intense industrialization process, based on heavy industry sectors that are great consumers of energy, raised the energy intensity. This increase was also a consequence of a higher standard of living. The result was that electricity production between 1958 and 2011 grew at a faster rate than GDP.

The aim of this research is to determine whether the increase in electricity production preceded GDP growth after 1958 or, on the contrary, whether GDP growth boosted electricity production. It analyses a longer time span than that studied by Ciarreta and Zárraga (2010), Fuinhas and Cardoso (2012) and Pirlogea and Cicea (2012), and uses a cointegration approach based on Pesaran and Shin (1999) and Pesaran et al. (2001), suitable for short data series like the one used in this work. Empirical evidence allows us to conclude that electricity production boosted economic growth in Spain from the late 1950s on.

The rest of the paper is organized as follows. The second section concisely describes the evolution of the electricity sector in Spain since the late 1950s. The third section summarizes the international empirical literature that analyzes the relation between growth in electricity consumption and GDP growth. The fourth section gives an account of the methodology used and provides the data and empirical evidence for the Spanish case. The paper ends with a report of the main findings obtained.

2. Evolution of the Spanish electricity sector since 1958

Since 1958, two important stages can be distinguished in the evolution of growth of Spanish GDP and electricity sector. The first lasts until the mid-seventies and reflects the period of expansion and modernization of the electricity sector as well as the take-off of the Spanish economy[1]. This marks the beginning of the second stage in which two subperiods can be differentiated: 1975-1984 and 1985-2011.

Figure 1 summarizes the trajectory of GDP and electricity production between 1958 and 2011. Note that the evolution of electricity production coincides with the evolution of GDP. However, it cannot be concluded from the figure whether the growth of electrical production preceded GDP growth or, conversely, whether it was GDP growth that boosted electricity production. The aim of this paper is to answer this question.

Between 1958 and 1974, there was a strong GDP growth (at an annual average rate of 7.1% cumulative) and a higher expansion of electricity production (10.5% cumulative annual average). In these years, the capacity of power generation and oil refining rose very quickly and the energy sector managed to meet the energy demand by relying on imported oil and natural gas (from the late 1960s on). Authors such as Germán Zubero (1990) and Garcia Alonso (2009) argue that the electricity sector was the cause of the industrial expansion and, hence, of Spanish economic growth, although they do not test it empirically.

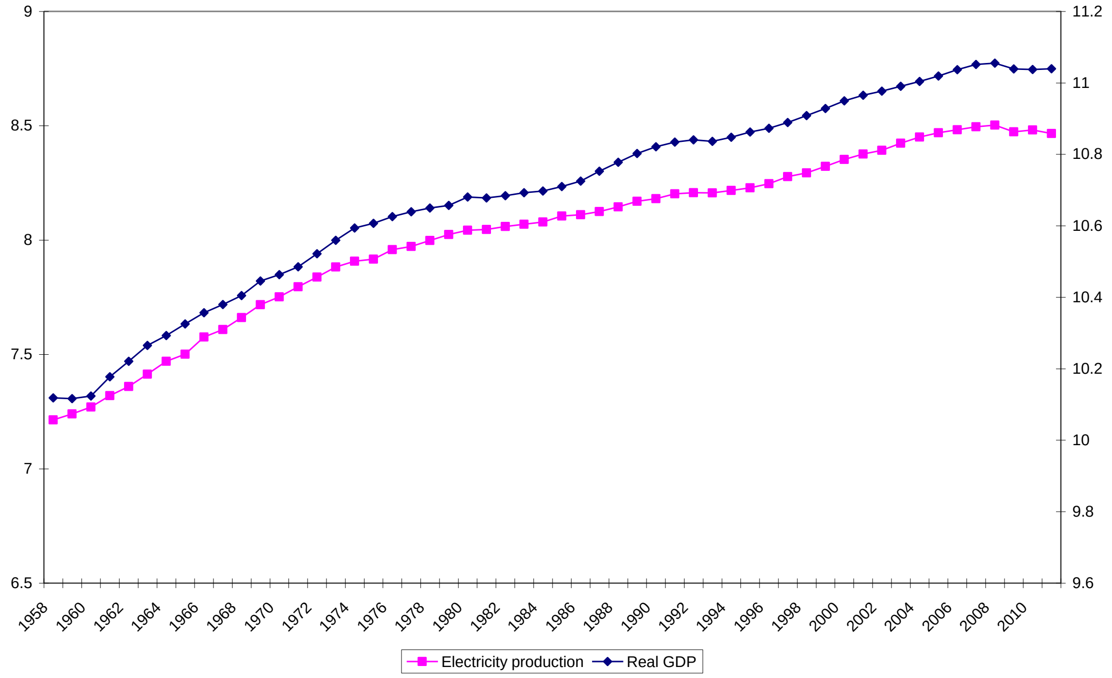
During this first stage, many power plants were projected and partially financed, through public founds, under the National Electricity Plan 1971-1981. This favoured a large expansion of hydroelectric power and, above all, of conventional thermoelectric power, both of which exhibited a very similar installed capacity in 1974. In these years the transmission and distribution network was tripled and completed, achieving a full interconnection between the various electricity production enterprises.

