Alam, Shahi Md. Tanvir

Article

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Renewable Energy (Solar and Wind) Generation and its Effect on some Variables for Selected EU Countries with Panel VAR Model

Shahi Md. Tanvir Alam*

Stipendium Hungaricum PhD. Fellow, Doctoral School of Economics, Faculty of Economics and Business Administration, University of Szeged, Hungary. *Email: shahi.tanvir@gmail.com

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ABSTRACT

Keeping the world livable, the policy makers are giving their extended focus on green energy. They are trying to move on hand-on-hand with rising green energy and lessening carbon dioxide (CO_2) emission steading the economic activities especially for the open and developing countries. This can be helpful to provide a more lucrative economic environment to meet the extended demand of the society. The paper highlights to find out whether the economic growth, renewable energy (RE) consumption, fossil fuel-based energy generation and CO_2 emission are significantly impactful on RE generation or not? Is there any mutual, bi-directorial, unidirectional relationship with each other? For this, the Vector Autoregression (VAR) model is run. The paper focuses on six EU countries who are practicing auction scheme for deploying robust green energy (especially solar and wind) by reducing dependency on fossil fuel and expanding their economy with less CO_2 emission. The result of the analysis shows that a positive influence of each concern variable on RE generation and auction scheme might have a significant impact if robustness of the generation occurs.

Keywords: Auction Scheme, CO_2 Emission, Economic Growth, Fossil Fuel, RE Generation
JEL Classifications: C32, D44, O44, P18, Q42

1. INTRODUCTION

Depending more on fossil fuel (FF) based power plants, the developed countries released thousands of tons of carbon dioxide (CO_2) and other green house gases (GHG) in the troposphere and energy sector emits two-third of the global GHG (Matthaus 2020). According to our present knowledge, the excessive amount of CO_2 in the air is the root cause of global warming and climate change.[1] Observing the detrimental significances of climate modification, a strong opinion is growing in the countries against using FF in power generation and paying attention to energy transition, i.e., increased usage of renewable energy sources (RES). They are investing in research and development of related technologies. International organizations and development agencies of the world also prefer and encourage investments in renewable energy (RE) field. In that the universal policy makers are focusing on 100% zero carbon free energy generation by 2050.

According to the report IEA (2021_b), almost 90% of electricity should come from RES, with wind and solar photovoltaic (PV) together accounting for nearly 70% by 2050. A special analysis has also been carried out with the participation of international monetary fund (IMF) and International Institute of Applied System Analysis. It shows that the enormous challenges of transforming our energy system is also a huge opportunity for our economics, with the potential to create millions of new jobs and boost economic growth. The report also states that the transition to net zero is for and about people to provide around 4% of cumulative emissions reductions. Finding out the potentiality of solar and wind

1 https://www.carbonbrief.org/solar-wind-nuclear-amazingly-low-carbon-footprints 4–6 grams CO2 emits for generating one kilowatt-hour (kWh) electricity from solar/wind. The emission range is 109 grams for coal, 78 grams for gas, 700 grams for high-speed furnish oil (HFO) and 350 grams for liquified natural gas (LNG).

technologies, those are included in the energy system targeted by the energy democracy as a prime site of political-economic contests and those are picked-up for deploying high volume of RE (Angel, 2016; Burke and Stephens, 2018).

Mu et al. (2018) found an impact of the RE policy of China on employment generation. They find that there is an increase of employment due to the expansion of solar PV and wind power generation. Oh et al. (2020) finds a positive relation among RE policies, RE generation and GHG emission reduction (i.e., environment). The large share of RE will support to emit less amount of GHG in the environment. Zhang et al. (2021) used the provincial data of China for the period 2000–2017 to investigate the aggregate effects of low-emission electricity. The investigation shows that if the ratio of low-emission electricity to total electricity is increased by 1%, then the gross domestic product (GDP) will up by 0.16%, and CO_2 will decrease by 0.848%. Literally, it has said that low-emission can chase the target of low-carbon economic development. Rennkamp et al. (2017) depicts that RE policy lessens the CO_2 emission and creates socio-economic upliftment for the state. With the sufficient democratic support, RE policy may be implemented in middle-income countries.

Getting these co-benefits, the robustness of RE deployment is highly prioritized and the robust deployment depends on the market-independent policies rather than market dependent policies due to its stronger, cost-effectiveness, higher investment security and lower cost. Those mentioned features are mostly associated with the RE 'auction scheme' (Couture and Gagnon, 2010).

