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Evaluating the impact of new renewable energy on the peak load - An ARDL approach for Portugal

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Abstract

The integration of intermittent renewable energy will lead to demand surplus, whenever the need for generation from combined-cycle plants increases. This paper focuses on Portugal, a country in which wind power is largely integrated, and which has recently made major investments in solar power. The results show that coal energy management does not contribute to smoothing out the intermittency problems of intermittent renewable energy. The results further demonstrate that the inclusion of intermittent renewable energy in the electricity system leads to a huge need for combined-cycle generation. Thus, this suggests that a differentiated price policy will only be effective if, instead of consumption, the focus is on net load.

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Keywords: Net load; Intermittent renewable energy; Combined-cycle plants; ARDL; Demand surplus

1. Introduction

The intermittent renewable energy sources (hereafter RES-I), namely wind and solar-photovoltaic, are characterized by intermittent and unpredictably generation with variable costs close to zero. However, the penetration of RES-I implies high initial investment costs. These costs are an obstacle to investors, and therefore generation by RES-I would have to be subsidized. The most common contracts used to finance wind power and solar energy are the feed-in tariffs, which provide RES-I with dispatch priority at a fixed price throughout the period of consumption/generation [1, 2].

This work intends to add to the literature by investigating changes in peak electricity periods when there is RES-I generation. To do this, four Autoregressive Distributed Lag (ARDL) models will be developed to compare the differences between electricity demand and electricity net load with generation from thermal sources. No comparable methodology was found in the literature. In order to analyze the

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intermittency problem of RES-I, it is crucial to define the notion of net load. Net load is defined in the literature as the total electricity demand minus the total renewable energy [3, 4], or minus wind power [5, 6]. In this paper, the electricity net load (hereafter ENL) is defined as the demand for electricity minus the supply from wind and solar power.

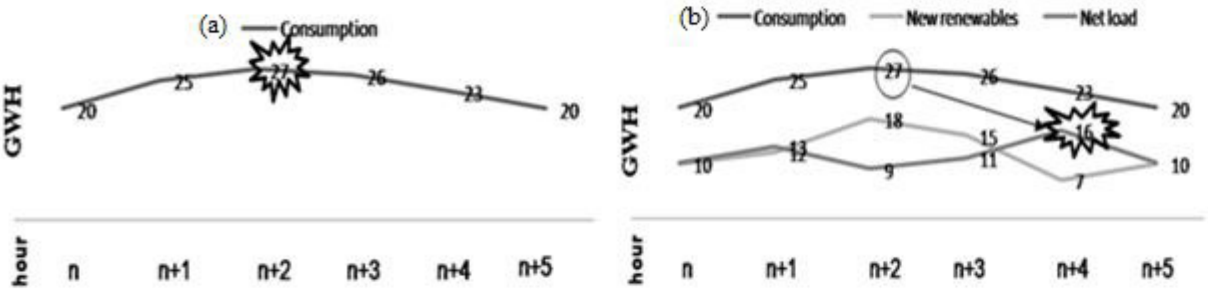

Figure 1 (a) Demand surplus before the integration of RES-I. (b) Demand surplus with integration of RES-I

With non-renewable sources, the variable costs vary with the price of raw materials. As such, when there is higher consumption, the demand for raw materials also increases, leading to an increase in its price. Thus, before the integration of RES-I, it was crucial to smooth the load diagram by decreasing consumption peaks. The consumption peak corresponds to the generation peak of the total thermal sources. Fig.1, (a) and (b) serve as examples of the demand surplus before the integration of RES-I, and illustrate the ENL concept, respectively.

Fig.1 (a) represents a situation of electricity demand in GWh over a period of 6 hours on a given day (values are merely illustrative). So, before the integration of RES-I, critical consumption would be in the period n+2, i.e. a consumption of 27 GWh. Considering the intermittent nature of resource availability, the peak-pricing concept has to be adapted to the new energy mix challenges.

