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Energy and Mineral Resources Exploitation in the Delignitization Era: The Case of Greek Peripheries

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Abstract: The efficient and sustainable exploitation of energy resources may secure a sustainable economic growth for different regions. However, the peripheries are subject to social, economic, and political constraints, with limited power over energy management. The present work examines regional convergence in exploitation efficiency as synopsized in the GDP generated by energy and minerals in an era of the country's efforts to shut down the lignite-run power production. With the assistance of panel unit root tests, we confirm non convergence of the variables employed, an expected result given the fact that different energy sources are being used for energy production by each different periphery, generating different economic results. In the second stage the methodology employed is a Bayesian vector auto-regressive model (BVAR) with an informative prior on the steady state. The particular methodology outperforms the conventional VAR methodology due to limited degrees of freedom. The Impulse response analysis and the Variance Decomposition analysis confirmed interlinkages among the regions studied. This result implies that the growth generated by different energy and mineral resources are interconnected. Furthermore, the energy transition taking place in Megalopoli and West Macedonia, where the two greatest lignite industries were located until recently, affects the growth generated by energy and resource exploitation for all the other peripheries, according to our findings. The novelty of the present work stands on the concept to detect interlinkages of energy and resources-based growth for the peripheries in Greece with the assistance of the Bayesian Var. The results of the present work are significant, since our findings suggest to policy makers tools to promote economic growth generated by energy based on alternative energy sources, including the environmentally friendly ones, by taking into consideration the interlinkages established by the existing infrastructure and the conventional energy sources used.

Keywords: energy GDP; regional convergence; Greece; Bayesian VAR; energy transition; energy policy

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1. Introduction

Climate change is accompanied by significant damage in the global environment with potential irreversible changes in global ecosystems. The abundance of environmental problems is driven mainly by the reliance on fossil fuels to power economic growth and by industrialized forms of agriculture, for the feeding purposes of an increasingly wealthy global population. Keeping in mind the above it becomes necessary for the current fossil fuel-based economic system to turn into another more environmentally friendly model within the process of energy transition [1].

The energy dependence of Greece on lignite and its connection to the country's economic growth validates the lignite consideration as a national fuel. Within the EU effort for the establishment of a carbon-neutral economy, energy transition is a necessary step. Energy transition for Greece entails delignitization. Thus, in order for Greece to be a pioneer in energy transition, it submitted in 2019 a 10-year National Energy and Climate Plan (NECP) that unveils how to cease all energy production from coal until the year 2028 [2].

The European Green Deal [3] provides a synopsis of the attitude of the European Union towards a zero-emission EU. This agreement suggests a new strategy for a wealthy and fair society, based on an economy that is efficient with its resources, as climate neutrality by 2050 is a high priority issue. This action improves the target expectations compared to the initial ones (corresponding to a 40% emission reduction target set for 2030). Energy transition is a feasible target for Greece, given that the energy and mineral resource availability can promote an energy mix that can make energy security an achievable target. Despite the potential impediments of the Greek roadmap to energy transition, the existing situation in terms of conventional and renewable sources is illustrated in Figure 1, which was derived by IPTO [4].

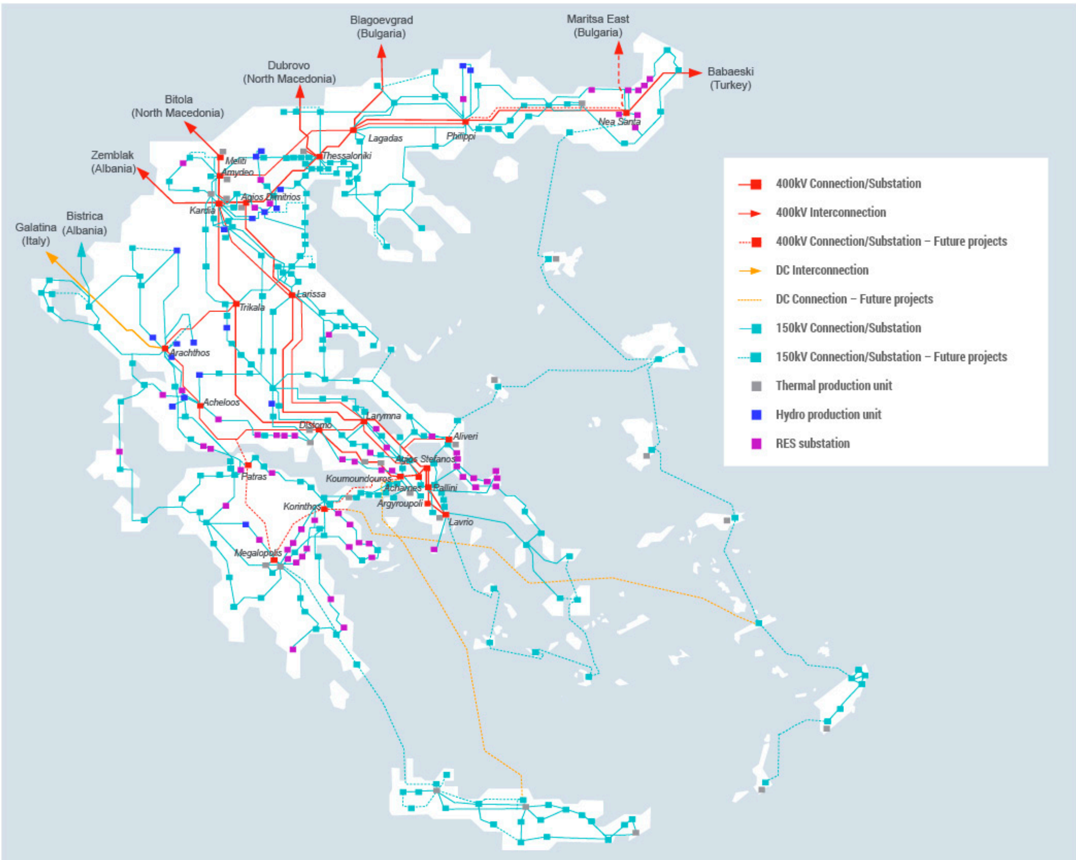

Figure 1. The existing interconnection electricity network production (conventional and renewable energy sources) [4].

Evidently, Figure 1 illustrates the electricity network production, providing an insight to the conventional, RES substations, along with thermal and hydro production units that also play a significant role in the electricity production. Within the regime established by the National Plan, the efforts of the policy makers focus on the reduction of Greenhouse gas emissions being generated by conventional energy sources and their substitution with environmentally friendly energy sources such as Renewable Energy Sources (RES). The particular energy sources are considered more efficient than fossil fuels—a fact that is stressed in the National Plan strategy. This shift of the energy sector from fossil-based energy sources to renewable energy sources defines the concept of energy transition. This process may be achieved gradually, while the major elements of energy transition, which should be taken into consideration, involve the increasing penetration of renewable energy into the energy supply mix, and the onset of electrification and improvements in energy storage [5,6].

Furthermore, the energy transition will be expanding as long as environmental, social, and governance (ESG) factors are the investors' priorities [7].