2. THEORETICAL BACKGROUND AND THEORETICAL MODEL

RES have started its remarkable role in sustaining the current economic growth and in recent years, it has been instrumental in pushing the energy access frontier all over the world. Simelyle and Dudzeviciute (2017) says considering the competitiveness of a specific country in the international arena, energy consumption and its efficiency are interrelated, especially in the case of consumption in the industrial sector. Further, high implications are found for using extended amount of RE in changing the competitiveness of nations and having an accumulated beneficial return in global stage.

The global scenario is rapidly changing and the share of RES in the energy-mix across the globe is increasing due to the drastic fall in RES price, technological progress, and growing environmental concerns. As a feasible substitute font of energy globally, RE is getting priority due to climate change, FF exhaustion, subjects of energy security, technology modernization and high and unpredictable prices of petroleum-based fuels (Ferrer et al., 2018; Do Xuan et al., 2020). Shifting from FF-based energy to RE, energy subsidy for FF poses substantial constraints and a lot of evidences says that the continuation of subsidies has adverse effect on the countries' social, fiscal and environment sector (Beaton et al., 2013; Pegels et al., 2018). Sometimes, the high volatility of FF becomes an obstacle for economic growth. When the energy prices are fairly stable, then economic growth might improve and if they are unstable, the price could rise that would be negatively impactful to the economic growth (Frimpong et al., 2018; Takentsi et al., 2022).

According to monthly electricity statistics report of IEA (December 2020), globally RE production was 3,269.1 terawatt-hour (TWh) in 2020 that was 7.5% higher than in 2019. The share of renewable electricity in the mix was 31.6% in same year, up from 28.6% in 2019. Wind and solar production were mainly responsible for this increase in renewables, up respectively by 95.8 TWh or 11.6% and 73.0 TWh or 20.2% in 2020 compared to 2019. Since 2018, wind production has increased by 20.1% and solar production by 28.4% highlighting the dynamic growth of the wind and solar power sector. As per the report of IEA (2021_a), global CO_2 emission declined by 5.8% in 2020, or almost 2 Gigatons (Gt) CO_2-the largest ever decline and almost 5 times greater than the decline of 2009 that followed the global financial crisis, CO_2 emissions fell further than energy demand in 2020 owing to the pandemic hitting demand for oil and coal harder than other energy sources while renewables increased.

Furthermore, the report of IEA (2021_b) says that an unparalleled clean energy investment boom lifts global economic growth. Total annual energy investment surges to US$ 5 trillion by 2030, adding an extra 0.4% point a year to annual global GDP growth. Not only that the environmental protection activities ensure economic merit by creating the net job in the whole economy, in that the related reallocation of resources is typically channeled to labor-intensive renewable sector (BMU, 2009; Frondel et al., 2010). By stimulating the demand for local installation, locally-manufactured components and local planning, solar PV is found as a scope to support the local employment and engagement of labor (Sweeney, 2015).

The public awareness and robust support are increasing due to the growing emphasis on environmental issues. Power generation from the FF-based sources may gain price benefits from higher efficiency on smart technologies; but RE market is moving faster than that market. Cost reduction of clean energy arise from fundamental physics and material cost from scale as well as lower labor costs through manufacturing automation and lower waste driven by higher efficiency. The country trend like Scandinavian countries or Germany are shifting FF subsidies to RE investments while creating new decant and healthy job and ensuring a just, inclusive transition. IRENA-GCGET (2019) report emphasizes that RE can be utilized at outmost level at any scale and it is possible to lend them better to decentralized forms of energy production and consumption. The report also mentions that RE sources have about zero marginal cost and especially solar and wind sources enjoy cost reduction about 20% for doubling of capacity.

Abolhosseini and Heshmati (2014) states that the three support mechanisms, used to finance RE development programs: Auction, tax incentives, and tradeable green certificates. Some countries are familiarized cash incentives in private sector for utility-scale RE generation. Some have initiated interest free/negligible level of interest-based credit scheme to the expansion of RE. Focusing on auction scheme Pegels et al. (2018) states that auction helps to fix the tariff level in a competitive way, i.e., testing the market prior to approving subsidies. The emerging market like China, India, Brazil, South Africa practiced auction scheme and in the most cases they found it highly effective for gaining RE capacity growth and ensuring supply of clean electricity at low cost. Supporting the cost savings Beg et al. (2002) and Rennkamp et al. (2017) argue that cost savings and implementing RE programs have been pointed as potential fields to create win-win situation where emission reduction and economic development go hand in hand.

Based on the other papers, we got that executing so many variables may not upsurge the possibility to discover more factors of RE generation rather those hamper the results and their explanation. Thus, the energy generation from RE and finding its significance on different variables like sovereign spread ($10Y_{i\text{-}US,t}$), gravity ($GDP_{i\text{-}w,t}$), FF-based energy generation ($E_{ff,i,t}$), renewable consumption (solar and wind) ($R_{COM\ s\text{-}w,i,t}$), carbon dioxide emission ($CO2_{i,t}$) using VAR model added with exogenous shocks like auction dummy and IMF dummy will be implemented in this paper.

