The dynamics of the Italian electricity generation system: an empirical assessment

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Abstract: - This article focuses on how electricity generation sources interact with each other and with economic activity in Italy. This country has gone through a period of instability in its economic activity. It is very dependent on the importation of electricity and of raw materials for electricity generation. These factors make the analysis of the dynamics of interaction between the various sources in Italy particularly interesting. Monthly data is used, employing an ARDL approach. This approach allows the use of variables I(0) and I(1) at the same time, as well as allowing an understanding of the difference in the short- and long-run effects. The Toda-Yamamoto causality test was used to determine causal relationships. In general, the results show empirical evidence for the substitution effect between hydropower and fossil fuels. The hydropower generation source has a positive impact in the short-run, and a negative one in the long-run, given that, the possibility of expanding capacity in this generation source has almost been exhausted. In the long-run, economic activity encourages renewable energy generation, but the opposite is not verified. This result is consistent with the fact that the contribution of renewables is a result of the goals outlined by the European Union. Thus policy makers should stimulate the endogenous production of electricity. The target set by the European Union should take into account the degree of wealth of the countries. This work also contains a detailed discussion about energy policies to make the accommodation of generation sources within the system more flexible.

Key-Words: - ARDL approach; Toda-Yamamoto causality test; economic growth; renewable and non-renewable electricity; Italy;

1 Introduction

For a long time, electricity has been becoming an essential good, not only for the each country's sustainable development, but also for the wellbeing of humankind. This utility can be generated from several sources, from both renewable and non-renewable sources. For several reasons, such as fighting climate changes or reducing energy dependence, renewable sources are being increasingly used to generate electricity. Meanwhile, there is a widespread trend toward the electrification of economies. As is well-known, the main function of any country's electric power system is to ensure that electricity supply meets electricity demand without shortages, in both peak and off-peak periods. However, one of the challenges of managing an electric power system is the simultaneous accommodation of the various electricity generation sources.

The European Union has been giving great importance to the promotion of renewable energy policies [1][2][3]. However, the intermittency of renewables is a big handicap for renewable energy, specifically new renewables like wind and solar photovoltaic. The adoption of measures to promote renewables, such as feed-in tariffs, and the problem of intermittency, could even result in idle wind capacity [4].

It is the need to diversify the electricity mix in this context, and the consequences of that diversification on the economy, particularly on economic growth, that motivates this paper. It is focused on analysing the Italian electricity system because of the special characteristics of this country. For instance, in this country fossil fuels are the main electricity generation source, and imports are essential to meet electricity demand. Italy is a net electricity importer, as well as an importer of raw fossil materials for generating electricity. The Italian economy has experienced a turbulent period similar to other countries in southern Europe, mostly associated with the sovereign debt crisis.

The relationship between electricity generation sources and economic activity is analysed here. Electricity generation sources have different characteristics and, as such, diverse impacts on economic activity are expected. In this way, understanding how the electricity system is accommodating the various generation sources is crucial to finding a sustainable electricity mix. This analysis is carried out by controlling for adjustment variables, namely pumping and the external trade in electricity. Bearing in mind that the electricity mix is a critical issue in the long-run, and that decisions are taken in the short-run, the ARDL approach is used to identify the short- and long-run effects. Results show that economic activity is caused by electricity generation sources as well as the export-import ratio (RXM). The substitution effect between fossil and renewable energy sources (RES) is proven in the short-run, while in the long-run the back-up role is proven. The RXM causes fossil sources and RES, which reveals the importance of the foreign market for the Italian electric power system.

2 Literature Review

There is an abundance of literature focused on the energy consumption / economic growth nexus. Nonetheless, the results are far from unanimous. This is a consequence of diverse factors, as summarised by Oztuk [5]. The literature is mostly organized around testing four hypotheses [6], as follows. The *Neutrality Hypothesis*, which implies non-causality between energy consumption and economic growth. The *Conservation Hypothesis* implying a causal relationship from economic growth to energy consumption, indicating that energy conservation policies do not have a significant effect on Growth. The *Feedback Hypothesis* states that energy consumption causes economic growth and vice-versa. Finally, the *Growth Hypothesis*, predicts a unidirectional causal relationship from energy consumption to economic growth. Under this hypothesis, energy conservation policies can reduce economic growth, so energy consumption plays an important role in economic growth, and can be seen as a factor of production, like labour and capital.

Studies that analyse the growth-energy nexus use several samples, various econometric methodologies, and both micro-econometric and time series techniques.