Given that the RES-I are intermittent, the best scenario for accommodating these RES-I is making demand follow the availability of the natural resources. In this way, the higher costs of electricity may not be present in times of higher consumption. This will happen whenever the need for generation from thermal sources increases.

In Fig. 1 (b), there is a change regarding the period of peak consumption due to the RES-I, i.e. the peak period is not period n+2 (consumption = 27 GWh) but period n+4 (consumption = 23 GWh). This peak change is due to the greater need for electricity production by thermal sources during period n+4. Thus, it can be seen that, with the integration of RES-I, the most problematic moments are the peaks observed in the ENL, since it is at these times that renewable production is lower.

This paper seeks to answer the question: could intermittent electricity contribute to the reduction of demand surplus? The objectives are to identify the differences between the presence and absence of generation from combined-cycle gas turbine plants (hereafter CCGT) in relation to consumption and ENL. By clarifying the relationship, the impact of RES-I on the remaining generation sources will be identified. To do this, the paper focuses on Portugal, a country with substantial integration of wind power and one of the most isolated countries in Europe. The main outcome shows that the RES-I, by not following the increases of electricity demand, causes an increased need for generation by CCGT.

The paper is developed as follows: section 2 presents a review of the literature; section 3 is devoted to presenting the data and methodology used and the preliminary results; section 4 presents the main results, as well as the robustness checks and a discussion of the results; and section 5 presents the conclusions.

2. Literature Review

In order to reduce the emission of greenhouse gases (GHG), some European countries have set targets for RES integration. By 2020, the goal is for at least 20% of energy consumption to be from renewable sources (Directive 2009/28/EC) and for this amount to reach 27% by 2030 (2030 Energy Strategy).

To achieve this goal, several forms of electricity generation from RES-I have been added to the energy mix of European countries [7]. RES-I have the characteristics of intermittent, non-dispatchable generation. Due to their intermittence, the adoption of these RES-I causes changes in the characteristics of electricity demand [3]. Intermittent energy causes the need to increase the flexibility of the electricity market [7]. However, the most recent coal-fired thermal power plants with carbon capture have low flexibility [8], much like conventional ones. This means that combined-cycle sources should be provided, which are more flexible, and have the ability to ensure a faster response to the extremely sudden changes in production of RES-I [9].

There is evidence in the literature that the generation of electricity from RES-I causes a higher reduction in the base-load and intermediate-load than in the peak-load [3]. In this perspective, it is necessary to consider the impact of RES-I in order to define the changes that occur in all of the load groups (base, intermediate and peak).

The impact of renewable energy integration is sometimes considered to reduce capacity, as well as CO2 emission costs [5]. However, reductions in electricity capacity do not always follow reductions in costs. There is evidence in the literature that renewable energy contributes to smaller price fluctuations, which in itself does not guarantee that these are lower, since prices depend on the penetration of renewables [3]. It is well known that a larger penetration of RES-I requires backup capacity as well as flexibility to manage surplus, by such means as pumping or exporting [12, 13]. These requirements may be reduced in the future, because in a situation of a great penetration of wind power, there are moments when the ENL would be negative, i.e., renewable production would exceed the demand for electricity. In that scenario there are two alternatives, the excess electricity is stored (equivalent to the current pump) or the demand must have high flexibility (which could reduce the need for backup) [6]. Fortunately (?), there is evidence in the literature of the concept of V2G/G2Vof electricity, which consists in the use of electric cars as storage/supply components in the electricity grid, in combination with the two previous alternatives [12]. However, there are other solutions which can create flexibility, for example, the demand response through setting electricity tariffs [13].

It is often reported in the literature that, in order to accommodate renewable energy, it is necessary to store it. It also indicates that the existence of a renewable energy surplus (negative ENL) does not allow the use of all the electricity from renewable sources, and therefore the greater the renewable energy penetration, the larger the amount of energy wasted [6, 16, 17].