The energy transition process is vital for the organization of climate change mitigation strategy along with other actions, while decarbonization may well lead to a rate approaching 90% reduction of carbon emissions. This transition is a global phenomenon, as intelligent technology systems and market instruments are tools for decarbonization, and knowledge is a necessary tool for EU members to increase the use of renewable energy in their energy generator systems [8,9].

The extended use of this appropriate technology has multiple socioeconomic and environmental impacts. More specifically, landscape degradation, land degradation, pollution, desertification, destruction of underground aquifers, and deforestation of forest ecosystems are a few examples of common environmental problems [10,11].

Nowadays, delignitization is considered a very important breakthrough for the national energy map, and at the same time, it is a source of sustainable economic growth in Greece. In other words, this turn to new clean energy resources entails the prioritization of eco-efficiency and sustainability as the main features of economic development. Environmentally friendly energy sources could be used in a way where not only the particularities but also the competitive advantages of local communities are taken into consideration [12,13].

The process of delignitization has already started, since occasionally the electric charge is not based on the operation of a lignite unit. Based on the limitation in terms of time set by the Greek government for the purpose of delignitization, it is now imperative to come up with alternatives for a successful lignite detoxification process, in order for the effects on the local economy and society to be limited [2].

In figures, lignite's share in gross final energy consumption (GFEC) decreased by 49% from 2015 to 2020, while the share of RES increased by 29% over the same period. This can be ascribed on the devaluation of the Greek lignite-fired plants, the lower cost of natural gas, and the significant cost of GHG emissions, increasing by more than 80% over the 2017–2019 period. Thus, although the long-term macroeconomic impact of decarbonization has long been regarded beneficial for countries like Greece that base their energy production on coal [6,13], examining its side-effects on societal, economic, and energy security related aspects in detail for shorter horizons becomes critical, especially when applied rapidly.

One of the major issues involved in the study of the particular issue concerning energy policy in terms of regions or countries is related to the convergence of energy intensity or productivity. Understanding the dynamics of energy productivity and resource extraction may well have implications for energy policy. Implicit convergence of energy productivity for all the regions studied in the long run is compatible with a common energy policy. Otherwise, a common energy policy is not optimal [14].

In that case, and under the current conditions, the implementation of energy policies is the responsibility of regional or local authorities, and therefore formulating an efficient energy productivity policy requires knowledge of the dynamics of energy productivity at the state level [15].

Energy transition may well lead to economic and demographic shrinkage. The constant pressures on the local economy within the process of gradual reduction of lignite activity may be accompanied by unemployment rate expansion and income loss in the region.

More specifically, the changes in the labor market due to internal and external migration and the need for position changes that entail further education, are a few examples of socio-economic problems, while cultural degradation due to the disappearance of traditional activities, along with the aesthetic degradation of ex-lignite areas lead to significant cultural problems [2].

Taking into consideration the above, amendments and adjustments that would allow for economic growth of each affected area and to confront numerous socioeconomic impacts is a perquisite. All the necessary amendments should be synopsized in a Fair Development Plan (Master Plan) that can provide the affected region with all the policy tools to confront the socioeconomic issues that arise. The particular Master Plan is in the stage of construction and is divided into five pillars of an economy (clean energy, industry, handicrafts and trade, smart agricultural production, sustainable tourism, technology, and education), complying with EU objectives, aiming for a green, smart, more cohesive, and social friendly Europe. The main priority is to create sustainable jobs in the lignite areas and to attract productive investments that will substitute those that will be lost due to de-lignizitation. Greece has set, as its main goal, the withdrawal of all lignite plants by the year 2028, with the majority of the units, representing over 80% of the current installed capacity, to be withdrawn by the year 2023 [15]. This goal will now mark the official transition of Greece to a new differentiated mixture of electricity production that will no longer be based on lignite. This is a difficult and time-consuming process, which requires a synergy of all the involved parties in order to be successful. Considering the comparative advantages and the emerging opportunities generated in the research areas, an Integrated Program with a duration of a more than decade is required [2]. The objective of carbon neutrality along with the decarbonization process, as synopsized in the energy transition, has been the subject of extensive studies conducted by the European Commission and other research institutions [16,17].

The need for a fair energy transition is what the affected regions must claim. It is now commonly accepted that fossil fuels have reached the end of their life cycle, and the gradual transition from such fuels to more environmentally friendly energy sources is imperative, in order for a country to meet climate and energy commitments resulting from either the Paris Agreement on Climate Change or the Green Deal for a zero-carbon economy. One of the main factors driving the transformation of the energy model exploitation is the significant improvement of the competitiveness of RES technologies, both in terms of increasing their efficiency and reducing the cost of purchasing equipment for the whole de-lignification process. To this direction, all parties involved must submit their proposals in order to promote RES on a regional and national level and minimize the adverse effects of delignizitation on regions that depend the most on lignite. The problem of energy transition is not only found in the Region of Western Macedonia (Greece), but also in other countries such as Bulgaria (Southwestern Bulgaria) and Poland, namely in the region of Silesia [18]. More specifically, the EU countries mentioned above lack the energy infrastructure and suffer from lower institutional support. The above-mentioned conditions function as impediments to the energy transition in those countries [18].

The path of energy transition and the consequent economic growth may be conducted through different mechanisms while the different types of approaches used are analyzed in the following paragraphs [15]. The criteria for the categorization are as follow: private or public mechanism of energy transition or resources property, the maintenance or the redistribution of the power, and the type or the existence of growth.

The first two categories, namely the "status quo approaches" and the managerial reform approaches, are characterized by capitalist balance of power. Furthermore, the first type considers a greening system based on a voluntary, private, and market-mechanism basis while, for the second one, the public sector becomes relevant. The other two types of approaches suggested are the "structural reform approaches", and the transformative approaches. The structural reform stresses the need for power redistribution and public interventions for energy transition while the last category, the "transformative approaches", suggest that a radical change of the economy is needed. given its connection to socio-economic and environmental impacts.

As far as the type of growth is concerned, green growth is a common feature for the first two approaches, and prosperity without growth is a characteristic for the last two categories [19].

The non-homogeneity between the regions of the country along with the specific conditions dominating in each studied area implies the necessity for different types of energy transition in each one. What is more, regardless of the absorption of community or non-community funds, the strategic planning must give direction to any subsidies and potential investments (private and public sector). Furthermore, the heterogeneity of the regions of Greece can, on the one hand, create comparative advantages and opportunities for employment, growth, and investment, but, on the other hand, creates disadvantages due to their special characteristics. This means that any transition and especially the energy transition should consider all the characteristics of the 13 regions of Greece and especially those directly affected, such as the PDM. Based on the common or non-common characteristics, any Strategic Transition Plan must be created. Characteristics such as geographical location, whether or not it is an agricultural region, and whether it is an urban problem area, must be taken into account in a transition process. By taking into account the results of the financing programs [17] we observe that in relation to other countries of the European Union, the absorption rates are low. Greece has high rates of absorption of funds only for the period 2007–2013. The recent experience unveils the heterogeneity and certainly the misallocation of funds in the last 20 years, facts that have left the country vulnerable to new challenges. The challenge of the energy transition and the obligations arising from its acceptance will uncover the weaknesses and disadvantages of the Greek economy [18].