In general, this literature on the nexus reveals some insufficiencies, particularly because it does not consider the nature of the interactions within the electricity mix, with the exception of Marques et al [7] and Marques and Fuinhas [8]. As such, this research will not focus specifically on energy consumption and economic growth, but instead on the interaction between electricity generation by source, and on economic activity. Renewable energy has assumed a greater importance due to the targets of energy policies adopted by the European Union. The application of these policies has achieved a reduction in the emission of greenhouse gases, with an increase in energy efficiency [9] [10]. The effect of GDP on renewable energy depends on the level of participation of renewable sources [11]. The consumption of electricity from renewable sources has different effects in developed and developing countries [12]. Countries with high growth rates are able to respond to high energy prices through an increase in production using renewables [13]. Ohler and Fetters [14] studied the relationship between the generation of electricity from renewable sources and output growth, for a panel of 20 OECD countries, for the years 1990-2008, and found a bidirectional causality, which supports the feedback hypothesis.

A well-known characteristic of renewable sources is the intermittency of their generation flow. The introduction of such sources into the electricity system, requires a flexible system [15]. A flexible system is characterized by: high generation capacity by conventional sources; high capacity interconnections with other countries; electricity storage and Demand Side Management (DSM). The flexibility mechanisms of different system are discussed in Lund et al [16].

3 The Italian Electric Power System

The Italian power system made modifications to the generation mix, namely the discontinuation of nuclear plants (1988), the introduction of new renewable energy and the integration with foreign markets. The scarcity of natural resources for electricity generation, and electricity imports limit alternatives for electricity generation.

The Italian electricity market went through a liberalization process, from 1999 until 2007. The transmission system operator in Italy is TERNA. The separation of the transmission and distribution processes occurred in 2004, and was created by the Italian wholesale electricity market, IPEX (Italian Power Exchange). Bigerna [17] proposed a new monitoring mechanism for the promotion of a competitive market, based on the application of penalties.

The Italian electricity market operator, *Gestore dei Mercati ENERGITICI* (GME), operates on the day-ahead market, in the form of an auction market. The electricity market is divided into seven regional zones. This Italian zonal market can be seen with more detail in Gianfreda and Grossi [18]. The submarkets have specific demand characteristics and different market structures, and the electric power system suffers severe transmission bottlenecks [19].

The electricity mix in Italy uses both conventional and renewable sources. They are plants powered by coal, fuel oil and natural gas; multi-fuel power plants with coal and oil or natural gas and oil; gas turbine plants; combined cycle gas turbines (CCGT); hydro power with storage or run-of-river; wind power; solar photovoltaic; geothermal and other renewables. Figure 1 shows the aggregated evolution of the use of hydro, fossil fuel and RES sources for generation. A decrease in fossil is contemporaneous with a gradual increase in RES. Several factors might be influencing the reduction in consumption, such as improved energy efficiency and the consequences of the sovereign debt crisis.

Solar PV and wind are complementary sources, as noted by Monforti et al [20]. In Italy, an increase of 1 GWh in production of solar and wind power reduces the wholesale market price, by 2.3 €/MWh and 4.2€/MWh, respectively. However, the same authors point out that these savings are far from enough to counterbalance the financing of programmes to promote renewables. Economic instruments that incentivize the use and development of wind and solar PV sources are feed-in tariffs and green certificates, respectively. For Antonelli and Desideri [21] these programmes are disadvantageous to the production mix and for Italy's final consumer, given that these costs are included in the consumer retail price.

4 Data and Method

4.1 Description of variables and research hypothesis.

Monthly data is used in this study, for the period of January 2005 to October 2014, i.e. 118 observations. The period was chosen according to the availability of data for electricity generation by sources. Data for renewable energy sources is only available from January 2005 onward. October 2014 was chosen based on data available in November 2014. The data from electricity generation by source is available from the European Network of Transmission System Operators for Electricity (ENTSO-E), in the section Data-Country Data Packages, the shortest frequency available is monthly. The industry production index was extracted from EUROSTAT. The industrial production index is used as the economic activity indicator, because the shortest available GDP frequency is quarterly. The IPI is used as an imperfect proxy of GDP, and does not include all sectors of the economy [22] [23].