For constructing the theoretical model, the paper has attentive on the postulation of a prolonged Cobb-Douglas function (1) pointing to the broad economic activity (Thompson, 2006; Moyer et al., 2013) with capital (K_t), labor (L_t) and energy (E_t) plus damages (D_t) due to greenhouse gas (GHG) emission which studies as:

$$Y_t = (1 - D_t) A_t L_t^{(1-\alpha-\beta)} * K_t^{\alpha} * E_t^{\beta} \quad (1)$$

Here, A_t is a technology-parameter reliant on time. All the countries in European Union (EU) are shifting their economy towards the green economy and for lowering down the GHG to mitigate the D_t damages, they are picking-up the RES for electricity by diminishing FF-based sources highlighting the "net zero emission target by 2050'. In connection with the target, the countries are practicing the RE auction scheme for robust deployment of RE; side by side reducing dependency on FF-based energy generation. For the sake of the theoretical model and quantitative analysis of the paper, the author has differentiated between globally and locally practiced variables as the authors have picked-up some EU countries (like Greece, Italy, Poland, Portugal, Romania, Spain) whose economies are open in nature, close geographic similarities and following RE auction scheme for the last few years to chase the net zero target.

In the model, it is considered the sovereign spread ($10Y_{i\text{-}US,t}$) variable. Because, capital accumulation (i.e., K_t) and funding scenario for the selected countries are extremely settled by the world market sentiment which may be steered by the home-grown monetary policy. In this regard, for explaining the comparative affluence of funding, the sovereign spread between the i[th] trial state and the 10-year bond of US have been measured as benchmark for unfolding the comparative comfort of funding – where higher values signify liquidity scarcity (Capelle-Blancard et al., 2019; Shimbar and Ebrahimi, 2020).

In the case of output (Y_t), less strong economies do not play a vigorous role and they are not price taker from the global market and for this, the author planned to use a gravity-proxy that generally explains the gap between the GDP of sample countries and the global economy ($GDP_{i\text{-}w,t}$). Here is mentionable that the higher values of ($GDP_{i\text{-}w,t}$) indicate the relative smallness.

Due to robust disposition of RE by following auction scheme, the EU countries are lessening their dependency on FF-based electricity generation ($E_{ff,i,t}$) along with the economy becomes more energy efficient. Side by side, the economies emit less carbon dioxide ($CO_{2,i,t}$) locally for consuming/producing less electricity based on FF by which GHG has negative feedback on the economy in the form of various damages (D_t). But it is needed to point out that the damages are not solely acknowledged by the local CO_2 emission ($CO_{2,i,t}$).

To denote the exogenous shocks in the model, we augmented West-Texas Intermediate oil price ($P_{WTI,i,t}$) to represent the situation of FF pricing; an IMF dummy ($d_{IMF,i,t}$) variable that postulates country precise emergency periods when i[th] country required funding from the IMF and an auction scheme dummy ($d_{AS,i,t}$) variable to epitomize the support instrument for installing RE robustly by the sample countries. Notably, the systematic auctioning schedule ensures a continuation of RE project in the pipeline and helps to add more RE in the system (IRENA-CEM, 2015; IRENA, 2017).

In this paper, we categorized the RE into two main slices: solar and wind energy ($R_{GEN\ s\text{-}w,i,t}$). These two types of RE generation do not emit any direct CO_2 after the asset is bent and fitted.[2] The usage of higher-level RE can care of the impression of circular economy and the higher the consumption of RE ($R_{COM\ S\text{-}W,i,t}$) and lessen the usage of FF. However, the paper focuses on the identification of the country-specific factors in RE to comprehend the i[th] country's capability to encounter the net zero emission target by 2050 under the applied Cobb-Douglas specifications following the below mentioned theoretical model:

$$\begin{aligned} \Delta \ln R_{GEN\ s-w,i,t} &= \text{Constant} + \alpha_1 \Delta \ln 10Y_{i-US,t} \\ &+ \alpha_2 \Delta \ln GDP_{i-w,t} + \alpha_3 \Delta \ln E_{ff,i,t} + \alpha_4 \Delta lnR_{COM\ s-w,i,t} \\ &+ \alpha_5 \Delta \ln CO2_{i,t} + \beta_1 \Delta \ln P_{WTI,i,t} + \beta_2 d_{IMF,i,t} + \beta_3 d_{AS,i,t} + \varepsilon_t \end{aligned} \quad (2)$$