Within this socioeconomic framework, the present work makes an effort to examine the convergence or to detect asymmetries in energy and mineral resources exploitation, as reflected by the GDP generated by energy and mining for peripheries in Greece in an era of delignitization, also providing an insight into energy dependence within the regions and how alternative energy sources may minimize the potential impacts and unveil energy sources that could serve as perfect energy substitution to fossil fuels.

The rest of the manuscript is organized as follows; Section 2 provides an insight into the existing literature, Section 3 presents methods and data, Section 4 presents the results, and Section 5 provides the conclusion.

2. Literature Review

The decarbonization in the EU is an imperative activity in order for the 100% GHG emissions reduction by the year 2050 to be achieved. Towards to this objective, the decarbonization of energy systems is one of the most significant issues to be addressed, while delignitization and its substitution by environmentally friendly energy sources is a solution [19–21].

Delignitization is a process affected by a number of different factors, namely technological, policy, and societal ones. The regional convergence of peripheries in Greece, in order to be studied and interpreted, asks for a subtle description of the energy profile of each individual region. The major determinants of energy profiles are the economic structure, climate, and energy markets [22].

The energy profile of each region studied is necessary in order to formulate the strategy and planning for the implementation of an energy policy within the barriers of the region, either in terms of production or in terms of consumption [23–25]. The energy plans made for different regions in different countries involve energy efficiency and the expansion of renewable energy, with the most significant referring to Canada, Italy, and regions in other countries [26–30]. The significance of regional planning has been accepted a reason as to why the EU has taken a number of initiatives aiming at developing energy plans from local and regional authorities, such as the Covenant of Mayors initiatives (CoM 2020 and 2030) [30–33].

Keeping in mind the above, in the following paragraphs we present the energy profile of the peripheries studied in the present manuscript. More specifically, starting from Thessaly and based on data derived by HAEE, solar energy and water are the main energy sources. Implicitly, 14% of the total solar power in Greece in the year 2018 was produced in Thessaly, which is also one of the country's producers of hydroelectric power. One particularity in this periphery involves the wind energy, since, despite its potential, the installed wind energy capacity is only 19 MW according to HWE, making the region the second last in the particular energy source exploitation [34].

For the case of Eastern Macedonia and Thrace, the role of gas and wind are the most significant ones. In addition, the region hosts an oil production structure near the town of Kavala. More specifically, the particular periphery is considered an energy hub for Southeast Europe. Two projects are under construction, including two major transnational pipelines, namely the Trans Adriatic Pipeline and the Interconnector Greece–Bulgaria. This project covers almost 500 km of pipeline. In the case of wind energy, Eastern Macedonia and Thrace produced in the year 2019, 466 MW, making the particular periphery the third largest installed wind energy capacity region [35].

The next region studied is the central Macedonia, which is also considered an energy hub for Greece, as its neighboring regions are namely East and West Macedonia. In addition, it hosts one of the four petroleum refineries while its contribution to solar energy is also worth mentioning, since it constitutes 17% of Greece's photovoltaic capacity. Its role in the natural gas transportation is also major, given that the project of the Trans Adriatic Pipeline with origin in Azerbaijan and destination in the region of Europe, with intermediate destinations Greece, Albania, and Italy, crosses through the region. In other words, more than 1000 km of pipelines is connecting different points in northern Greece and neighboring Balkan countries [34,35].

Western Macedonia is responsible for half of the total power supply including five thermoelectric power stations owned by the National Power Production Company. The total capacity reaches 4108 MW corresponding to 33% of the company's total capacity. The planned closure of the coal-based power production by the year 2028 is going to alter the total energy profile in the region. More specifically, the lignite-based infrastructure will be transformed either to biomass-based or electrical energy storage centers for the wider Balkan region. This activity will be accompanied by a renewable exploitation, namely wind and solar power, which are expected to compose the energy transition master plan. For the year 2019, Western Macedonia had an installed wind energy capacity of 151 MW [36].

Another periphery is Epirus. For the case of Epirus, an important issue worth mentioning is related to a project on finding oil and gas reserves. More specifically, there are signs that the area including the Ionian Sea, the Adriatic, and the western slope of the Dinaric Alps may harbor vast oil and gas reserves, while this project involves a Spanish-Greek join venture [37].

The Peloponnese Is also Greece's second most important region for renewable energy production. In 2019 the region was the site of over 16% of Greece's wind farm capacity, according to the HWEA, with 587 MW [38].

The existing literature for the specific subject, especially with the assistance of Bayesian VAR methodology, is limited. More specifically the existing works are focusing either on the energy efficiency or energy productivity and the convergence of energy efficiency either in terms of countries or regions within a country. An analysis of the models used in energy efficiency is provided by Refs. [39,40]. The majority of the studies in terms of regional convergence of energy productivity focus on Chinese provinces. Hence, Herrerias and Liu [41], based on monthly data of energy intensity, confirmed the existence of convergence in three clubs and one divergent. In another work, Zhang and Broadstock [42], with more data (but until 2008) and based on energy intensity, studied the dynamic path of energy intensity in Chinese provinces for the period 1995 to 2008. According to their findings, three convergent clubs were identified.

In the case of a country framework, most manuscripts use either electricity intensity or electricity consumption. Kim [43] and Yu et al. [44] have examined energy convergence for 109 countries and for the same time period (1971–2010). Kim confirmed convergence for all countries in terms of electricity intensity while Yu et al. found four convergent clubs and some countries that are not members of a convergent club. Finally, Apergis and Christou [45], studying energy convergence for 31 countries, confirmed non-convergence.

The novelty of the present manuscript stands in the fact that we study the energy and resource-based regional convergence for a country that is going through energy transition, using the Bayesian Var methodology. The particular methodology is suitable for short samples and therefore our data outperforms a classical VAR model. In addition, we used for the B-VAR model the Minnesota prior specification. This process incorporates valuable information concerning the distributions of the parameters [46].

The findings of the present work would provide an insight to the dynamics of the sectoral growth, providing the potential for regional and sustainable economic growth with significant implications for the whole country. This, along with the fact that Greece has been through a recession for more than a decade with disastrous impacts for the economy and for the society, adds more value to the results of the present work. The next section analyzes the methodology implemented, namely the BVAR methodology. The particular set of methods and their superior forecasting have been known since the works of Litterman [47] and Doan, Litterman, and Sims [48].

3. Methods

The present manuscript involves the study of regional growth generated by energy and resources exploitation, with the GDP per capita evolution being generated by energy and mining for all the peripheries in Greece for the time period 2000–2018.

Despite the fact that our data do not include the completion of delignitization, it is significant to identify potential interdependencies and to unveil in non-lignite areas the use of alternative energy sources, and how these could be spread in Greek regions in order for the appropriate energy policy tools or even the statistical analysis focusing on panel unit root tests, in order to examine whether all the peripheries in Greece behave in the same way along with time and whether the absorption of ESPA projects is successful and efficient for the substitution of lignite with alternative energy sources. All the data employed were derived by National Statistical Service for the years 2000–2018 [49]. The next Figure 2 illustrates the evolution of the GDP per capita generated by the energy of all the peripheries for the time series studied.