The sources of electricity generation considered, are hydropower, fossil fuels, renewable energy sources (excluding hydroelectric), and the system management variables are the rate of coverage of imports by exports and pumping systems. The hydropower (*LHYDRO*) includes the energy generated by stored water and run-of-river (mini-hydro). The fossil fuels (*LFOSSIL*) include electricity generation by hard coal, oil, gas and mixed fuels. The renewable energy sources (*LRES*) (excluding hydro), are also called new renewables and include wind power, solar photovoltaic, biomass and geothermal. The other variables used are the adjustment variables of the system. The rate of coverage of electricity imports by electricity exports (*LRXM*) was computed by dividing exports by imports. The electricity consumption in water pumping systems (*LPUMP*) allows the storage of generated electricity that cannot be sent into external markets.

The mainstream literature focused on the nexus is looking for empirical evidence for the four traditional hypotheses described above, namely *neutrality hypothesis, conservation hypothesis, feedback hypothesis and growth hypothesis.* This study goes beyond that traditional approach, analysing not only the relationship between energy consumption and economic growth, but also analysing the nature of the relationships between the various electricity sources that constitute the electricity mix in Italy. As such, in addition to testing those traditional hypotheses, five new research hypotheses regarding the relationships between the electricity sources were defined, as follows.

- *H1 – Contrary to fossil sources, RES do not stimulate economic growth.*

Some of the recent literature has not confirmed the positive effect of new renewable sources on economic growth. For instance, Marques et al [7], analyzing the Greek economy, concludes that renewables are not causing economic growth. Given that Italy is under the influence of common objectives defined within the EU concerning RES targets, it is anticipated that fossil sources will stimulate economic growth, unlike renewable sources.

- *H2 – The development of RES requires higher income levels.*

The development of renewable electricity sources is associated with large investments, given that they are capital intensive. In the literature, these investments are associated with countries with higher levels of wealth. This appears be a necessary condition that enables the countries to accommodate this effort to diversify sources, while avoiding increased tariffs on consumers. Ultimately, this prevents the economy, as a whole, from having to bear the high development costs of these investments in renewables.

- *H3 – The increasing penetration of RES into the electricity mix causes a substitution effect on fossil sources.*

As the use of renewable sources increases, the replacement of installed fossil fuels sources is expected. Indeed, assuming that demand is not affected by the additional use of renewable sources, then the larger the use of RES, the lower the use of fossil sources will be.

- *H4- Both hydropower and fossil sources are backing up Renewable Energy Sources.*

Hydropower allows the storage of water in order to alter the time when electricity is generated and, as such, even though renewable, it is not a source with the same intermittency characteristics as wind and solar PV. Besides its long tradition in generating electricity, recent technological developments now enable it to be quickly turned on. This fact is more apparent in run-of-river hydropower plants, which are usually coupled with pumping.

- *H5 – RES provokes electricity exports.*

Bearing in mind the intermittency in the generation of renewables, it is expected that at some periods of the day coinciding with a greater availability of resources, including wind, this may lead to oversupply. Thus, if demand is kept unchanged, it is expected that this excess of electricity could be used to export or, alternatively, to pump water for storage.

4.2 Method

The fact that the Italian electric power system is heavily managed therefore presupposes the existence of endogeneity between the variables. VAR/VECM, models are specifically used to deal with this type of question. The ARDL model [24] is another type of relatively robust structure, but with different assumptions. This structure allows a different integration order of variables, provided they are not I(2). It also allows different independent variables, different lag-lengths within the model and it is less restrictive. The ARDL model is particularly useful for allowing the observation of the short- and long-run effects separately.

To examine the stationary properties, traditional tests are made. The traditional tests are ADF (Augmented Dickey-Fuller test) [25], PP (Phillips-Perron test) [26] and KPSS (Kwiatkowski-Phillips-Schmidt-Shin test) [27]. These tests may show inappropriate results, due to the existence of structural breaks in the time series. Due to the characteristics of the variables and the monthly frequency of the data, the system is subject to shocks. To overcome this potential problem, unit root test with structural breaks are made, Zivot and Andrews [28] and Perron [29].

Different orders of integration of the variables were detected, and the causality test developed by Toda and Yamamoto [30] was implemented. This econometric technique can be used independently of the stationarity proprieties of the variables. This procedure is based on a WALD test in a VAR model in levels [31]. Toda-Yamamoto causality is a mixed analysis in the short- and long-run.