3. Methodology

3.1. Data

Monthly data is used for the period from July 2007 to September 2015, with a total of 99 observations. The selected period begins in July 2007, as it was on this date that the MIBEL market between Portugal and Spain was established. September 2015 is the most recent date for data collection. All data is available on REN’s Monthly Statistics, except MIBEL prices, which were collected from the OMIE. Table 1 lists the variables and summary statistics for total generation of thermal plants minus CCGT (COAL), total generation of thermal plants (TERMOR), electricity consumption (CONS), electricity net load (ENL), RES-I generation, total generation of renewable energy minus wind and solar-photovoltaic generation (RE), hydro generation (HYDRO), Mibel prices (MIBEL), Pumping consumption (PUMP) and export/import ratio (REXP). All the values are in GWh, except the Mibel prices that are in Eur/MWh.

Table 1. Variables and summary statistics

Variable	Descriptive Statistics				
	Obs	**Mean**	**Std dev**	**Min**	**Max**
COAL	99	1229.687	396.2385	267	2198
TERMOR	99	1548.556	509.0514	313	2639
CONS	99	4162.465	278.25	3728	4920
ENL	99	3377.374	361.5209	2698	4301
RES-I	99	785.0909	305.6216	271	1655
RE	99	679.8788	135.8636	429	988
HYDRO	99	847.4545	520.3952	291	2350
MIBEL	99	47.5535	12.8933	15.39	76.55
PUMP	99	80.9697	37.2124	22	191
REXP	99	2.3529	4.8002	1	37.1364

Thermal energy is generally the backup power source for RES-I and as such, its interaction with photovoltaic and wind energy is decisive. Thermal energy is divided into coal energy and total thermal energy (coal and combined-cycle). The impact of combined-cycle generation is determinant because its characteristic of flexibility serves as a response to the intermittency of the RES-I. Thus the coal source (*COAL*) and total thermal sources (*TERMOR*) are defined as the dependent variables.

In order to understand the relationship between the different thermal sources and the RES-I, in a perspective of assessing the impact of RES-I on peak load, an indirect correlation is carried out by measuring the consumption (*CONS*) and the electricity net load (*ENL*), i.e. *CONS* minus *RES-I*.

The other factors that influence thermal generation are all the remaining sources of electricity generation and/or import/export, to ensure that all electricity consumption is satisfied. These are, the renewables (*RE*), composed mostly of thermal biomass; hydroelectric generation under the ordinary regime (*HYDRO*); pumping (*PUMP*); the export/imports ratio of electricity (*REXP*); and also MIBEL's market electricity prices for Portugal (*MIBEL*) because of its potential influence on dispatchable generation.

3.2. ARDL approach

The fact that any electricity system, which also includes Portugal's system, is managed in real time, leads to endogeneity between variables. To deal with the endogeneity, the VAR/VEC model is often used. However the ARDL model [16] is also suitable in the presence of endogeneity and copes well with it. The ARDL model can also deal with the uncertainty about the order of integration of the variables, providing that no variable is I(2). This is so in our case (see Table 2). The ARDL also allows checking the short- and long-run effects between the variables. The ARDL model is specified as follows:

$$\Delta y_t = c + \sum_{i=1}^{k} \beta_i .\Delta y_{t-i} + \sum_{i=0}^{k} \beta_{i+2} .\Delta x_{t-i} + \beta_{i+3} . y_{t-1} + \sum_{i=0}^{k} \beta_{i+4} .x_{t-1} + \beta_{i+4} ID + \varepsilon_t \quad (1)$$

where y=[*COAL*, *TERMOR*] corresponds to the dependent variables in the estimated models; x=[*CONS*, *ENL*, *RES-I*, *RE*, *HYDRO*, *MIBEL*, *PUMP*, *REXP*, *ID*] corresponds to the exogenous variables in the models; c is the constant; β_i andβ_{i+3} are the coefficients of the dependent variables; β_{i+2}a and β_{i+4} are the coefficients of the explanatory variables; y_{t-i} , y_{t-1} , and x_{t-1} correspond to the lags of the dependent and explanatory variables, respectively;and ID corresponds to the dummies used to control for the outliers.