The pattern of each time series is similar for all the peripheries. In particular, after the year 2010 a sharp degrease is evident, and after the year 2014, stability is a stylized fact for all the peripheries with a slight increase in the years to come. There is one exception however, and that is the case of Dytiki Macedonia, a periphery for which the GDP is still increasing and the lowest price is not evident for the year 2014.

Figure 3 illustrates the skewness and kyrtosis of the variables studied in order to unveil the direction of outliers and the peak of the PDF of the time series.

The skewness and kurtosis of the variables employed validate that our data deviate from the normal distribution and therefore the BVAR methodology provides more accurate results.

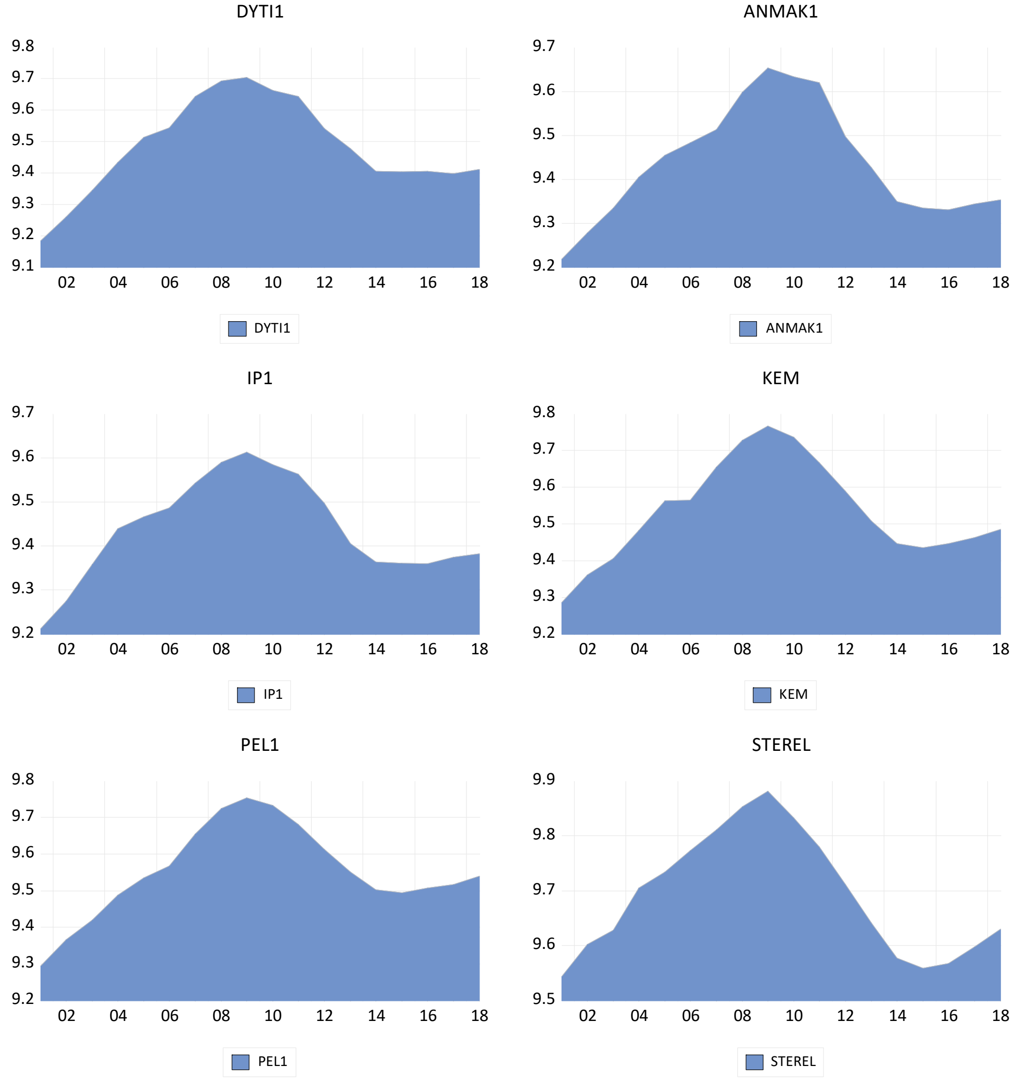

Figure 2. The evolution of GDP per capita generated by energy and mining in a logarithmic form for all the peripheries in Greece in the years 2000–2018 (Source NSI own calculation).

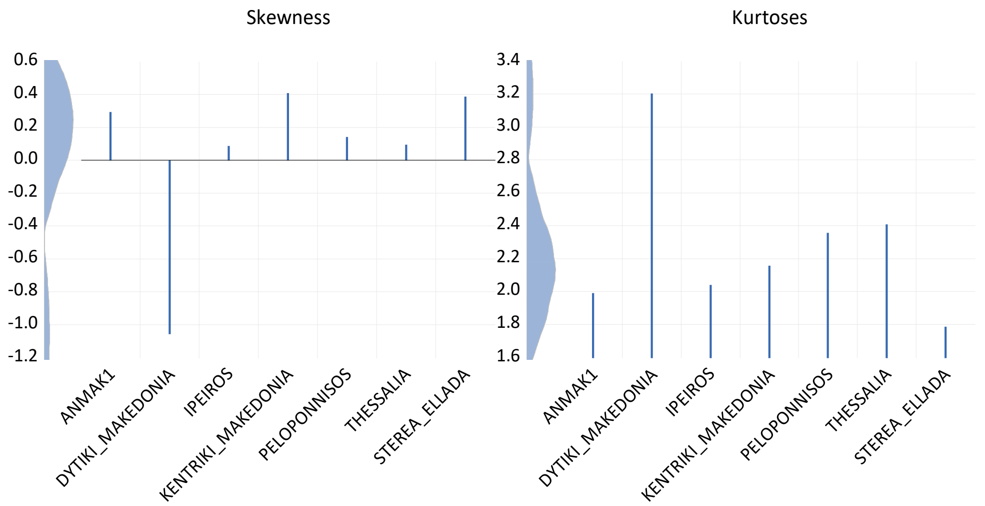

Figure 3. The skewness and the kurtosis of the variables employed in our analysis for the studied time period (Source: NSI, own data processing).

More analytically, the methodology employed on our data involves two stages: the first stage involved panel unit root tests in order to examine the convergence in the energy- and resource-based economic growth of each studied region, while the second stage involves the employees of Bayesian VAR. This particular technique outperforms the conventional VAR in the case of small samples, while the prediction error of regional BVAR model is significantly smaller than other models. The use of this technique has been recently applied to the use of renewable or non-renewable energy sources and its interlinkages with GDP [50–52].

Different panel unit root tests were employed often and individually in order to detect whether different peripheries do react in the same way in different shocks of the economy. The next paragraphs describe the estimation models used in our study.