The second stage begins around 1975, when the effects of the economic crisis (originated by the sudden, sharp increase in oil prices and raw materials in 1973) begin to affect the Spanish economy. The economic crisis was a turning point in the Spanish

[1] See Carreras and Tafunell (2010) for further details.

evolution given that, from then until 2011, the last year studied, the average annual GDP growth rate declined to 2.8% and the average annual growth rate of electricity production fell to 3.6%.

Figure 1: Real Gross Domestic Product and electricity production. Evolution in logs: 1958-2011



Note: Production of electricity in megawatt hours and GDP in billion pesetas 1995.
Sources: Prados de la Escosura (2003), National Statistics Institute and UNESA (2005).

The early years of this second stage were very hard because the lower GDP growth was accompanied by a sharp rise in unemployment and inflation. Energy policy aimed to satisfy demand, at minimum cost and with maximum safety, and energy planning was initiated through the National Energy Plan (NEP). After 1979, these plans also pursued diversification and energy saving[2].

Until 1984, the increase in electric power was led by nuclear power plants (whose power increased at an annual rate cumulative average of 17.8% between 1975 and 1984) and, to a much lesser extent, by conventional thermal power plants (5.4%). The growth of hydroelectric power was lower, 1.9% (annual cumulative average). The extension of the installed power capacity enabled electricity production to advance between 1975 and 1984 at an annual cumulative average rate of 4.3% (less than half of that achieved in the first phase).

[2] See Romero Luna (2001) for greater details of the first NEP.

After 1985, the Spanish economy experienced a new growth period, slower in some years (early 1990s) and stopped in 2008. The growth of the installed capacity is explained by the increase of renewable energy (at a cumulative rate of 4.4% per year between 1985 and 2011) and conventional thermoelectric power (3.6%), rather than by nuclear power (1.2%).

3. Electricity production and economic growth

Energy, in general, and electricity, in particular, plays an important role in an economy on both the consumption and production sides. For this reason, the causal relationship between electricity and economic growth is an important matter to investigate due to the implications that the results obtained could have in terms of energy policy. That is, these outcomes could serve to sustain the provision of electricity in a country or not, a decision that could affect growth.

Therefore, this association has been widely studied since the oil crisis, especially in the past two decades. In general terms, and using a specific methodology for time series, these studies confirm a strong link between the two variables[3] Nevertheless, the results obtained are far from conclusive, something which often depends not only on the particular features of the country but also on the use of an appropriate methodology, the variables used and the period considered[4].