Based on the set model, the expected outcome is: In all-purposes high sovereign spread level can hamper investment, reasoning sluggish economic growth and thus low level of CO_2 discharge for deploying RE by reducing dependency on FF-based electricity generation ($\alpha_1<0$) -nevertheless an extreme liquidity-scarcity can distract funding from green energy venture as well ($\alpha_1>0$). This assorted symbol points on the deficiency of market impartiality for a green monetary policy. When the underlying economy has a lesser portion in the global economy, then the worth of the gravity-proxy is higher. As economic productivity depends on energy practice, this variable should have optimistic stimulus on CO_2 emission ($\alpha_2>0$); but the condition is to attain a country at a certain post-industrial level of growth. As higher level of RE-

2 https://www.carbonbrief.org/solar-wind-nuclear-amazingly-low-carbon-footprints

generated electricity reduces the gradual dependency on FF-based electricity, so energy consumption from RES has analogous effect as RE has still small stake in energy blend ($\alpha_3>0$; $\alpha_4>0$). For the substitute of FF, RE usage mentionable solar and wind energy can potentially reduce the CO_2 emission ($\alpha_5<0$). We see that the last three variables have capableness to methodically diminish the GHG in the set model.

3. DATA AND METHODS

3.1. Data

The selected EU countries started to emit a large amount of CO_2 after 1982 aligning with global scenario and the growing trend continues since 2010 with some hindrances only when there were some experiences of recession (Figure 1). After the tremendous attention to the green energy, how the countries' economic, financial and industrial sectors are performing by keeping the carbon-neutrality target in the prime position in future and the paper attains this phenomenon.

The figure shows the gradual declination of CO_2 emission due to high focus in green energy.

RE generation especially solar and wind has started to rise in the selected countries in the 2000 s and the increasing production has the inspiration to consume more RE and this inspiration insists to reduce persistent dependency on the FF-based energy generation (Figures 2-4).

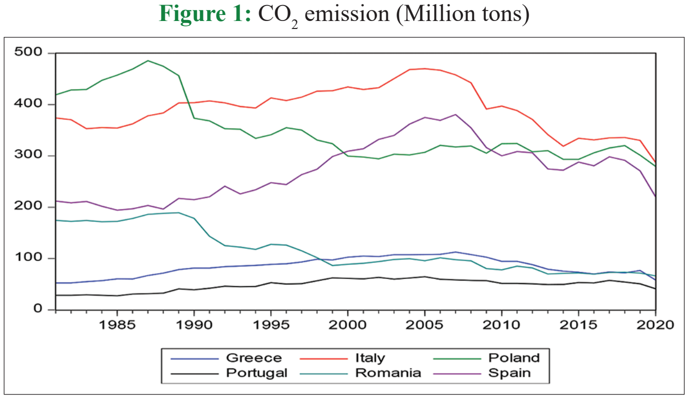
The figure depicts the high expansion of solar and wind energy especially after 2000 s.

The figure explains the higher-level consumption of solar and wind energy after 2000 s.

The figure shows the gradual fall of FF-based energy generation due to the expansion of RE (both generation and consumption).

It can be focused that the above mentioned figures are satisfying our assumption primarily, i.e., the higher level of RE generation increases the higher level of RE consumption, on the other side reduces the dependency on FF-based energy generation and it also lessens the emission of CO_2.

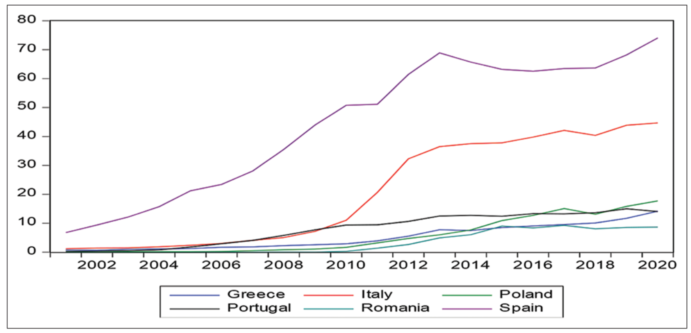
Figure 1: CO_2 emission (Million tons)



Source: Author's edition, bp Statistical Review of World Energy July 2021[3]