For the first stage we employed two different panel unit root tests, namely the Im [53] and the Breitung and Das [54] panel unit root test. The Im et al. test [53] belongs to the first generation panel unit root test, the main feature of which is that cross-sections are independent, while the limit theory allows us to derive the asymptotic normality of panel test statistics. The Im-Pesaran-Shin (IPS) test is employed on the following Equation (1):

$$\Delta y_{it} = a_i + \rho_i y_{i,t-1} + \sum\nolimits_{z=1}^{\rho_i} \beta_{i,z} \Delta y_{i,t-z} + \varepsilon_{it}\ . \tag{1}$$

In terms of individual unit root tests for testing the null hypothesis of $H_0 : \rho_i = 0$ (where $i = 1, 2, 3, \ldots N$) for each individual group, the statistic employed is the average Augmented Dickey Fuller (ADF) test provided by the following Equation (2);

$$t_{IPS} = \frac{1}{N} \sum\nolimits_{i=1}^{N} t_{iT}(p_i, \beta_i), \tag{2}$$

where $t_{iT}(p_i, \beta_i)$ is the unit root t statistic estimated for each cross-section item (each country in our case).

For small samples, the unit root test is modified with the standardization of this statistic. The null hypothesis is $H_0 : \rho_i = 0$, while the statistic employed is described by the following Equation (3):

$$\begin{gathered} W_t = \frac{\sqrt{N}\left[t_{IPS} - N^{-1}\sum_{i=1}^{N}\left[E t_{iT}(p_i, 0)|\rho_i = 0\right]\right]}{\sqrt{N^{-1}\sum_{i=1}^{N}\left[Var t_{iT}(p_i, 0)|\rho_i = 0\right]}}\ , \\ \xrightarrow{d} N(0,1) \\ t, N \to \infty \end{gathered} . \tag{3}$$

The results' robustness as well as the sensitivity of the test on the heterogeneous nature of the alternative hypothesis are restrictive for the power of the rejection of the null hypothesis. Therefore, the authors employed a second panel unit root test, which is the Breitung test [54]. Breitung is a panel unit root test without necessitating bias correction factors, since variable transformations need to be preceded. Attributed to the pooled construction, the test is against an homogenous alternative [55]. Particularly, the data are generated by the following models (4–6):

$$y_{it} = l_i + k_i t + v_{it}, \tag{4}$$

where $v_{it} = \rho_{it} v_{it-1} + \varepsilon_{it}\ \varepsilon_{it} \sim iid(0,\ \sigma^2)$.

For this test, the transformed data, on which this test was employed, are given by the following formula:

$$\begin{gathered} (\Delta y_{it})^* = \left[s_t \Delta y_{it} - \tfrac{1}{T-t}\left(\Delta y_{it+1} + \ldots + \Delta y_{iT}\right)\right] \\ t = 1, 2, \ldots, T-1,\ where\ s_t^2 = (T-t)/(T-t+1), \end{gathered} \tag{5}$$

$$\text{And } y_{it-1}^* = y_{it-1} - y_{io} - \frac{t-1}{T}(y_{iT} - y_{io}). \tag{6}$$

The null hypothesis examined is the following.

$H_0 : \rho_i = 0$, while the test suggested by Refs. [55,56] and employed in our work is provided by the following Equation (7):

$$B_{n.T} = \left(\frac{\hat{\sigma}^2}{nT^2}\sum_{i=1}^{n}\sum_{t=2}^{T-1}\left(y_i^* - 1\right)^2\right)^{-\frac{1}{2}} \frac{1}{T\sqrt{n}}\sum_{i=1}^{n}\sum_{t=2}^{T-1}(\Delta y_{it})^* y_{it-1}^* = (B_{2nT})^{-\frac{1}{2}} B_{1nT}\ . \tag{7}$$

Within the Bayesian vector autoregression (BVAR) methodology, Bayesian techniques are employed to estimate a vector autoregression (VAR) model. The main difference between BVAR and standard VAR models lies on the fact that the BVAR model parameters are treated as random variables, with prior probabilities, rather than fixed values.

In most studies, the length of the data sets employed is limited and, therefore, the methodology of VAR does not produce accurate results. Furthermore, based on the results of Kapetanios [57,58] and Lenza et al. [59], the BVAR models in forecasting macroeconomic variables, used in the decision-making process by authorities, provide accurate results. In our case, the relatively small sample size of the sectoral GDP and in particular GDP attributed to energy and mining for all peripheries in Greece, significantly limits the degrees of freedom and therefore the model to be estimated makes the use of conventional VAR difficult to provide accuracy in the parameters' estimation due to the dimensionality problem.

The Bayesian shrinkage approach provides a solution to this problem. Explicitly, in the Bayesian statistics, each individual parameter is a random variable, with a particular probability distribution. All these probability distributions, by combining the prior distribution and the posterior distribution, obtained with the data information, are reflected to the likelihood function.

The VAR to be estimated is described by the following model;

$$\mathrm{yt} = \sum_{\mathrm{j}=1}^{\mathrm{p}} \Pi\mathrm{j}\mathrm{y}_{\mathrm{t-j}} + \epsilon_{\mathrm{t}},$$

where:

yt = (y1t, y2t, . . . , yMt)′ is an M vector of endogenous variables;

Πj are M × M matrices of lag coefficients;

εt is an M × M vector of errors where we assume εt~N(0,Σ).

In case xt = (y′t − 1, . . . , yt − p) are stack variables being formed, for example, Y = (y1, . . . , yT)′, and let y = vec(Y ′) the multivariate normal assumption on εt is transformed to the following:

$$(\mathrm{y} \mid \beta) \sim \mathrm{N}((\mathrm{X} \otimes \mathrm{IM})\beta, \mathrm{IT} \otimes \Sigma).$$

The Bayesian estimation of VAR models in the next stage oscillates around the derivation of posterior distributions of β and Σ based upon the above multivariate distribution, and prior distributional assumptions on β and Σ.

In order to show how each prior is based on an initial estimate of Σ × Σ, for priors other than those based on Litterman, we only need to consider the component of each prior relating to the distribution β × β, and in particular its covariance.

The prior selection was based on a methodology introduced by Giannone et al. [58] (hereafter GLP).

$$\beta \mid \beta 0 \sim \mathrm{N}(\beta\mathrm{GLP}, \mathrm{HGLP} \otimes \Sigma).$$

HGLP is assumed to be a diagonal matrix. The diagonal elements corresponding to endogenous variables, i, j at lag ll are specified by:

$$\mathrm{HlGLP, i, j} = \left(\frac{(\lambda 1)}{\phi \mathrm{jl}^{\lambda 3}}\right)^2 \text{ for } \mathrm{i} = \mathrm{j}$$

where λ1, λ3, and ϕj are the hyper-parameters of the prior.

The particular methodology involves the implementation of optimization techniques, aiming at the selection of the optimal hyper-parameter values. On the other hand, it is possible to optimize only a subset of the hyper-parameters and select others.

To be more specific, ϕjϕj is predetermined without being based on optimization, as ϕj = σjϕj = σj is the square root of the corresponding (j, j)th element of an initial estimate of Σ. In case ϕj is optimized rather than set, an initial estimate is employed and is considered as the starting point of the optimizer.

4. Results

In the first stage of the present manuscript, we employed different panel unit root tests. The results of those tests, including Levin et al. and the Breitung test, are illustrated in Table 1.

Table 1. Results of the panel unit root tests.