Some of these analyses, which, in the literature, are included in the so-called *growth hypothesis*, find an unidirectional causality that runs from electricity consumption to economic growth. This means that in countries that follow this pattern, a reduction in electricity consumption, as a result, for example, of a conservative energy policy, could lead to lower economic growth. This hypothesis is found to be prevalent in the developed world, as suggested by Chontanawat et al. (2008). Previously, Wolde-Rufael (2005) had already pointed out the long run relationship between energy use per capita and per capita real gross domestic product (GDP) for 19 African countries for the period 1971–2001. Akinlo (2009) investigated the causality relationship between energy consumption and economic growth for Nigeria during the period 1980–2006. The results show that there is only unidirectional causality running from electricity

[3] The Granger causality methodology has been widely implemented in this kind of research.
[4] A complete survey about this can be found in Payne (2010), Odhiambo (2010) and Ozturk (2010).

consumption to real GDP. Apergis and Payne (2010) found that electricity consumption played an important role in the growth of South America.

Other countries, on the contrary, reveal the opposite relationship. That is, a higher rate of growth leads to a higher electricity consumption, a result that fits into the *conservation hypothesis*. If this is the case, policies implemented to stimulate or to reduce electricity consumption would not have any effects in terms of economic growth. This happens, for example, in countries such as Indonesia and Mexico or in Australia, a fact reflected in the analysis of Murry and Nan (1996) and Narayan and Smyth (2005), respectively. Ang (2008) found a strong support for causality running from economic growth to energy consumption growth in Malaysia, both in the short and long-run.

In others countries there are some evidences of the feedback hypothesis, that is, of a bi-directional causality between electricity consumption and economic growth, with the consequent beneficial effects. Masih and Masih (1977), for example, found bidirectional causality between real income and energy in Korea and Taiwan. Soytas and Sary (2006) assessed the impact of a change in energy consumption on income and viceversa in G-7 countries. They concluded that there are causality relations between energy consumption and income in all countries, but the direction of causality seems to differ across countries. Yoo and Lee (2010) also found this relationship in their sample of a large set of economies that included the OECD countries and other developing countries such as Malaysia and Singapore. Their results showed a statistically significant inverted-U-shaped relationship between per-capita income and electricity consumption. It can be expected that electricity consumption increases at an increasing rate with per-capita income.

Finally, some of the economies suggest the absence of a causal relationship between these variables, supporting the *neutral hypothesis*, as in the case of France, Germany, Portugal, India, Portugal, Luxembourg, Norway, UK, USA and Zambia (Murry and Nan, 1996); in Korea between 1981 and 2000 (Wankeun and Kihoon, 2004) China and India (Chontanawat et al., 2008) or in Indonesia (Jafari et al 2012).

Many studies have found seemingly contradictory empirical evidence. Bowden and Payne (2009) exploited U.S. annual data from 1949 to 2006 to examine the causal relationship between energy consumption and real GDP using aggregate and sectoral primary energy consumption measures within a multivariate framework. Long-run causality tests revealed that the relationship between energy consumption and real GDP was not uniform across sectors. Causality was absent between total and transportation primary energy consumption and real GDP, respectively. Bidirectional causality was present between commercial and residential primary energy consumption and real GDP, respectively. The results indicated that industrial primary energy consumption caused real GDP. Finally, Abbas and Choudhury (2013) examined the causality between electricity consumption and economic growth in India and Pakistan at aggregated and disaggregated level. At the aggregated level, India confirmed neutral hypothesis while Pakistan confirmed feedback hypothesis.

In general, most of the studies mentioned above focus their attention on the electricity consumption side and only a few of them consider the output side, that is, the role played by electricity generation. However, there are some countries where non-technical transmission and distribution losses are very high so that consumption figures are grossly underestimated.

Therefore, this question is worth investigating for the same reasons mentioned for electricity consumption. As we said before, if the causality runs from the electricity supply to economic growth, a reduction in electricity generation would lead to a fall in growth. On the contrary, if the causality operates in the opposite direction, policies implemented to reduce electricity supply will have little or no adverse effects on economic growth.