A general ARDL model is specified as follows:

$$\phi(L,p)y_t = \beta_i(L,q_i)x_{it} + \alpha' z_t + \varepsilon_t \quad (1)$$

where L is the lag operator; $\phi(L,p) = 1 - \phi_1 L - \phi_2 L^2 - \phi_3 L^3 - ... - \phi_p L^p$ and $\beta_i(L,q_i) = B_{i0} + \beta_{i1} L + \beta_{i2} L^2 + ... + \beta_{iq} L^{q_i}$ and z is a vector of deterministic variables including the constant, trend and exogenous variables with fixed lags, p and q_i are the lag lengths, α' represents the coefficient of the deterministic variables, and ε is a error term. y_t is the dependent variable and x_{it} represents explanatory variables. The general form of the unrestricted error correction model (UECM) of the ARDL is shown in equation 2.

$$\Delta y = \sum_{i=1}^{k} \beta_{i0} \Delta x_{it} + \alpha' \Delta z_t - \sum_{j=1}^{\hat{p}-1} \theta_j^* \Delta y_{t-j} - \sum_{i=1}^{k} \sum_{j=1}^{\hat{q}i-q} \beta_{ij}^* \Delta x_{i,t-j} - \theta(1,\hat{p}) ECT_{t-1} + \varepsilon_t \quad (2)$$

The coefficients θ_j^* and β_{ij}^* relate to the short-run dynamics of the model's convergence to equilibrium. A statistically significant Error Correction Term (ECT) characterizes the long memory of the variables. There is a certain adjustment speed between the variables for the model to converge to equilibrium.

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 Likelihood ratio exclusion test.

5 Results

5.1 Unit root tests.

The null hypothesis for the ADF test and PP test is: the variable has a unit root, i.e., the variable is non-stationary. Contrary to the ADF and PP tests, the KPSS test has a null hypothesis, of stationarity. This test reveals no consensus about the integration order of the series. In some cases, they appear to be borderline I(0)/I(1). Nonetheless, the tests confirm that variables are not I(2). To make sure that the variables are not I(2), additional unit root tests with structural breaks were carried out, Zivot and Andrews (Table 1) and Perron. For both tests the null hypothesis is that the variable has a unit root with structural breaks. The tests confirm that the variables are definitely not I(2).

5.2 Toda-Yamamoto causality test

The Toda-Yamamoto procedure can be observed in Table 2. The variable LPUMP was used as an exogenous variable, because it was not caused by any variable, but causes other variables.

The Toda-Yamamoto approach exhibits the desired econometric properties in residual tests. The error term follows normal distribution (Jarque-Bera statistic: 9.2488; p-value: 0.5087). Serial correlation of the first order does not exist (LM statistics: 18.6789, p-value: 0.8123) and the errors are homoscedastic (chi squared: 651.6598, p-values: 0.4194).

Globally, all variables cause and are caused, so the variables are endogenous. As you can see LIPI is caused by all variables, LRES is also caused by all variables. LHYDRO is only caused by LFOSSIL at 1% significance level and LRXM is only caused by LIPI. A visual representation can be seen in Figure 2.

5.3 ARDL model

After the verification of the stationary and endogeneity properties of the variables, the ARDL model was estimated. Five ARDL models were estimated, their dependent variables are electricity generation sources, industrial production index and ratio of coverage of imports by exports, both in first differences. Where the dependent variables are *DLIPI*, *DLHYDRO*, *DLFOSSIL*, *DLRES* and *DLRXM*, they correspond to the models I, II, III, IV and V, respectively.

Impulse and shift dummies were used to control the outliers and structural breaks identified in Zivot-Andrews unit root tests with structural breaks. These dummy variables should be used as sparingly as possible.

The ARCH test for heteroscedasticity has the null hypothesis: homoscedasticity. In this test the null hypothesis cannot be rejected, regardless of order test. To the Breusch-Godfray serial correlation LM test, the null hypothesis of no serial correlation, cannot be rejected in the first order serial correlation. In the second and third orders, this also cannot be rejected, except in model II. The Jarque-Bera normality test confirms that the error term follows normal distribution. The coefficient stability test CUSUM and CUSUM squares suggest the parameters' stability for all equations (Figure 2). The tests ensure the quality of the estimates.

The likelihood ratio exclusion has been performed for each model. The independent variables are statistically significant, and consequently should be preserved in the model. Semi-elasticities and elasticities for all models were performed in Table 3.

In model I, an increase of 1% in electricity generation under HYDRO, decreases IPI by 0.378%, in the long-run. In respect to the short-run, an increase of 1 percentage point (pp) in *DLHYDRO*, *DLFOSSIL*, and *DLRES* lagged once and *DLRXM* has an impact of 0.330, 1.166, -0.167 and 0.095 pp, respectively. The *HYDRO* model indicates that *FOSSIL* produces an effect in the short- and long-run, of 0.279 pp and -1.553%, respectively. The semi-elasticity of IPI in model III reveals the positive effect on electricity generation by *FOSSIL* sources. *HYDRO* sources have a different effect on *FOSSIL* sources, in both the short-run (-0.135 pp) and long-run (1.180%).