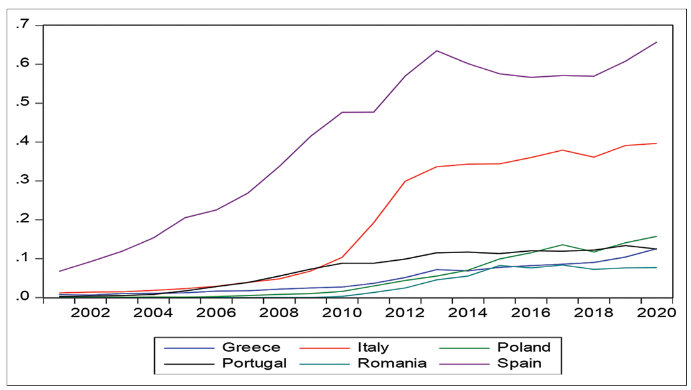
In the paper, the author analyzed the annual data between 2001 and 2020 as the robustness of the RE basically started in these periods. Comparatively six developing and open economies (Greece, Italy, Poland, Portugal, Romania and Spain) of EU are considered as sample where the auction scheme is being practicing after 2010 for vigorous deployment of RE. For a stipulation of homogenous load-factor for premeditated solar

Figure 2: Total solar and wind generation (terawatt-hour)



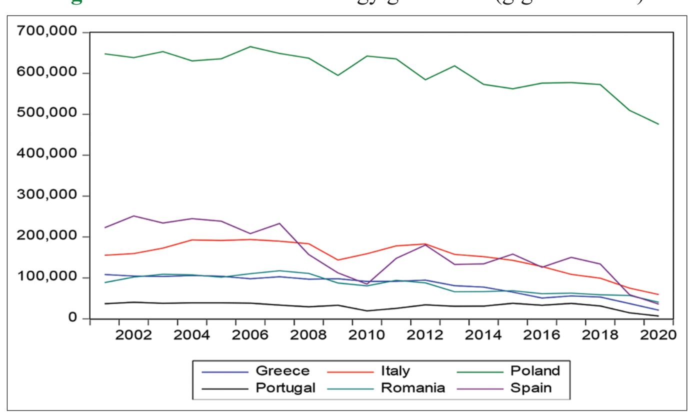
Source: Author's edition, bp Statistical Review of World Energy July 2021[4]

Figure 3: Total solar and wind consumption (exajoules)



Source: Author's edition, bp statistical review of world energy July 2021[5]

Figure 4: Fossil fuel based energy generation (gigawatt-hour)



Source: Author's edition, bp statistical review of world energy July 2021[6]

3 http://www.bp.com/statisticalreview

4 http://www.bp.com/statisticalreview

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and wind generation potential, all the selected countries are pigeon-holed by similar climate, costal belt and geographical position. Moreover, most of the countries were affected by developing debt-crisis in different times which is directing on their acquaintance towards external funding conditions.

Energy sector are being retrieved from the database of bp statistical review of world energy, financial data are obtained from Refinitiv Eikon database and world Bank database is the source of GDP data (Table 1). As the selected EU countries were taking part in various IMF programs, so just the general resources account was measured only when the payout occurred from IMF towards the i^{th} state. It is required to mention that the paper does not reflect the poverty reduction and growth trust due to other reasons. Further, the paper counts down the auction scheme for at least a single time practiced by the sample countries.

As it is mentioned earlier that the robustness of RE started in 2000 s and afterward and all the sample countries did not occupy RE from that period, so due to missingness of data, the panel data can be treated as unbalanced which is measured by the panel VAR model (Table 2). On the other hand, there is no unit-root in the data and the standard deviation and mean of the data are time-invariant and for this the VAR satisfies the stability condition.

Table 1: Data sources

Name of the variables	Sources
Renewable generation (solar and wind) ($R_{GEN\ s\text{-}w,\ i,t}$)	bp statistical review of world energy July 2021
Sovereign spread ($10Y_{i\text{-}US,t}$)	Refinitiv eikon database
Gravity ($GDP_{i\text{-}w,t}$)	World bank
Fossil fuel based energy generation ($E_{ff,i,t}$)	Eurostat
Renewable consumption (solar and wind) ($R_{COM\ s\text{-}w,i,t}$)	bp statistical review of world energy July 2021
Carbon dioxide emission ($CO_{2i,t}$)	bp statistical review of world energy July 2021
WTI oil price ($P_{WTI,\ i,t}$)	bp statistical review of world energy July 2021
IMF dummy ($d_{IMF,i,t}$)	IMF country report
Auction scheme dummy ($d_{AS,i,t}$)	AURES II reports