Levels		First Differences	
Common Unit Root Process		**Common Unit Root Process**	
Levin, Lin, and Chu t	−2.97077 *** (0.0015)	Levin, Lin, and Chu t	
Breitung t-stat	0.932 (0.8244)	Breitung t-stat	−3.10 *** (0.00)
Individual Unit Root Process		**Individual Unit Root Process**	
Im, Pesaran, and Shin W-stat	−0.99590 (0.16)	Im, Pesaran, and Shin W-stat	−3.04271 (0.00)
ADF-Fisher Chi-square	19.7635 (0.14)	ADF-Fisher Chi-square	30.90 (0.00)
PP-Fisher Chi-square	20.3082 (0.12)	PP-Fisher Chi-square	28.89 (0.01)

*** Reject of unit root hypothesis for a 5% level of significance.

Based on the results provided by the Levin, Lin, and Chu test, as illustrated in the previous table, the examined group does not have a unit root that is stationary, providing evidence for the interaction among the variables. However, all the other tests provide evidence on group stationarity in the first difference. Two conflict results have been derived; however, given the small sample size, we consider the Breitung test as being more reliable, a result that validates the non convergence of all the Greek peripheries.

The heterogeneity of the panel data models used in cross-country or in cross regional analysis introduces a new kind of asymmetry in the way the null and the alternative hypotheses are treated, which is not usually present in the univariate time series (or cross-section) models [59].

The most significant part of this analysis is the estimation of the Bayesian Var Model. Within the B-VAR framework, the model that is set up includes seven endogenous variables, namely the GDP per capita generated by energy for the seven peripheries studied, two lags as indicated by Schwarz-Bayesian (BIC) criterion, and an exogenous temporal dummy (dum) to capture the effects of the recession in the year 2009. The model estimation results are provided in Table 2. Based on our findings interlinkages are not validated in the short run though the values of Rsquare validate satisfactory fit of the model estimated to the data employed.

The Litterman–Minnesota prior with diagonal VAR estimate and prior specification of the hyperparameters is employed in our study. As far as the parameters selection is concerned, the following must be mentioned; λ1 (the overall tightness on the variance of the first lag) is set to a small value because the prior information dominates the sample information. λ2 is the relative tightness on the variance of the other variables) and λ3 is the relative tightness of the variance of lags. They are set greater than zero because we use a diagonal VAR and the lag decay is important for our analysis [60].

Table 2. Short and long run dynamics.

	Anmacthraki	Ditmaked	Ipeiros	Kenmak	Pelop	Stelad	Thessal
Anmacthraki (−1)	1.003066	−0.018389	0.000119	0.009849	0.005461	0.015285	−0.007071
	(0.21695)	(0.26470)	(0.21527)	(0.22086)	(0.22013)	(0.21572)	(0.22364)
Anmacthraki (−2)	−0.771959	−0.111404	−0.368996	−0.290676	0.031464	−0.015154	−0.392047
	(0.94099)	(1.11321)	(0.93525)	(0.95469)	(0.95264)	(0.93740)	(0.96600)
Ditmaked (−1)	−0.035887	0.923456	−0.009095	−0.002699	−0.019970	−0.005468	0.009656
	(0.19201)	(0.23393)	(0.19054)	(0.19544)	(0.19481)	(0.19094)	(0.19790)
Ditmaked (−2)	0.081782	−0.196274	0.061957	0.074132	0.195364	0.086290	0.133486
	(0.32587)	(0.38657)	(0.32381)	(0.33073)	(0.32991)	(0.32446)	(0.33447)
Ipeiros (−1)	0.002025	−0.035304	0.994781	0.018743	−0.013794	0.004396	0.004279
	(0.25473)	(0.31059)	(0.25277)	(0.25930)	(0.25845)	(0.25330)	(0.26257)
Ipeiros (−2)	−0.020002	1.353606	0.031	−0.065178	−0.046993	−0.158388	−0.872624
	(1.45198)	(1.66036)	(1.44)	(1.46783)	(1.46592)	(1.44796)	(1.48321)
Kenmak (−1)	0.020537	−0.011107	0.010531	1.000190	−0.000291	0.009418	−0.012833
	(0.18139)	(0.22132)	(0.17998)	(0.18465)	(0.18404)	(0.18035)	(0.18698)
Kenmak (−2)	−0.247156	1.554305	0.215058	−0.640769	0.060688	−0.356863	−0.157566
	(0.97423)	(1.14853)	(0.96843)	(0.98802)	(0.98603)	(0.97067)	(0.99969)
Pelop (−1)	0.003928	−0.046396	0.007916	0.008382	0.991228	0.004767	−0.000431
	(0.20346)	(0.24815)	(0.20188)	(0.20711)	(0.20643)	(0.20230)	(0.20972)
Pelop (−2)	−0.040906	−0.283044	−0.289896	−0.281425	−0.614025	−0.187152	−0.255068
	(0.70702)	(0.84884)	(0.70225)	(0.71848)	(0.71661)	(0.70385)	(0.72730)
Stelad (−1)	0.010892	−0.004798	0.002039	−0.006419	−0.000185	0.992444	0.003407
	(0.18688)	(0.22791)	(0.18544)	(0.19023)	(0.18961)	(0.18582)	(0.19263)
Stelad (−2)	0.562849	−0.757388	0.314559	0.893064	0.313909	0.311356	0.912910
	(0.90470)	(1.03982)	(0.90022)	(0.91524)	(0.91369)	(0.90191)	(0.92423)
Thessal (−1)	0.023921	−0.046275	0.022621	0.024399	0.006009	0.025656	0.981865
	(0.20886)	(0.25454)	(0.20726)	(0.21259)	(0.21190)	(0.20769)	(0.21527)
Thessal (−2)	0.302166	−1.196745	−0.088785	0.307483	0.015259	0.206390	0.470658
	(0.85819)	(0.99919)	(0.85344)	(0.86915)	(0.86767)	(0.85533)	(0.87902)
C	0.384089	−0.219835	0.225052	−0.445248	0.253667	0.430147	−0.268508
	(2.97405)	(3.02186)	(2.97198)	(2.97688)	(2.97658)	(2.97276)	(2.98216)
R-squared	0.854103	0.848504	0.782918	0.878183	0.783968	0.629457	0.893215

Post-estimation of the BVAR was followed by the estimation of the impulse response functions and the forecast variance decomposition to obtain long-run information and in sequence to identify the dynamic features of the B-VAR approach. Both of the aforementioned methodologies provide the system dynamics of the estimated model (Figures 4 and 5).

The impulse response functions capture the effects of a-unit shock as a proportion of a variable (%) on the other variables in the B-VAR model.

Furthermore, the forecast-variance decomposition provides a notification on the extent to which the forecast error variance of each of the variable can be explained by exogenous shocks to the other variables [60,61]. Based on our findings, the results to be presented and analyzed are provided in the next paragraphs.