6 Discussion

This paper is focused on the analysis of the dynamics of interactions between electricity generation sources, both renewable and non-renewable. Moreover, the paper assesses the kind of relationships that could be observed between these various sources and economic activity. The sectorial measure, the Industrial Production Index, is used, given that the GDP data was unavailable on a monthly frequency. This data frequency is revealed to be appropriate. Indeed, working with annual data would involve an unsatisfactory number of observations, meanwhile the required time span does not distinguish between the contributions from each renewable source, given that they are very recent. Accordingly, great care must be taken when comparing this paper with the traditional literature focused on the energy-growth nexus. The ARDL approach used has allowed the analysis of the effects verified both in the short- and long-run. Moreover, the results from the Toda-Yamamoto causality test and the ARDL approach reveal great consistency.

There is evidence for the feedback hypothesis for fossil sources, but only in the short-run. Actually, there is a causal relationship from fossil to IPI and the reverse is also true. However, this relationship is not observable in the long-run. The nature of the effect of hydropower is dissimilar in the short- and long-run. Regarding renewables, except hydro, these sources do not stimulate economic activity, in contrast to fossil sources. Instead, *RES* lagged once is hampering economic activity, which, for example, is in line with Ocal and Aslan [32], therefore the *H1* is supported. In the meantime, in the long-run, the IPI is an incentive for the deployment of renewables, which is also consistent with the literature. Indeed, it seems that the greater wealth of a country allows it to increase its contribution to renewables, so *H2* is verified. If renewables require abundance and prosperity, the obvious question is how can the poorest countries, or countries with budgetary difficulties, such as Italy and other EU countries, meet the targets for renewables? The recent worldwide crisis, which is particularly affecting Southern European countries, has forced some countries to accept adjustment programmes. These programmes further hindered the development of the economy, making it more difficult to proceed with the deployment of renewable sources.

As is commonly known, these goals are not conditional on the level of wealth of each country. Accordingly, aggressive strategies to promote renewables in the absence of strong domestic financial support could provoke undesirable consequences for the prosperity of the country. In fact, this evidence is observed in the negative effect from renewables to IPI, observed in model I, which is consistent with that noted by Antonelli and Desideri [21]. In short, IPI requires greater use of fossil sources in the short-run, given that these sources are able to enlarge their contribution to the electricity mix almost instantaneously. In turn, RES are stimulated by IPI only in the long-run. On one hand these sources don’t have the capacity of storage and as such they cannot instantly satisfy any additional demand. On the other hand, the enhancement of economic activity releases financial resources to invest in renewables. All this evidence constitutes strong support for a revision of the EU targets, which should be fixed in accordance with the performance of economic activity.

What has been said before suggests that the path traced by renewables is mostly defined by the decision makers. In fact, this autonomous behaviour of renewables is also corroborated by the highly statistical significant presence of an increase trend. In the short-run there is indication of a substitution effect between RES and fossil, therefore H3 is partially verified. However, this effect is significant only at 10%. In contrast to this, in the long-run there is no evidence of a substitution effect between these two kinds of sources. The opposite is true, i.e., more RES requires more fossil availability to back the intermittency of the renewables, and thus *H4* is verified. Regarding the variables external trade and pumping, which are variables of the management of the system, external trade is not shown to be significant in the long-run, but pumping reveals a contribution to generate hydropower in the long-run. In the short-run, only external trade is statistically significant. This suggests that the external trade in electricity is being used in the short-run to accommodate RES, by backing them, so *H5* is not verified.

Conclusion

The interactions between electricity sources and economic activity were studied in Italy, for the time span from January 2005 till October 2014. Italy is confronted with the need to diversify its electricity mix in the medium and long-run, but meanwhile, is faced in the short-run with severe budget constraints that have been made worse by the sovereign debt crisis. The Toda-Yamamoto causality testing and the ARDL approach were carried out, in order to be able to fully understand the dynamics of adjustment both in the short- and long-run. This paper contributes to the literature not only by analysing a specific Southern European country, but essentially by enriching the analysis of the traditional energy-growth nexus. Indeed, the dynamics of adjustment of the various electricity sources is crucial to fully understand the consequences of diversifying the mix.