Source: Author's edition. IMF: International monetary fund

3.2. Method

In the Vector Autoregression (VAR) model, the variables are in the form of time series and autocorrelated, the model is appropriate for handling such time series and autocorrelation problems. Further, the VAR model considers the dynamic and causal relationships among economic variables, which is a benefit that classical regression models cannot ensure so. For this, VAR is suitable in policy analysis (Kumar and Paramanik, 2020). VAR is able to process even a lesser amount of time series variables, where a priori endogeneity is presumed for individual variable and their dynamics are taken into interpretation. This dynamic interpretation of a set of *N* time series variables $y_t = (y_{1t},\dots, y_{kt})'$ can be defined simply by the below mentioned basic VAR model form (3) (Lütkepohl-Kratzig, 2004; Gábor et al., 2020):

$$y_t = A_1 y_{t-1} + \ldots + A_p y_{t-p} + \varepsilon_t \tag{3}$$

Where y_t is the model variables for the $(Nx1)$ vector, F_i is the matrix which contains (NxN) autoregression coefficients and the $\varepsilon_t = (u_{1t}, \ldots u_{Kt})'$ is the unobserved error term vector with $(Nx1)$ Gaussian distribution where $(\varepsilon_t \sim (0, E(u_t u_t'))$ is a positive definite covariance matrix. Optimal lag-length of the model is nominated by the Schwarz (or Bayesian) information criteria (SC), Akaike information criteria (AIC), Hannan–Quinn information criteria (HQ) to check steadiness and asymptotic normality of the data. After that the standardized condition for stability is tested to see whether the modulus values are smaller than one or not that infers the invertible explanations and the explanations of infinite order-vector moving averages (Lütkepohl, 2005; Gábor et al., 2020).

At the time of forming the equation (3), quite a few boundaries of the parameters are conceivable: The short-term restrictions can be casted-off to explain the arrangement of shocks in case of Cholesky's formation. On the other hand, the long-term restrictions can be described of the shocks for Blanchard-Quah's formation. For doing this, firstly we need to familiarize the structural version of the shorten VAR form (4) (with a time lag ρ and three variables with structural coefficients A and A^s):

$$y_t = A_1^s y_{t-1} + \ldots + A_p^s y_{t-p} + Bu_t$$
$$where \varepsilon_t = A^{(-1)} Bu_t and S = A^{(-1)} B \tag{4}$$

,

Table 2: Descriptive statistics and unit-root tests

Head of the descriptive statistics	$CO_{2i,t}$	$E_{ff,i,t}$	$GDP_{i\text{-}w,t}$	$10Y_{i\text{-}US,t}$	$R_{COM\ s\text{-}w,\ i,t}$	$R_{GEN\ s\text{-}w,\ i,t}$
Mean	10.35002	−0.026552	−0.003473	−0.063736	1.539328	6.218036
Median	10.37727	−0.021017	−0.00112	−0.2902	1.750746	6.431424
Maximum	10.44307	0.840846	0.057437	24.3555	3.075278	7.799048
Minimum	10.14681	−0.706975	−0.05911	−23.5253	−0.65332	3.971268
SD	0.077858	0.238875	0.022535	3.868075	1.090909	1.12139
Skewness	−0.977287	0.322562	0.138542	0.43251	−0.327972	−0.323379
Kurtosis	3.106358	5.877313	5.506677	29.67932	1.896296	1.893788
Jarque-Bera	16.44426	37.31655	27.29587	3057.96	7.074491	7.046921
P	0.000269	0.0000000	0.000001	0.0000000	0.029093	0.029497
Unit-root test						
Levin, Lin and Chu t*	−6.69910	−8.39954	−2.91101	−5.24036	−8.18219	−8.19192
P	0.0000	0.0000	0.0018	0.0000	0.0000	0.0000
Observations	103	103	103	103	103	103

Source: Author's edition, EViews 10

It is our assumption that the value of certain coefficients is zero and u_{1t} affects instantly the other variables simultaneously, while u_{2t} affects only the variables 2 and 3 simultaneously and u_{3t} only the third in Cholesky's restriction (5):

$$\varepsilon_t = Su_t = \begin{vmatrix} s_{11} & 0 & 0 \\ s_{21} & s_{22} & 0 \\ s_{31} & s_{32} & s_{33} \end{vmatrix} \begin{vmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \end{vmatrix} \quad (5)$$

The structure of the *S*-matrix unfolds the short-term possessions and in the Eviews 10 econometric program it is resolute by the loading order of the variables into the VAR model-presumptuous that there exists a shock which affects every variable, and the end variable of the order is the one which affects itself only. The construction of the *S*-matrix (Table 3) was determined by the paper's theoretical model provided with the highest global influence for the exchange rate as an external balance proxy variable and the smallest, local for the liquidity.