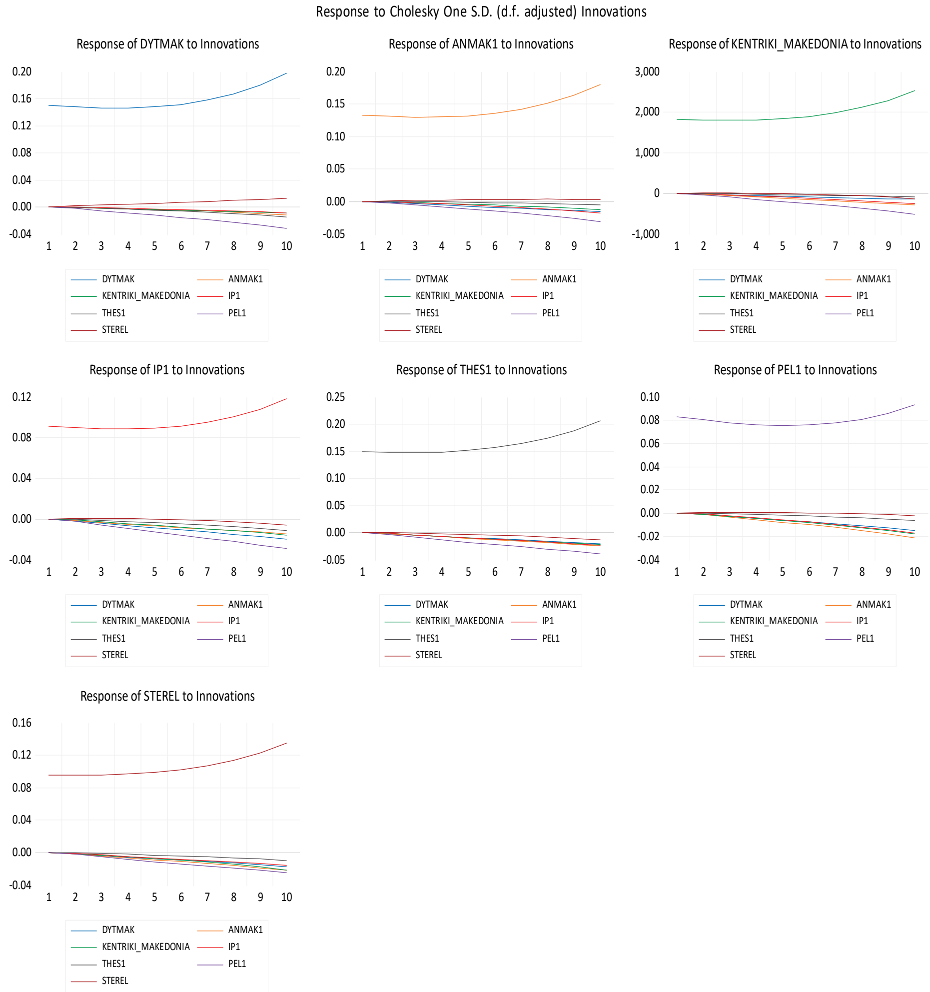

Figure 4. Impulse response analysis. (Source NSI own elaboration).

More specifically, for the case of impulse and response analysis, an innovation in Anatoliki Macedonia and Thraki and a positive long term response for the next 10 periods is recorded for Sterea Ellada and Thessalia, while a slight negative one is recorded for all the other regions. The innovation recorded for Ditiki Macedonia seems to affect the GDP in a negative way in the long term for Peloponnisos, a result that is indicative of the competitiveness in the energy production among the two regions. In addition, an increase in the long term is illustrated in the last period for Anatoliki Macedonia and Thraki and Sterea Ellada. As far as Ipeiros is concerned, with the exception of Kentriki Macedonia, all the other regions seem to be affected in a negative way in the last two periods. An innovation in Kentriki Macedonia seems to be affected in a positive way in the last two periods while the response of sectoral GDP for Anatoliki Macedonia and Thraki is decreasing in this innovation in the long term. In the case of Peloponnese, an innovation entails an increase in the long term of its behavior while, with exception the case of Thessaly and for all the other regions in the period 9 and 10, a decrease in this sectoral GDP is evident, with Anatoliki Macedonia and Thraki being affected the most. As far as Sterea Ellada is concerned, an innovation leads to a decreasing value for Peloponnese, Ipeiros, and Kentriki Makedonia, while a positive response is predicted for all the other regions. Finally, an innovation in Thessaly is leading to a positive response in Sterea Ellada (a significant one) within the last two periods, while a negative response is predicted for all the other regions under review [61].

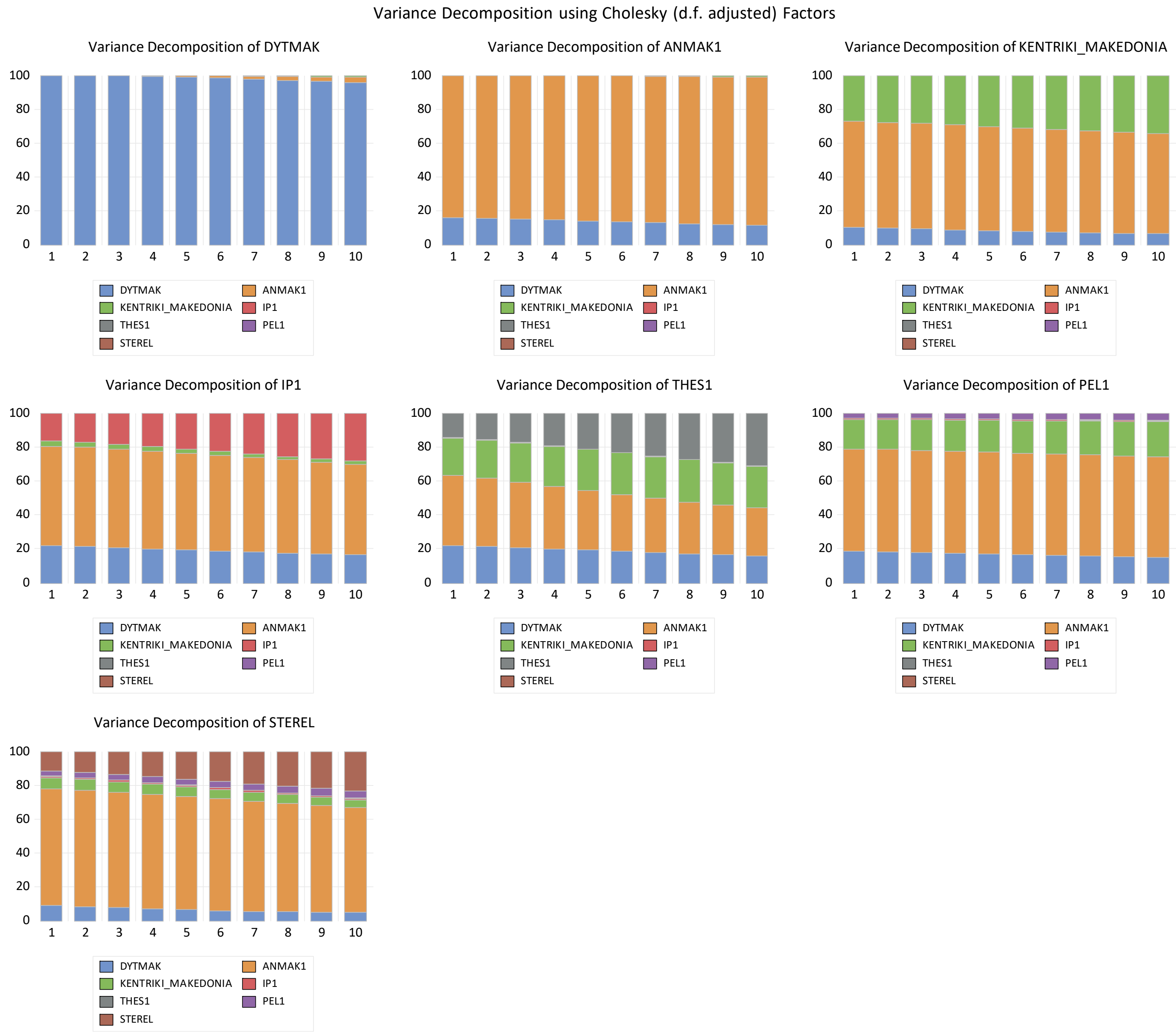

Figure 5. Variance decomposition analysis. (Source NSI own elaboration).