The findings of this paper confirm the presence of the feedback hypothesis in Italy, but only for fossil sources and only in the short-run. Moreover, this paper provides support for the argument that the deployment of renewables requires that the country is capable of supporting the cost of investing in renewables. Indeed, forcing countries with financial difficulties to accomplish demanding targets for renewables could further worsen the already weak condition of their economies. In this way, the EU's 2020 Climate and Energy Package, seems excessively ambitious for Italy.

References:

[1] European Commission, "DIRECTIVE 2001/77/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market," *Off. J. Eur. Communities*, vol. 6, 2001.

[2] European Commission, "DIRECTIVE 2003/30/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport," *Off. J. Eur. Communities*, vol. 4, no. 11, 2003, pp. 42–46.

[3] European Commission, "DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC," *Off. J. Eur. Communities*, 2009, pp. 16–62.

[4] R. Flora, A. C. Marques, and J. A. Fuinhas, "Wind power idle capacity in a panel of European countries," *Energy*, vol. 66, Mar. 2014, pp. 823–830.

[5] I. Ozturk, "A literature survey on energy–growth nexus," *Energy Policy*, vol. 38, no. 1, Jan. 2010, pp. 340–349.

[6] A. Omri, "An international literature survey on energy-economic growth nexus: Evidence from country-specific studies," *Renew. Sustain. Energy Rev.*, vol. 38, 2014, pp. 951–959.

[7] A. C. Marques, J. A. Fuinhas, and A. N. Menegaki, "Interactions between electricity generation sources and economic activity in Greece: A VECM approach," *Appl. Energy*, vol. 132, 2014, pp. 34–46.

[8] A. C. Marques and J. A. Fuinhas, "The role of Portuguese electricity generation regimes and industrial production," *Renew. Sustain. Energy Rev.*, vol. 43, 2015, pp. 321–330.

[9] M. Kanellakis, G. Martinopoulos, and T. Zachariadis, "European energy policy—A review," *Energy Policy*, vol. 62, Nov. 2013, pp. 1020–1030.

[10] D. Helm, "The European framework for energy and climate policies," *Energy Policy*, vol. 64, Jan. 2014, pp. 29–35.

[11] A. C. Marques, J. a. Fuinhas, and J. R. Pires Manso, "Motivations driving renewable energy in European countries: A panel data approach," *Energy Policy*, vol. 38, no. 11, Nov. 2010, pp. 6877–6885.

[12] G. E. Halkos and N. G. Tzeremes, "The effect of electricity consumption from renewable sources on countries economic growth levels: Evidence from advanced, emerging and developing economies," *Renew. Sustain. Energy Rev.*, vol. 39, 2014, pp. 166–173.

[13] T.-H. Chang, C.-M. Huang, and M.-C. Lee, "Threshold effect of the economic growth rate on the renewable energy development from a change in energy price: Evidence from OECD countries," *Energy Policy*, vol. 37, no. 12, Dec. 2009, pp. 5796–5802.

[14] A. Ohler and I. Fetters, "The causal relationship between renewable electricity generation and GDP growth: A study of energy sources," *Energy Econ.*, vol. 43, 2014, pp. 125–139.

[15] A. S. Brouwer, M. Van Den Broek, A. Seebregts, and A. Faaij, "Impacts of large-scale Intermittent Renewable Energy Sources on electricity systems, and how these can be modeled," *Renew. Sustain. Energy Rev.*, vol. 33, 2014, pp. 443–466.

[16] P. D. Lund, J. Lindgren, J. Mikkola, and J. Salpakari, "Review of energy system flexibility measures to enable high levels of variable renewable electricity," *Renew. Sustain. Energy Rev.*, vol. 45, 2015, pp. 785–807.

[17] S. Bigerna, C. Andrea Bollino, and P. Polinori, "Marginal cost and congestion in the Italian electricity market: An indirect estimation approach," *Energy Policy*, 2015, pp. 1–10.

[18] A. Gianfreda and L. Grossi, "Forecasting Italian electricity zonal prices with exogenous variables," *Energy Econ.*, vol. 34, no. 6, 2012, pp. 2228–2239.

[19] P. Garrone and A. Groppi, "Siting locally-unwanted facilities: What can be learnt from the location of Italian power plants," *Energy Policy*, vol. 45, 2012, pp. 176–186.

[20] F. Monforti, T. Huld, K. Bódis, L. Vitali, M. D'Isidoro, and R. Lacal-Arántegui, "Assessing complementarity of wind and solar resources for energy production in Italy. A Monte Carlo approach," *Renew. Energy*, vol. 63, 2014, pp. 576–586.