Given that relative changes are more representative than absolute ones, the variables were transformed to their natural logarithms. Thereafter the prefix L means natural logarithm of the variables. To ascertain the order of the variables' integration, traditional unit root tests were performed (Table 2). They are Augmented Dickey-Fuller (ADF) [17], Phillips-Perron (PP) [18] and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) [19].

Table 2. Unit roots tests

Variables		ADF			PP			KPSS	
		C	CT	None	C	CT	None	C	CT
LCOAL	Level	-4.2414***	-4.3620***	-0.2583	-4.3018***	-4.4653***	-0.2219	0.4558*	0.1253*
	1st dif	-11.103***	-11.065***	-11.162***	-11.403***	-11.371***	-11.470***	0.0472	0.0230
LTERMOR	Level	-3.7785***	-4.1698***	-0.2386	-3.8271***	-4.3067***	-0.2007	0.7227**	0.0867
	1st dif	-10.910***	-10.866***	-10.968***	-11.441***	-11.406***	-11.513***	0.0587	0.0356
LCONS	Level	-0.5642	-1.2857	-0.5582	-5.2107***	-5.1735***	-0.4668	0.3293	0.0639
	1st dif	-4.9629***	-4.9291***	-4.9563***	-18.940***	-19.059***	-19.071***	0.1963	0.1709**
LENL	Level	-1.1926	-7.6017***	-2.5809**	-4.6164***	-7.5406***	-0.9683	1.2989***	0.0986
	1st dif	-4.4937***	-4.5878***	-3.9824***	-42.171***	-41.916***	-33.105***	0.1892	0.1652**
LRES-I	Level	-3.0658**	-5.1910***	2.6952	-3.7209***	-5.1899***	0.4197	1.1435***	0.1678**
	1st dif	-7.3250***	-8.0577***	-6.6223***	-13.374***	-13.393***	-13.417***	0.1418	0.0616
LRE	Level	-2.4383	-2.7842	0.2964	-2.4459	-2.9330	0.3179	0.9434***	0.2578***
	1st dif	-10.705***	-10.719***	-10.744***	-10.702***	-10.720***	-10.739***	0.0859	0.0236
LHYDRO	Level	-4.5653***	-4.6929***	-0.2927	-3.6844***	-3.7568**	-0.3632	0.2289	0.0607
	1st dif	-8.1045***	-8.0739***	-8.1483***	-8.1077***	-8.0769***	-8.1515***	0.0339	0.0291
LMIBEL	Level	-3.5990***	-3.6212**	-0.2200	-3.5990***	-3.6212**	-0.1139	0.1674	0.1031
	1st dif	-9.9091***	-9.8567***	-9.9604***	-10.543***	-10.474***	-10.616***	0.0582	0.0522
LPUMP	Level	-3.6322***	-4.5894***	-0.0022	-3.4171**	-4.5979***	0.0162	0.8674***	0.0927
	1st dif	-12.187***	-12.124***	-12.239***	-13.469***	-13.392***	-13.507***	0.0457	0.0452
LREXP	Level	-4.8508***	-5.0611***	-4.1142***	-4.9841***	-5.2172***	-4.2167***	0.4343*	0.0475
	1st dif	-10.385***	-10.332***	-10.439***	-15.877***	-15.832***	-16.000***	0.0886	0.0797

Notes: None denotes without constant and trend; C denotes constant; CT denotes constant and trend.
***, **, * Denotes significance at 1%, 5% and 10% level respectively.