Table 3: Structure of the S-matrix of the short-term effects

Variable	Shocks					
	$CO_{2i,t}$	$E_{ff,i,t}$	$GDP_{i-w,t}$	$10Y_{i-US,t}$	$R_{COM\ s-w,i,t}$	$R_{GEN\ s-w,i,t}$
$CO_{2i,t}$	s11	0	0	0	0	0
$E_{ff,\ i,t}$	s21	s22	0	0	0	0
$GDP_{i-w,t}$	s31	s32	s33	0	0	0
$10Y_{i-US,t}$	s41	s42	s43	s44	0	0
$R_{COM\ s-w,i,t}$	s51	s52	s53	s54	s55	0
$R_{GEN\ s-w,i,t}$	s61	s62	s63	s64	s65	s66

Source: Author's calculation in EViews 10

Table 4: Roots of characteristic polynomial

Root	Modulus
0.972501 − 0.073899i	0.975305
0.972501 + 0.073899i	0.975305
0.283287 − 0.858387i	0.903925
0.283287 + 0.858387i	0.903925
− 0.434899 − 0.533967i	0.688664
− 0.434899 + 0.533967i	0.688664
− 0.354528 − 0.567282i	0.668953
− 0.354528 + 0.567282i	0.668953
− 0.119546 − 0.580733i	0.592909
− 0.119546 + 0.580733i	0.592909
0.525375 − 0.126983i	0.540503
0.525375 + 0.126983i	0.540503

Source: Author's edition, EViews10

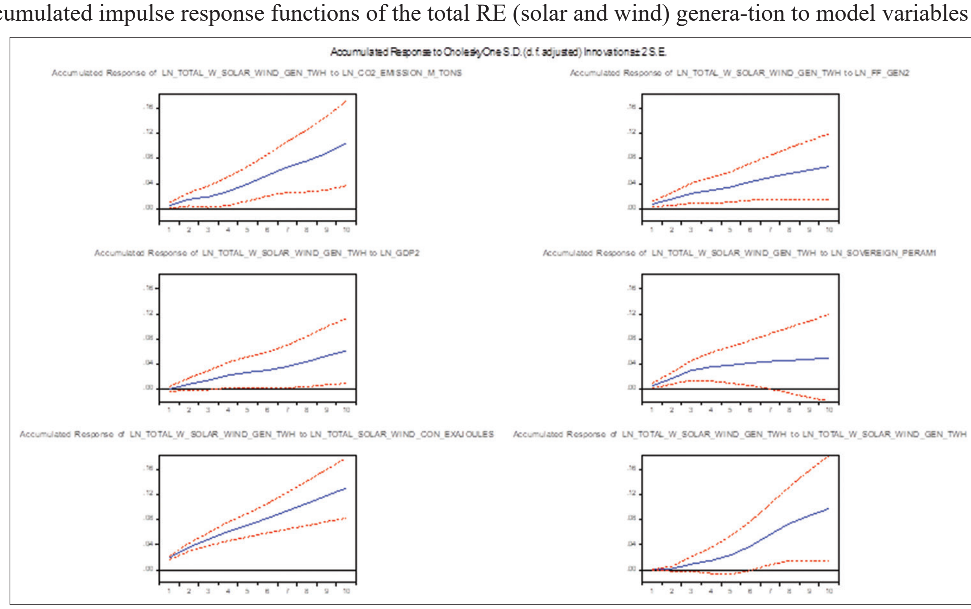
The impulse response analysis is a vital stage in econometric analysis that is used in VAR model. The functions under this analysis are being considered as the effect of a unit shock on a given model variable where the shock of variable *i* is to variable *j* and ceteris paribus. Again, for a definite time horizon, variance decomposition denotes to the breakdown of the prediction error variance. The decomposition process specifies the short-term and long-term influence of certain variables, i.e., the percentage of the uncertainty of variable *i* that is to be accredited to the j^{th} shock after period *h* (Dinh, 2020).

4. RESULTS AND ANALYSIS

The paper considers 0–2 Lag length of the model following the Lag Order Selection Criteria for meeting the stability condition. The model does not get any of the inverse roots of the characteristic polynomial lied outside the unit circle with this circumstance rather all modulus were smaller than 1 that means the VAR model satisfies the stability condition (Table 4).