[21] M. Antonelli and U. Desideri, "The doping effect of Italian feed-in tariffs on the PV market," *Energy Policy*, vol. 67, 2014, pp. 583–594.

[22] R. Sari, B. T. Ewing, and U. Soytas, "The relationship between disaggregate energy consumption and industrial production in the United States: An ARDL approach," *Energy Econ.*, vol. 30, no. 5, Sep. 2008, pp. 2302–2313.

[23] J. Chevallier, "A model of carbon price interactions with macroeconomic and energy dynamics," *Energy Econ.*, vol. 33, no. 6, 2011, pp. 1295–1312.

[24] Y. Shin and M. H. Pesaran, "An Autoregressive Distributed Lag Modelling Approach to Cointegration Analysis," 1999.

[25] W. A. Dickey, David A.; Fuller, "1979.pdf." Journal of the American Statistical Association, pp. 427–431, 1979.

[26] P. Phillips, Peter; Perron, "Testing for a unit root in time series regression," *Biomètrica*, vol. 75, 1988, pp. 335–346.

[27] Y. Shin, D. Kwiatkowski, P. Schmidt, and P. C. B. Phillips, "Testing the Null Hypothesis of Stationarity Against the Alternative of a Unit Root : How Sure Are We That Economic Time Series Are Nonstationary?," vol. 54, 1992, pp. 159–178.

[28] E. Zivot and D. W. K. Andrews, "Further Evidence on the Great Crash, the Oil-Price Shock, and the Unit-Root Hypothesis," *J. Bus. Econ. Stat.*, vol. 10, no. 3, 1992, pp. 251–270.

[29] P. Perron, "The Great Crash, the Oil Price Shock, and the Unit Root Hypothesis," 1989.

[30] H. Y. Toda and T. Yamamoto, "Statistical inference in vector autoregressions with possibly integrated processes," *J. Econom.*, vol. 66, no. 1–2, 1995, pp. 225–250.

[31] S. B. Bruns and C. Gross, "What if energy time series are not independent? Implications for energy-GDP causality analysis," *Energy Econ.*, vol. 40, 2013, pp. 753–759.

[32] O. Ocal and A. Aslan, "Renewable energy consumption–economic growth nexus in Turkey," *Renew. Sustain. Energy Rev.*, vol. 28, Dec. 2013, pp. 494–499.