During this period some phenomena are observed which reveal statistical significance. They are a break that occurs every year around April/May in hydro generation. Considering that the beginning of 2012 was characterized by little rainfall, this led to the months of January/February having reduced capability for hydroelectric generation, and hence the structural break in April/May 2011 was included in the model (dummies *ID2011:05*, and *ID2011:04*). The case was also considered in which the MIBEL price reached a minimum (dummy *ID2010:03*). In the same way, the peak in the MIBEL price (dummy *ID2013:12*) was considered. Two more breaks (see Table 3) were identified throughout the Zivot-Andrews unit root test [20].

Table 3. Break point test

Variables	Zivot-Andrews test statistic	Chosen break point
LCONS	0.0401**	ID2009m12
LMIBEL	0.0152**	ID2008m12

The date that marks the upward trend of renewables and the downward trend of all the thermal energy; represented by the dummy*ID2009:12*.The downward trend in the MIBEL price; represented by the dummy*ID2009:01*(a following month was chosen for the observation of residues).

The following diagnostic residual tests were performed: the ARCH test for heteroscedasticity; Breusch-Godfrey serial correlation LM test; Jarque-Bera normality test, stability coefficients test of CUSUM and CUSUM of squares; and Ramsey RESET test. The robustness of the models was also checked.

4. Results and Discussion

This section will discuss the results attained.

4.1. Estimation results

After confirming that no variable are I(2), the ARDL models were carried out. Four ARDL models were estimated (I, II, III, and IV), two have *COAL* as the dependent variable (I, and II) and the remaining two (III, and IV) have *TERMOR* as the dependent variable, i.e., the sum of the cycle combined with the coal source. Taking into account each dependent variable, an analysis was performed in comparison to consumption and the ENL.

Model I (*COAL*/*CONS*) includes the relationship between *COAL* and consumption *CONS*. Model II (*COAL*/*ENL*) is focused on the relationship between *COAL* and *ENL*. Model III (*TERMOR*/*CONS*) relates *TERMOR* to consumption *CONS*. Lastly, Model IV (*TERMOR*/*ENL*) relates *TERMOR* to *ENL*. It should be noted that when *ENL* is considered, both the *CONS* variable and the RES-I variable are excluded, because *ENL* corresponds to *CONS* subtracted from *RES-I*.

Several tests have been applied to ensure the robustness of the models; the Heteroscedasticity Test ARCH, with the null hypothesis: homoscedasticity, which proved to be homoscedasticity for all models, in the first and second orders; the Breusch-Godfrey Serial Correlation LM test, with the null hypothesis: no correlation in the series, proving also that in the four models there is no correlation of errors in the first, second and third orders, except in the second order for model *COAL*/*ENL*; the Jarque-Bera normality test confirms that in all models the error term follows normal distribution; and finally, another test was carried out on the stability coefficient, the Ramsey RESET test, which also confirms that there is stability in the model. Table 4 summarizes the tests carried out on all four models:

Table 4. Diagnostic tests

Test	*I-COAL/CONS*	*II-COAL/ENL*	*III –TERMOR/CONS*	*IV – TERMOR/ENL*
ARS	0.8459	0.8408	0.8752	0.8762
Jarque-Bera	0.7269	0.8587	0.5763	0.5758
LM	(1) 0.2377 (2) 0.4573 (3) 0.3956	(1) 0.6906 (2) 0.0793 (3) 0.1346	(1) 0.9645 (2) 0.5982 (3) 0.7935	(1) 0.9925 (2) 0.9657 (3) 0.9952
ARCH	(1) 0.3512 (2) 0,2396	(1) 0.1894 (2) 0.3152	(1) 0.4098 (2) 0.5299	(1) 0.1207 (2) 0.2476
RESET	0.4155	0.2831	0.7964	0.8741

Notes: Diagnostic test results are based on F-statistics. () represents lags for the variables. ARS denoted Adjusted R-squared. Jarque-Bera is a normality test. LM is Breusch-Godfray serial correlation LM test. ARCH denotes ARCH test for heteroscedasticity. RESET is stability Ramsey RESET test.