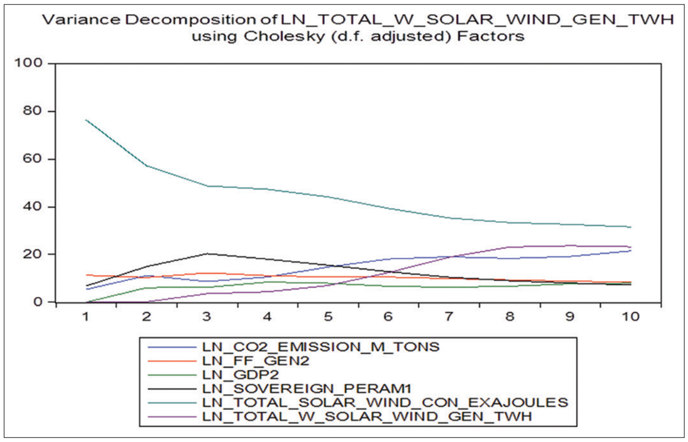
Impulse responses are presenting the progress of each variable's stimulus on the total RE (solar and wind) generation in time with a 95% (±2 standard error) confidence intervals (Figure 5). All the variables have positive effect on RE (solar and wind) generation. The CO_2 emission, FF-based electricity generation and RE (solar and wind) consumption have the highest significant impact, meaning that the more the RE is being generated, the CO_2 emission will be reduced highly; FF-based energy generation tendency will be reduced as well and RE (solar and wind) consumption will be

Figure 5: Accumulated impulse response functions of the total RE (solar and wind) genera-tion to model variables on the long run



Source: Author's edition, EViews10

Figure 6: Variance decomposition of total renewable energy (solar and wind) generation using VAR factors



Source: Author's edition, EViews10

enhanced which will help the sample countries to reach the carbon neutrality target. Not only that if the RE generation increases, then auction scheme will play a significant role on the robustness of the generation (the testing of quantile process estimate explains this). So, regularity of auction scheme is a potential tool to ensure the robustness of RE and its diversified gains. Sovereign spread maintained a significant positive influence up to 7 years, meaning that the relatively high premium diverts financial resources toward the usage of FFs for a certain period; after that it will motivate the usage of their renewable counterparts. Meanwhile, GDP has slightly significant impact on the total RE generation up to 8 years; later on, the level of significance is found more positive, meaning that the change of energy-mix will affect the country's GDP more significantly in the long-run.

Variance decomposition underlines that a major (~60%) of total RE (solar and wind) generation is explained by the model on the long-run (Figure 6*)*. Reinforcing our previous results, the data paints on the importance of generating more energy from renewable sources and inclusion of those into the energy mix will stop the further growth of CO_2 emission, expansion of RE consumption and reduction of FF-based energy generation. These results are parallel with our previously described anticipations at the theoretical model part.

5. CONCLUSION

After analyzing the data for the period 2001–2020, for the countries in question, the results remark that the VAR model soothes the stability condition. The paper gets a positive influence of each concern variable on the RE generation-more significant variables are CO_2 emission; FF based energy generation and RE consumption and sovereign spread. The extended Cobb-Douglas function for the six EU countries is being used in this paper keeping total RE (solar and wind) generation as a dependent variable. There were used the panel VAR (Vector Autoregression) model to scrutinize the exogenous shocks (i.e., practicing auction scheme, IMF funding requirement at the countries' crisis session and environment for FF pricing) where the shocks affect all of the considered variables. The paper points to the sample countries' ability to align with the carbon neutrality goal under the Cobb-Douglas function.

For getting the significant impact of the sovereign spreads, initiation of green monetary policy might be helpful. A green monetary policy indicates a more favorable refinancing, collateral conditions or asset purchase programs on the field of green bonds. Interest free credit scheme or negligible level of interest-based credit scheme might be a supportive instrument.

For supporting high energy growth and prompt capacity addition, RE auction scheme is getting its high attention as a RE support scheme. The scheme attracts more bidders to offer competitive unit price for renewables that is competitive with traditional FFs. Systematic/regular auctioning scheme keeps RE project in continuation and diversified gains will come out. But the auction scheme must be tailored specifying the specific countries.

The author points some literature gap for the targeted countries. The six relatively, developing, open, and emerging economies (Greece, Italy, Poland, Portugal, Romania, Spain) from EU were chosen as the representative sample. We considered them to be good subjects of a research that may show the difficulties of the parallel challenges of FF subsidy, economic development, greenhouse gases and the energy consumption. After analyzing the data for the period 2001–2020, the results remark that the VAR model soothes the stability condition. The paper gets an instinct retort on behalf of the expansion of each concern variable on the RE generation mentionable.

For attracting more investor to the RE generation, the policy makers are withdrawing subsidy from FF. In this transition period, the consumers should be insisted to be energy efficient and energy saver. Szabo (2022) suggests natural gas as the transitional fuel due to its comparative cleanliness features (compare with coal, liquefied natural gas-LNG, high-speed furnish oil-HFO).

Systematic political support and support from the local community would be able to present a economically viable clean energy transition to the society and shape the next progress of RE. So, central level decision is highly required.

Finally, the research was limited some variables. But the paper does not pay its attention to some burning topics like expansion of RE and contribution to regional economic development (like job creation, local GDP growth). So, further research can go on this issue.

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