Appendix

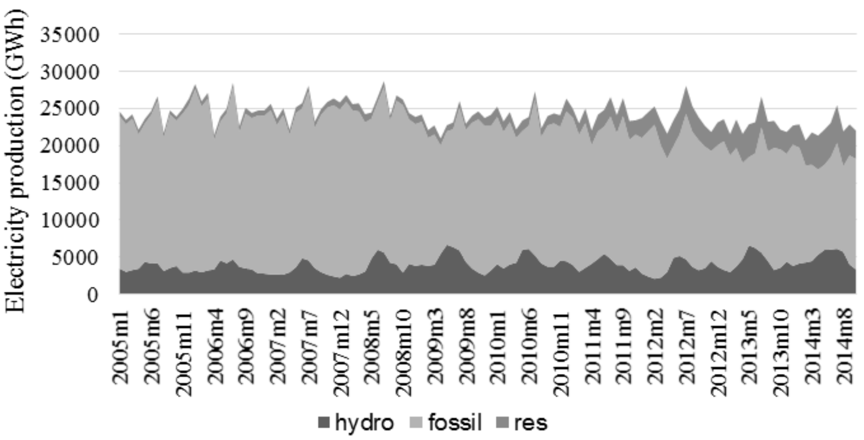

Figure 1. Electricity generation by sources

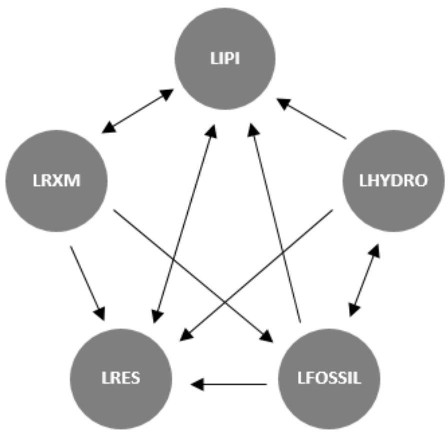

Figure 2: Diagram of causalities

Table 1. Unit roots tests with structural breaks Zivot-Andrews

Variables		C	Break point	T	Break point	CT	Break point
LIPI	level	-6.1529***	2008m8	-4.7797**	2007m1	-6.8676***	2008m8
	1st dif	-9.1104***	2009m10	-8.8482***	2008m9	-9.0814***	2009m10
LHYDRO	level	-6.9490***	2008m5	-6.4522***	2006m12	-7.1715***	2008m5
	1st dif	-7.3589***	2012m3	-7.2616***	2008m7	-7.3994***	2012m4
LFOSSIL	level	-5.3638***	2013m2	-5.2239***	2012m1	-5.2568**	2011m7
	1st dif	-8.1058***	2009m7	-8.3993***	2013m4	-8.1302***	2009m7
LRES	level	-6.1900***	2011m2	-4.8813***	2008m10	-6.0577***	2011m2
	1st dif	-9.5879***	2009m9	-9.4721***	2011m6	-9.5590***	2009m9
LRXM	level	-6.5492***	2010m2	-6.5407***	2007m12	-7.1610***	2009m1
	1st dif	-7.8879***	2008m4	-7.7850***	2009m4	-5.8453***	2009m1
LPUMP	level	-6.2865***	2010m7	-5.0958***	2007m12	-6.2512***	2010m7
	1st dif	8.6853***	2011m9	-8.0290***	2010m9	-8.7788***	2011m9

Notes: C stands for constant; T stands for trend; CT stands for constant and trend; ***, ** and * represents significance levels of 1%, 5% and 10%, respectively

Table 2. Toda-Yamamoto

	Dependent Variable				
	LIPI	LHYDRO	LFOSSIL	LRXM	LRES
LIPI does not cause		2.1382	0.8320	7.1845**	5.9427*
LHYDRO does not cause	5.2518*		8.2481**	0.6802	6.5433**
LFOSSIL does not cause	29.3526***	17.2411***		0.6850	4.8857*
LRXM does not cause	9.8669***	2.8805	6.3530**		5.7179*
LRES does not cause	5.7682*	0.5417	1.9582	3.4185	
ALL	35.3210***	29.3143***	19.0759**	20.5671***	15.562**

Notes: the results are based on Chi squared statistics.
***, ** and * represents significance levels of 1%, 5% and 10%, respectively.

Table 3. ARDL Diagnostics tests, semi-elasticities and elasticities

	I - DLIPI	II - DLHYDRO	III - DLFOSSIL	IV - DLRES	V - DLRXM
Diagnostic tests					
ARS	0.7801	0.3994	0.5028	0.2434	0.3769
SER	0.126264	0.1397	0.0775	0.1273	0.4711
Jarque-Bera	0.125451	0.6975	0.5004	0.1509	0.7589
LM	(1) [0.4197]	(1) [0.2178]	(1) [0.1056]	(1) [0.8988]	(1) [0.5395]
	(2) [0.7119]	(2) [0.0103]	(2) [0.2717]	(2) [0.9920]	(2) [0.6399]
	(3) [0.8719]	(3) [0.0173]	(3) [0.0081]	(3) [0.7317]	(3) [0.7293]
ARCH	(1) [0.8089]	(1) [0.4526]	(1) [0.1924]	(1) [0.5586]	(1) [0.5475]
	(2) [0.8490]	(2) [0.1810]	(2) [0.3626]	(2) [0.8301]	(2) [0.7453]
ECT	-0.7129***	-0.4735***	-0.0560***	-0.4009***	-0.3883***
Semi-elasticities					
DLIPI			0.2883***		
DLHYDRO	0.3303***		-0.1350***		0.4637*
DLHYDRO(-1)		0.2789***		-0.1396*	
DLFOSSIL	1.1657***	-0.3253**			2.0731***
DLFOSSIL(-1)				-0.5166***	
DLRES(-1)	-0.1675**				
DLRXM	-0.0950***		0.0539***		
DLRXM(-1)				0.0591***	
Elasticities					
LIPI				0.7417***	-0.6691***
LHYDRO	-0.3777***		1.1796***		
LFOSSIL		-1.5526***		0.2722***	
LPUMP		0.1923**			

Notes: diagnostic tests results are based on F-statistics. [ ] represented the p-values of F-statistic and ( ) represented lags for the variables. ARS denoted Adjusted R-squared. SER means standard error of regression. Jarque-Bera is a normality test. LM is Breusch-Godfray serial correlation LM test. ARCH denotes ARCH test for heteroscedasticity. ECT means Error Correction Term.***, ** and * represents significant level for 1%, 5% and 10%, respectively.