There are papers, such as Yoo and Kim (2006) for the case of Indonesia, that find a uni-directional causality that runs from economic growth to electricity generation without any feedback effect. Ghosh (2009) obtains a similar result for the case of India. On the contrary, Morimoto and Hope (2004) highlight the opposite causality for Sri Lanka. In this country, the increment in electricity supply played an important role in explaining its economic growth.

In sum, there are a lot of works that deal with this matter by both the consumption side and the production side but the results obtained from them are mixed. Although there are studies covering a wide range of countries, the particular case of Spain has barely been investigated, despite the importance of the electricity sector in explaining the process of industrialization that began in the late fifties. Is electricity consumption a stimulus to economic growth in Spain? Or is economic growth a stimulus for electricity consumption? Ciarreta and Zarraga (2010)'s paper, focusing on the 1973-2008 period, finds a unique relationship that runs from economic growth to electricity consumption, supporting the *conservation hypothesis*. On the contrary, Fuinhas and Cardoso (2012) take into consideration the period 1965-2009 and, after controlling for sporadic and permanent shocks, obtained empirical support for the *feedback hypothesis* in Spain. Pirlogea and Cicea (2012) found that energy consumption with natural gas led to economic growth in Spain in the short term and that this relationship is only valid in this direction, confirming the *growth hypothesis*. In other words, the results are also not conclusive for Spain.

What results will we find if we consider the period from the beginning of the industrialization process up to the present? Will the conclusion differ if we consider electricity consumption instead of electricity production? The following section aims at answering these questions.

4. Data and econometric methodology

4.1. Data description

Annual data for the period 1958-2000 for real GDP are from Prados de la Escosura (2003) and from the National Statistics Institute from 1995 onwards. The necessary information about electricity supply and consumption for the same time span has been collected from Ministerio de Industria, Energía y Turismo and from UNESA (2012).

4.2. Econometric methodology

The methodology employed in this paper is based on that proposed by Pesaran and Shin (1999) and Pesaran et al. (2001). They developed a new cointegration approach, the autoregressive distributed lag (ARDL) bounds testing approach, that has many advantages over the traditional one proposed by Engel and Granger (1987) and Johansen and Juselius (1990). The first and the most important advantage is that the order of integration of the series does not matter so non-stationary and stationary variables can both be taken into account. The second advantage is that this new methodology produces robust results even in small sample sizes. The third advantage is that this methodology leads us to estimate the short-run and the long-run equilibrium relationship at the same time, avoiding the problems of omitted variables and of autocorrelation. Moreover, the bounds test permits us to obtain the causal relationship between the variables and distinguish between the dependent and the explanatory variables.

The application of the ARDL model has become very popular in some areas of economics and especially in energy market analysis, a field in which the temporal dimension of the data available is usually short (Narayan and Smyth (2005, 2007), Narayan at al. (2008), Ghosh (2009), for example).

For all the reasons mentioned above, it seems that this approach is appropriate for studying the case of Spain: we have a relatively small sample (53 observations), we want to know the direction in which the causality between them operates and, although the order of integration of the variables used is I(1) (see Table 1), we must be careful with these results because the power and the size properties of conventional unit roots are reduced as a consequence of the relative short data span.

Insert Table 1

The ARDL bounds testing approach is based on a dynamic specification that involves separately estimating the following unrestricted error-correction models in which the two variables are considered as the dependent variable[5]:

$$\Delta LGDP = a_{LGDP} + \sum^{n}_{i=1} b_{il LGDP} \Delta LGDP_{t-1} + \sum^{n}_{i=1} c_{il LEP} \Delta LEP_{t-1} + \sigma_{1 LGDP} LGDP_{t-1} + \sigma_{2 LGDP} LEP_{t-1} + dt + \varepsilon_{1t} \quad (1)$$

$$\Delta LEP = a_{LEP} + \sum^{n}_{i=1} b_{il LEP} \Delta LEP_{t-1} + \sum^{n}_{i=1} c_{il LGDP} \Delta LGDP_{t-1} + \beta_{1 LEP} LEP_{t-1} + \beta_{2 LEP} LGDP_{t-1} + dt + \varepsilon_{1t} \quad (2)$$

where *LGDP* represents the log of *GDP*, *LEP* the log of electricity production, Δ is the first difference operator and *t* is a deterministic trend.