The last analysis conducted in the present manuscript involves variance decomposition, while the results derived by the estimated model are illustrated in the next figure. For the case of Ditiki Macedonia, the variance is explained mostly by GDP in Sterea Ellada in the 6th and 7th period, while the sectoral GDP from its own seems to disappear in the last period. In general, this part of the figure is the one that is the most interesting and unexpected one.

5. Discussion

The results derived and described in the previous section are indicative of asymmetries and interconnection both in terms of energy consumers and producers. To be more specific, the connectivity involves either gas, electricity, or hydrocarbons.

In the following paragraphs we provide all the information about the future projects and the existing situation on the ways of energy transmission among Greek regions in order for the energy transmission to be successful, without equality problems due to a lack of energy sources.

The electricity transmission system is illustrated in Figure 6.

Figure 6. Interconnections of the Greek electricity transmission system [62].

Gas, which is a highly significant energy source, is also consumed through a National Gas Transmission System that is being established in the mainland of Greece.

The particular system includes The Operation and Maintenance Centers of the Sidirokastro Border Metering Station, Eastern Greece, Northern Greece, Central Greece and Southern Greece, The Measuring Stations of Sidirokastro Serres and Gardens of Evros, The Gas Metering and Regulating Stations, The main gas transmission pipeline and its branches, The Compression Station in Nea Mesimvria, Thessaloniki, The Remote Control and Telecommunications system, and the Cargo Control and Distribution Centers. The particular natural gas transmission system is illustrated in Figure 7.

Figure 7. National natural gas transmission system [63].

Due to the necessity for stronger interconnections with neighboring systems, a national plan for natural gas was organized. This plan also aims to establish new interconnections and to develop new natural gas transmission pipelines. This project may well enhance the role of Greece in the European energy market.

The particular project introduces the following actions; the Design and implementation by East Mediterranean Pipeline (EastMed), the Construction of the 3rd tank (increase of LNG storage space) in Revythousa and completion of the works for the enhancement of the gasification rate of the drainage capacity of the terminal, the final investment decision and construction of a connecting pipeline Greece–Italy Poseidon (Poseidon), the Implementation of the Greece–Bulgaria (IGB) connecting pipeline, the completion and operation of Trans-Adriatic Pipeline TAP, the implementation of the project of the Independent Natural Gas System (ASFA) Alexandroupolis, implementation of the connection between Greece and the Republic of Northern Macedonia, and, last but not least, the implementation of the project of the underground gas storage in South Kavala.

In order for all the above sub-projects to be successful, a number of issues have to be addressed. First of all, the cross-party political agreement is a requisite: despite differences relating to the timing of the retirement of lignite power plants, it is possible to secure a well-organized plan for the lignite substitution in Greece and therefore coordinated initiatives on behalf of the European Parliament, the Council and the Commission on issues of governance, funding, and maintenance of the new energy systems [64].

As far as delignizitation is concerned, the strategic plans to be conducted should include the tax motivations for attracting investments, land use change of ex lignite areas, since they are not used any more, while activities should be made in order for alternative farming and services to be promoted along with time use for the realization of the investments.

For each periphery, and thus for the whole country, the steps that should be taken involve among others the construction of a plan aiming for ecoefficiency and sustainable economic growth. This plan can be realistic only in case it takes advantage of the energy sources that can be found in each region and how their exploitation will promote economic growth [65,66].

This transition should be accompanied by a strategic plan to support changes in economic activity, the acquirement of new skills by the employers along with the environmental rehabilitation. More specifically, investments are a necessary tool that should be focusing on by the media, as well as the development of technology and infrastructure for energy resources, digitalization, renovation, cyclical economy enforcement, and assistance provision for job search to limit unemployment and to take advantage of the known human resources in the regions under review [67,68].

All these investments should aim to secure the land use change due to delignitization and being used for the developments of alternative agriculture, industry construction, and all the objectives concerning ecoefficiency in the specific regions to be achieved.

Another issue that should be addressed is the participation of stakeholders. This should be organized in a way being characterized by consultation and transparency. Transparency is a necessary ingredient for the governance system overseeing the transition process. As the last, but certainly not the least determinant for a successful transmission, is funding, given that delignitization is a process that asks for a long-term financial assistance. It is more than significant for a successful energy transition and a convergence in energy growth to absorb the EU Just Transition Fund in a successful and efficient way, and this can be done by taking into consideration different allocation criteria in the finance of these regions, while funds should be provided with reason and special care for the growth of ex lignite regions [64–67].

All the aforementioned actions are expected to provide a successful energy transition and convergence in growth generated by energy and resources exploitation to be achieved [67–69]. The next section presents some concluding remarks on the issue examined for the case of Greece.

6. Conclusions

Greece, within the framework of energy transition, has initiated the process of delignitization. This process is expected to affect multiple socio-economic figures in the country in an indirect way [61]. In addition, the changes in the use of energy sources may bring about equality issues in regions being delignified. The present work studies the convergence of energy and resource exploitation-based growth, as described by GDP, generated by energy sources and mining and all the related impacts. The objective of the present manuscript is to examine the regional convergence and to detect the interlinkages of the studied in order to implement an efficient energy policy. This study provides policy makers with a tool to indirectly identify and to effectively exploit alternative energy sources among other actions in order to satisfy the needs in energy and to overcome the energy transition in a positive way. Based on our findings, no convergence is validated, although interlinkages among the energy and resource-based exploitation growth are confirmed. The variance decomposition analysis as well as the impulse response analysis indicated the role of lignite growth-based peripheries to all the others. This result necessitated a hard effort in order to exploit alternative energy sources that will substitute lignite in a fruitful and prosperous way.

A strategic plan on behalf of the central government and regional authorities based on the particularities of each periphery coupled by an active and efficient participation of the stakeholders, could make a balanced regional economic growth in Greece a realistic target. The new situation will be indicative of a successful energy transition, based on other environmentally friendly energy sources in the rise of a new decade, with ecoefficiency being the key word for the implementation of an energy and resource management policy.

As a subject for future studies could be a similar study for the European Union in order the implementation of the energy policy to be effective and efficient.

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