The stability coefficient CUSUM and squares CUSUM test also suggests that there is stability in all models (Fig.3):

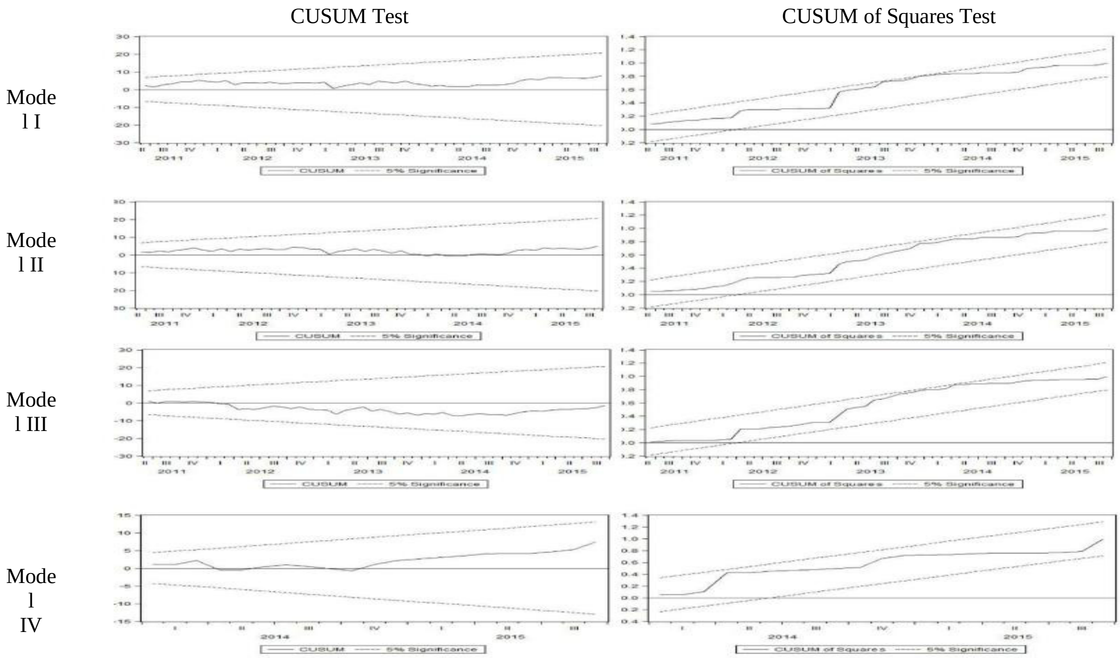

Figure 3. CUSUM and CUSUM of Squares

The stability coefficient CUSUM and CUSUM of Squares Tests also suggests that there is parameter stability in all models. In model *COAL*/*CONS*, *COAL*/*ENL* and *TERMOR*/*CONS*, the period calculated is from 2011:04 to 2015:10; in model *TERMOR*/*ENL* the period calculated is from 2014:01 to 2015:10. The periods used in the CUSUM, and CUSUM of Squares Tests differ in model IV due to the utilization of dummies. Table 5 summarizes the elasticities and semi-elasticities of all four models.

Table 5. Semi-elasticities and elasticities

Semi-elasticities	*D(LCOAL)*		*D(LTERMOR)*	
	Model I	Model II	Model III	Model IV
D(LCONS)	0.6742***	---	0.7966***	---
D(LHYDRO)	-0.3038***	-0.2292***	-0.2675***	-0.2563***
D(LMIBEL)	0.9974***	1.0696***	0.8376***	0.8576***
D(LREXP)	0.1620***	0.1518***	0.0806**	0.0995***
D(LENL)	---	0.4085**	---	0.7161***
D(LRES-I)	---	---	-0.1542***	---
Elasticities				
LRES-I(-1)	0.5794***	---	---	---
LRE(-1)	-1.8261***	-1.2716***	-0.9608**	-0.8356**
LHYDRO(-1)	-0.2636**	---	---	---
LMIBEL(-1)	---	0.3921*	---	---
LPUMP(-1)	---	0.2101**	---	---
LREXP(-1)	---	---	-0.3378**	-0.3708***
ECT(-1)	-0.3243***	-0.3056***	-0.2189***	-0.2239***

Notes: ECT denotes Error Correction Term.
***, **, * Denote significance at 1%, 5% and 10%level respectively.