To determine the existence of a long-run relationship between the variables, Pesaran, Shin and Smith (2001) propose two alternative tests. On the one hand, they compute an F-statistic in order to test the joint significance of the first lag of the level of variables included in the analysis. On the other hand, a t-ratio is used to test the individual significance of the first lag of the level-dependent variable.

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[5] We first test the model with electricity production and then with electricity consumption. As both series have a correlation of 0.99, the results obtained in both cases are quite similar.

The null hypothesis of no cointegration among the variables in Equation (1) is H_0: $\sigma_{1LGDP} = \sigma_{2LGDP} = 0$ and the alternative hypothesis is H_1: $\sigma_{1LGDP} \neq \sigma_{2LGDP} \neq 0$, which we denote as $F_{LGDP}(LGDP/LEP)$. The hypothesis and the $F_{LEP}(LEP/LGDP)$ in Equation (2) are defined in a similar way. Moreover, we can use a t-ratio to test the null hypothesis of $\sigma_{1LGD} = 0$ in Equation (1) and $\beta_{1LEP} = 0$ in Equation (2) with and without a trend in the respective error correction model. Pesaran et al. (2001) provide the corresponding critical values. If the F-statistic or the t-ratio fall outside the band of critical values, a clear conclusion can be drawn about the existence or not of a long-run relationship between the variables, without needing to know whether the variables are I(1) or I(0). However, if these statistics fall within the band of critical values, we are not able to reach a clear conclusion without analysing the order of integration of the variables concerned.

In particular, if the estimated values of $F_{LGDP}(LGDP/LEP)$ and $t(LGDP/LEP)$ are higher than the superior band of critical values and those of $F_{LEP}(LEP/LGDP)$ and $t(LEP/LGDP)$ are below the band of critical values, it means that there is a unique relationship in the long-run in which the dependent variable is the level of income (*LGDP*) and the electricity production (*LEP*) is the explanatory variable. This outcome would confirm that the causality between the two variables runs from electricity production to growth.

Insert Table 2 and Table 3

As can be seen in Table 2, this is the case obtained in this analysis. The value of the F-statistic for the regression in which *LGDP* is the dependent variable, and considering two lags[6], is 12.328, higher than 7.30, the upper band critical value at the 5% level of significance. Moreover, *the t-statistic for* $t(LGDP/LEP)$ is also higher than its critical value (-3.777 versus -3,69)[7].

Additionally, the residuals are tested for stationary to avoid spurious results and to ensure the existence of the long run relationship. The ADF test exhibits a value of -6.755 which is higher than the critical value of -4.15 at the 1 per cent of significance.

[6] The optimum lag lengths have been determined using Akaike's information criterion.
[7] The critical values for the F-statistic at the 5% level of significance and for a model with one explanatory variable with constant and trend are [6.65, 7.30] and for the t-statistic [-3.41, -3.69].

So that residuals are stationary, thus indicating a stable long run relationship between the variables.

On the contrary, as Table 3 shows, the values for $F_{LEP}(LEP/LGDP)$ and $t(LEP/LGDP)$ obtained in the alternative regression where *LEP* is the dependent variable are 7.006 and -0.721, respectively, which fall within the critical band.

These results from Tables 2 and 3 lead to the conclusion that, in the case of Spain, electricity supply explains economic growth in the long-run with no feedback effect being observed. That is, economic growth does not cause more electricity generation. Therefore, the proper model to explain the relationship between both variables is the one showed in Table 2[8].

As seen in Table 2, long term coefficients associated to the lagged variables in level —*LGDP(-1)* and *LEP(-1)*— have the expected sign and are significant. The coefficient on the lagged income representing the convergence parameter is equal to -0.380 and significant to 5 per cent, as pointed out earlier. This indicates that 38 per cent of deviations from long run equilibrium level are corrected in each year. As a result, it will take approximately a year and a half to ensure full correction.

The sign of the variable *LEP(-1)* is positive and significant, indicating a long-term positive effect on the dependent variable, *GDP* growth. Elasticity amounts to 0.42 per cent (this is minus 0.16 over -0.38, the value of the convergence parameter) in the case of the relationship between electricity generation and *GDP*[9]. These results indicate that in the long-term, an increase in power production can increase growth of *GDP* by 0.42 per cent, which is not a negligible amount.

With respect to the variables in differences, positive and negative effects are detected in the short-run dynamics. In particular, *GDP* exhibits positive values and it is a significant variable in the first lag, indicating that an increase of one percent in the *GDP* of the previous year will result in a 0.314 per cent expansion in economic growth. Whereas electricity production has a negative, but not significant, impact on *GDP* in the short-run.

The dummy variable that captures the behavior difference in the sample from 2008 presents a negative sign, reflecting that the decline in both the dependent and the independent variable is due to the crisis.

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[8] Akaike information criterion advises the use of two lags in the model.
[9] The long run effect is estimated as $-(\sigma_{1LGDP/}\ \sigma_{2LGDP})$ in equation (1).

In addition, based on the coefficient of variation, the model explains 70.6 per cent of the variation in *GDP* growth and the results from the robustness tests for the model indicate no serial correlation (DW=1.867) and not a bad specification problem (LM= 0.803 and ARCH=0.240, the tests of autocorrelation and conditional heteroscedasticity, respectively).

Performing the same type of exercise to consider electricity consumption, similar results are obtained and these outcomes remain even when considering the structural change that occurs in the Spanish economy after the year 2007 (see Tables 4 and 5)[10].

As we can see in Table 4, electricity consumption has a positive and significant effect in *GDP* growth in the long run with an elasticity of 0.44 per cent (-(0.16/-0.36)), indicating that one percent increase in electricity consumption raise *GDP* growth on 0.44 per cent. Nevertheless, this variable, as electricity production variable, has a negative, but not significant, short-run impact. The residuals of the model are stationary, with a value for the ADF of -7.236, higher than the critical value, indicating a stable long-run relationship. Moreover, 70 per cent of the variation in *GDP* growth is explained by the model and there are no specification problems.

From the outcomes of Table 5 we can conclude that *GDP* growth in Spain does not explain electricity consumption. The values for $F_{LEC}(LEC/LGDP)$ and $t(LEC/LGDP)$ obtained in the regression where *LEC* is the dependent variable and *LGDP* the explanatory variable are 4.308 and -1.442 respectively, and both are below the band of critical values.

Insert Table 4 and Table 5

5. Conclusion and policy implications

The empirical results have yielded mixed results in terms of the four hypotheses related to the causal relationship between electricity consumption and economic growth (growth, conservation, neutrality and feedback). As previous research shows, the variation in the empirical results may be attributed to the selection of variables, model specifications, time periods of the studies, stage of development of the countries or econometric approaches undertaken.

[10] For the appropriateness of using dummies to control for sporadic or permanent shocks, see Fuinhas and Cardoso (2012).

The aim of this study was to re-examine the electricity-GDP nexus in Spain following the approximations made by some authors and using the ARDL bounds test approach, which is an appropriate methodology for short series. The present study differs from previous ones carried out for Spain in the following aspects: it uses data on electricity supply as well as on electricity consumption and considers a broader period of time, from 1958 to 2011.

It was found that electricity generation (as well as electricity consumption) was a stimulus for economic growth whereas economic growth did not lead to an increase in electricity generation or in electricity consumption. These outcomes support the growth hypothesis, as does Pirlogea and Cicea's work (2012) but contradict Ciarreta and Zarraga´s (2010) as well as Funhias and Cardoso's (2012) conclusions. In this context, it should be emphasized that from 1958 Spanish economy enjoyed a take-off as well as a period of expansion and modernization of the electricity sector. In any case, the results of this study should be interpreted with caution, as electricity does not reflect the total amount of energy used in Spain.