Please note that the elasticities were computed by the ratio of the coefficient of the variables in the long-run and the ECT, both lagged once, and then multiplied by -1.

In models *COAL*/*CONS* and *COAL*/*ENL*, the short-run causality between *LHYDRO*, *LMIBEL* and *LREXP* and the dependent variable *LCOAL*, are all in the same direction and of similar dimensions. In the long-run, the negative elasticity with the LRE is higher in the *COAL*/*CONS* model. Yet in the long-run, in the *COAL*/*CONS* model there is a relationship with *LRES-I* and *LHYDRO*, while in the second model the relationship occurs between *LMIBEL* and *LPUMP*.

In the *TERMOR*/*CONS* and *TERMOR*/*ENL* models, the short-run relationships between *LHYDRO*, *LMIBEL* and *LREXP* and the dependent variable remain in the same direction and with very similar dimensions, while there is a negative relationship with LRES-I. In the long-run, the relationship between the dependent and *LRE* continues to be negative with a greater dimension in the *TERMOR*/*CONS* model (with consumption (*LCONS*)), and there is a negative relationship with *LREXP*. In the *COAL*/*CONS*-*COAL*/*ENL* and *TERMOR*/*CONS-TERMOR-ENL* models, the relationship with *LCONS* and *LENL* is of larger magnitude for consumption, although of smaller magnitude in the *TERMOR*/*CONS-TERMOR*/*ENL* models.

4.2. Short-run relationships

In all the models, the short-run relationship with hydro energy is negative, which means that, when hydro availability is greater, the need for thermal output is lower. This is coherent with what happens with RES-I considering that thermal sources have higher generation costs.

The relationship with MIBEL prices (*LMIBEL*) is positive, indicating that when the price of MIBEL is higher, there is a greater predisposition to produce thermal electricity in order to benefit from its export. The existing relationship is reduced in the *TERMOR*/*CONS-TERMOR*/*ENL* models (coal with combined-cycle), which is expected, due to the higher generation prices of CCGT, and for this reason its export is less efficient.

The relationship with the export ratio is positive, i.e., the higher the export, the greater the generation by thermal sources. This relationship is connected to MIBEL prices, since the export takes place at the MIBEL price, and therefore, confirms that there is thermal electricity generation to export. The decrease in this ratio, for marginal values, in the *TERMOR*/*CONS*-*TERMOR*/*ENL* models, is again indicative of the extremely specific and essential function of such CCGT to respond to the intermittency of RES-I.

The negative relationship with RES-I is revealed only in the *TERMOR*/*CONS* model and not in the *COAL*/*CONS* model, which again leads us to conclude that there is substitutability between RES-I and the combined-cycle.

4.3. Long-run relationships

In the long run, there is a positive relationship between the RES-I and the total thermal energy in the *COAL*/*CONS* model, this relationship was not expected. However, because of the poor flexibility of coal, the output is relatively constant over the daily periods and for this reason there is a positive relationship with RES-I.

In the *COAL*/*CONS* model, a negative relationship with the hydro energy is also observed, which shows the existing substitutability between hydro and coal. In the *COAL*/*ENL* model there is a positive relation with MIBEL prices and pumping. This means that, globally, an increase in MIBEL prices leads to increased coal generation, which is related to electricity export. Pumping has a positive relationship that conforms to the existing opposing relation with hydro generation, i.e. when there is hydro generation, coal generation tends to decrease, but when there is pumping to postpone hydro generation for future use, coal generation tends to increase.