This causal relationship may provide a basis for a discussion on the appropriate design and implementation of energy and environmental policies. The unidirectional causality from electricity production (or consumption) to economic growth shows that a small and resource-limited economy, as the Spanish, is more vulnerable to energy shocks than other energy-sufficient economies. Since Spain is a country with high energy dependence, the government must first ensure the electricity supply. The improvements in the availability and accessibility of electricity will boost the growth prospects of the Spanish economy. Conversely, a shortage in supply of electricity will constrain the regular pace of economic growth.

And what can we state about the environmental questions or about a more efficient use of energy in a country that imports most of the primary energy consumed? As to the efficiency in the use of modern energies, Rubio Varas (2005) concluded that since 1850 Spain has increasingly needed more energy per output unit, whereas the opposite is observed for Europe. Even if, energetic intensity is not an appropriate energy efficiency indicator its evolution reflejcts inefficient electricity usage in industry, the commercial and household sectors as well as Spain's competitivite loss with respect to its European suppliers and customers. The improvement in efficiency is hindered by the fact in Spain the annual increase in retail electricity prices has been capped by the government, as Tarancón et al. (2011) claimed.

Environmental issues can be even more worrying, according to Iglesias et al. (2013). CO_2 emissions have grown in Spain at a faster pace than energy availability and GDP, given that highly polluting sources like coal and petrol continue to be used in the production of electricity. For that reason, environmental aspects constitute a great challenge in Spainsh energy policies. Spain should encourage its industries to adopt new technologies to minimize CO_2 emissions in order to abide by the recommendations of the Kyoto Protocol.

In sum, to reduce the energy dependency, to improve efficiency and lessen environmental problems, and to ensure uninterrupted energy supply and sustainable growth, Spain should continue to investigate and explore more efficient and cost-effective sources of energy, in particular the renewable energies, because traditional energy sources will be scarce before long.

Future research should include the observation of gas emissions in the examination of the causal relationship between electricity production and economic growth. This could shed additional light on the environmental impact of electricity production and consumption. It would also be interesting to analyse the relationship between GDP growth and electricity production, distinguishing energy sources.

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Table 1: Results of unit root tests (with constant and trend)

	LGDP			*LEP*			*LEC*		
	ADF	PP	KPSS	ADF	PP	KPSS	ADF	PP	KPSS
Levels	-2.534	-1.026	0.223**	-2.621**	-1.461	0.220**	-1.976	-1.612	0.219**
First-differences	-5.075**	-5.071**	0.070	-2.928	-5.933**	0.103	-4.027*	-4.058*	0.110

Note: ** and * represent the rejection of the null hypothesis of non-stationarity at the 5% and the 10% level of significance, respectively.

Table 2: OLS estimates of first-differences of real GDP in logs ($\Delta LGDP$) in Spain for the period 1958-2011

Explanatory variables	Coefficient (*t-statistic*)
Intercept	-7.183
	(-4.107)
Trend	0.006
	(4.606)
$\Delta LGDP(-1)$	0.314
	(2.079)
$\Delta LGDP(-2)$	0.158
	(1.018)
$\Delta LEP(-1)$	-0.006
	(-0.057)
$\Delta LEP(-2)$	-0.019
	(-0.22)
LGDP(-1)	-0.380
	(-3.777)
LEP(-1)	0.160
	(2.673)
D2007	-0.034
	(-2.584)
$R^2 = 0.706$	
Adj. $R^2 = 0.650$	
DW = 1.867	
F-statistic = 12.636	
AIC = -5.015	
LM=0.803	
ARCH= 0.240	
Bounds test for cointegration	
$F_{LGDP}(LGDP/LEP)$ =12.328**	
t(LGDP/LEP) =-3.777**	
DFA (resid)= -6.755***	

Notes: *LGDP* is the level of real GDP in logs and *LEP* is the level of electricity production in logs. The symbol Δ represents the first differences of the variables. *D2007* is a dummy variable that takes value 1 from 2008 onwards.