A negative relationship is found in all models with renewables without intermittency (*LRE*), however, the relationship is of smaller dimension in *TERMOR*/*CONS*-*TERMOR*/*ENL* models that consider the combined-cycle, i.e., because the renewable (*LRE*) has dispatchable generation, within the availability of raw material (biomass), acting as thermal substitutes, not replacing the generation of the combined-cycle that acts as backup for RES-I.

In *TERMOR*/*CONS*-*TERMOR*/*ENL* models a negative relation is also observed with the ratio of exports. Although the increase of MIBEL price leads to increased coal generation, the ratio of exports/imports causes a decrease in total thermal energy. We conclude that the rising price of MIBEL leads to increased coal generation due to the exports of other generation sources since, when the ratio of exports increases, there is less of a need for thermal generation due to surplus from other generation sources.

4.4. Relationship between the Consumption-Net Load

In models with coal generation, a more significant relationship is observed between coal generation and consumption than with the ENL. This relationship is observed due to coal generation being designed to operate for longer periods because of its characteristic of lower flexibility. When consumption is expected to be higher, the level of coal generation is projected to be higher, and therefore does not absorb the variations that the intermittency of RES-I gives to the ENL.

In models with total thermal sources, the relationship remains the same. However, this time the relationship between total thermal with ENL and consumption presents approximate values. This relationship is observed because total thermal takes into account combined-cycle generation, which being flexible, serves as a backup to absorb the intermittency of RES-I. So, the increased influence of the ENL on total thermal generation is due to a greater need for backup power. This need for backup power is greater in scale and/or occurs with more frequency, so the new notion of peak load has to focus on those moments. This means that RES-I cause a greater need for backup power, increasing the pressure on CCGT, and therefore create an electricity market that is more expensive.

Even with the frequency of monthly data, there are several moments, namely night-time, when combined-cycle generation is not necessary due to the abundance of RES-I. We can conclude that the impact of the increases in consumption are significant, because they are not fully followed by RES-I, and at this time an approximation is observed in the relationship between ENL and consumption.

A real-time pricing policy is necessary in order to control the times when demand is excessive, so that this surplus is no longer a surplus at peak consumption, but during net peak loads. It is also important to point out the importance of electricity storage in the future, as the excess from RES-I that is stored during excess generation times, could be used to smooth the ENL surplus.

5. Conclusion

In general it is concluded that thermal generation sources are essential for the stability of the electrical system. On one hand, coal sources contribute to network security by providing a substantially constant amount of generation over the daily period. The generation amount varies inversely, in general, with the availability of hydro and biomass. On the other hand, combined-cycle sources, by being more flexible, contribute to system stability in the presence of wind and solar energy, which are characterized by intermittent generation.

Coal energy, which contributes to the baseload, also plays an important role in the exchange of electricity between Portugal and Spain. Although the relationship between the export ratio and total thermal power is negative, this relationship suggests that most of the export occurs only when the other generating sources are abundant, so only those sources are exported. However, when we observe that the increase in MIBEL prices causes increases in coal energy, it suggests that the increase in coal serves to "release" power from other sources to the export target, and thus benefit from higher MIBEL prices. So, there is an important role for coal generation in the electricity exchange in the Iberian Peninsula through the MIBEL market.

When it comes to RES-I, the ENL is an essential measure to ascertain the impact these have on demand. Pricing policy on demand surplus should not continue to focus on the excesses of consumption, but on the ENL surplus. That is, the new renewable variable costs are almost zero and therefore, when the source of production has higher variable costs, a decrease in demand is needed, and this excess will be observed in the ENL, because the ENL represents all the consumption that will have to be satisfied by the existing production sources before the integration of RES-I. Through this investigation it can be shown that, when there is RES-I integration, the most critical periods of electricity consumption are not always linked to highest demand. However, it is not possible to determine when these periods occur. As a solution, the use of data with higher frequency is recommended to make it possible to calculate what periods are the most critical.

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