Table 3: OLS estimates of first-differences of electricity production in logs (Δ*LEP*) in Spain for the period 1958-2011 (Equation (2))

Explanatory variables	Coefficient (*t-statistic*)
Intercept	-4.694 (-1.973)
Trend	0.003 (1.433)
Δ*LGDP*(-1)	-0.042 (-0.186)
Δ*LGDP*(-2)	0.080 (0.361)
Δ*LEP*(-1)	0.025 (0.158)
Δ*LEP*(-2)	0.334 (2.475)
LGDP(-1)	0.002 (0.009)
LEP(-1)	-0.075 (-0.722)
D2007	-0.037 (-1.795)
R^2 = 0.667 Adj. R^2 = 0.603 DW = 1.867 F-statistic = 10.522 AIC = -4.203 LM=1.417 ARCH= 0.387 Bounds test for cointegration $F_{LGDP}(LEP/LGDP)$ =7.006 $t(LEP/LGDP)$ = - 0.721 ADF (resid)= -8.368***	

Notes: *LGDP* is the level of real GDP in logs and *LEP* is the level of electricity production in logs. The symbol Δ represents the first differences of the variables. *D2007* is a dummy variable that takes value 1 from 2008 onwards.

Table 4: OLS estimates of first-differences of real GDP in logs ($\Delta LGDP$) in Spain for the period 1958-2011 (Equation (1))

Explanatory variables	Coefficient (*t-statistic*)
Intercept	-5.311
	(-3.558)
Trend	0.005
	(4.212)
$\Delta LGDP(-1)$	0.307
	(2.052)
$\Delta LGDP(-2)$	0.242
	(1.601)
$\Delta LEC(-1)$	0.163
	(1.255)
$\Delta LEC(-2)$	-0.113
	(-0.811)
LGDC(-1)	-0.368
	(-3.832)
LEC(-1)	0.167
	(2.630)
D2007	-0.021
	(-1.717)
$R^2 = 0.700$	
Adj. $R^2 = 0.641$	
DW = 1.867	
F-statistic = 11.970	
AIC = -5.126	
LM=0.885	
ARCH= 0.797	
Bounds test for cointegration	
$F_{LGDP}(LGDP/LEC)$ =10.006**	
t(LGDP/LEC) =-3.832**	
ADF (resid)= -7.236***	

Notes: *LGDP* is the level of real GDP in logs and *LEC* is the level of electricity consumption in logs. The symbol Δ represents the first differences of the variables. *D2007* is a dummy variable that takes value 1 from 2008 onwards.

Table 5: OLS estimates of first-differences of electricity consumption in logs (ΔLEC) in Spain for the period 1958-2011 (Equation (2))

Explanatory variables	Coefficient (*t-statistic*)
Intercept	-2.856
	(-1.178)
Trend	0.001
	(0.565)
Δ*LGDP*(-1)	-0.031
	(-0.166)
Δ*LGDP*(-2)	-0.203
	(-0.993)
Δ*LEC*(-1)	0.297
	(1.623)
Δ*LEC*(-2)	0.255
	(1.259)
LGDP(-1)	0.121
	(0.771)
LEC(-1)	-0.126
	(-1.442)
D2007	-0.035
	(-1.984)
R^2 = 0.728	
Adj. R^2 = 0.675	
DW = 2.120	
F-statistic = 13.743	
AIC = -4.493	
LM=1.288	
ARCH= 0.752	
Bounds test for cointegration	
$F_{LGDP}(LEC/LGDP)$ =4.308	
t(LEC/LGDP) = - 1.442	
ADF (resid)= -7.293***	

Notes: *LGDP* is the level of real GDP in logs and *LEC* is the level of electricity consumption in logs. The symbol Δ represents the first differences of the variables. *D2007* is a dummy variable that takes value 1 from 2008 onwards.