RENEWABLE ENERGIES AND CLIMATE CHANGE: HOW TO EASE THE ENERGY TRANSITION?

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Overview

Climate change and global warming have attracted the attention of the regulator in recent times. One of the main goals of the 26th Conference of the Parties (COP26) is to ensure global net-zero emissions by mid-century keeping temperatures below 1.5 degrees (Allen, 2018). Encouraging investments in renewable energies for electricity generation is recognized as the most feasible solution to reduce greenhouse gases emissions. For this reason, we study how the renewable energy production is affected by economic and climate variables, considering the interactions among countries. Specifically, our aim is to answer the following research questions:

- Which factors allow the flourishing of renewable energy generation?
- How can policymakers and electricity producers facilitate the energy transition?
- How do countries influence to each other for the achievement of global climate goals?

Using the Matrix AutoRegressive (*MAR*) model proposed by (Chen, 2021), we analyze the joint impact of multiple macroeconomic and climatic variables on renewable energy production across multiple countries.
Our study considers the three European (EU27) countries of G7, Germany, France and Italy, from 1980 to 2020. The data come from different open data warehouses.
First, as economic indicator we include the quarterly GDP from OECD Database, as it is an omni-comprehensive measure of the economic activity of a country. Moreover, the literature has already explored the importance of such a variable in the analysis of the consumption and production of renewable energy as shown in (Khezri, 2021), (Ntanos, 2018), and (Saint Akadiri, 2019).
Second, we consider climate factors from Copernicus Climate Data Store (CDS), such as the total amount of precipitation, solar radiation, and wind speed that directly affect the renewable energy production. The Renewable Energy Generation data (hydropower, solar power, wind power) from CDS are explored separately. Indeed, as shown in (Khezri, 2021), the hydropower constitutes the most substantial amount of renewable energy consumption and considering all these sources together would not allow us to properly analyse the other components.
Third, we include the surface fluxes of CO_2, from Copernicus Atmosphere Data Store (CAMS), to investigate the relationship with the renewable energy, as in (Irandoust, 2016).

Methods

The *MAR* is a matrix variate extension to the traditional *VAR* model. Formally, for $p = 1$, *MAR(1)* is defined as:

$$\boldsymbol{X}_t = \boldsymbol{A}\boldsymbol{X}_{t-1}\boldsymbol{B}' + \boldsymbol{E}_t$$

where $\boldsymbol{X}_t$ is the $m \times n$ matrix observed at time t for $t \in \{1, 2, \ldots, T\}$, $\boldsymbol{A} = (a_{\boldsymbol{ij}})$ and $\boldsymbol{B} = (b_{\boldsymbol{ij}})$ are $m \times m$ and $n \times n$ autoregressive coefficient matrices and $\boldsymbol{E} = (e_{\boldsymbol{t,ij}})$ is a $m \times n$ matrix white noise.
The advantage of *MAR(1)* is that it requires $m^2 + n^2$ coefficients instead of $m^2 \times n^2$ of the unrestricted *VAR(1)*.
The iterated least squares method has been used for parameters estimation: the coefficients are estimated through an iterative procedure that takes as input the projection estimates.
Finally, the impulse response functions with orthogonal innovation (oIRFs) of a unit standard deviation change in $e_{\boldsymbol{t,ij}}$ are:

$$\boldsymbol{F}_{i,j}(k) = (\boldsymbol{B}^k \otimes \boldsymbol{A}^k)\Sigma[, m(j-1) + i]$$

where Σ is the variance-covariance matrix of the vectorization form of the error matrix $\boldsymbol{E}_t$ with size $mn \times mn$.

Results

The coefficient matrix $\boldsymbol{A}$ captures the interconnections among the variables showing:

- greenhouse effect for the net fluxes of CO_2 (Allen, 2018).

- the renewable energy production (solar, wind and hydro power) has a negative impact on CO_2 (Dong, 2019).
- the increase of total precipitation has a positive significant impact on the hydropower generation.

The coefficient matrix $\boldsymbol{B}$ has interpretation in the view of $\boldsymbol{BX'}_t$, which is the influence of the previous quarter indicators of a specific country on the current quarter indicators of all the other countries. For example, the model shows that the influence of Germany's indicators positively affects the indicators of the France and Italy: this might be intuitively due to its predominant economic position. Also, France has a positive impact on the other countries, mostly on Italy, and this might be justified by its environmental commitment as for the Paris Agreement from COP21.

Introducing a unit variance shock on climate variables, the oIRFs allow us to capture the impact on the renewable energy production on the country where we simulate the shock as well as on the others. A shock in the total amount of precipitation in Germany has a positive impact on hydropower but it negatively affects the solar power generation. We capture the impact of such a shock on the other countries with magnitude decreasing as spatial distance increases. The CO_2 emissions decrease in the long term, despite an increase in the short one.

We evaluate the predictive ability of the *MAR(1)* estimated by iterated procedure with respect to the vectorization, that is a special case of *VAR(1)*, through the projection procedure. The Mean Square Error results to be lower for the iterative procedure, showing the benefit of such approach.

Conclusions

This study aims to support the energy policies in order to reach the climatic goals. Why the renewable energy represents the best choice for a government in the short term? Because the alternative green solutions are feasible only in the long term. On the one hand the green nuclear, that is nuclear with zero impact on CO_2, has high cost and long times (10-15 years) to be built and its production would be effective in 2040. On the other hand, the green hydrogen that does not require huge quantity of energy to be produced is still under development and it is not cost-effective. Hence, governments should act in the adoption on renewable energy technologies that represent the main instrument in the short term.

With the proposed model, we provide knowledge on how climatic factors impact on the renewable energy generation and how the countries are interconnected during this energy transition. Furthermore, the oIRFs allow us to simulate the climate change and it is of primary importance for policymakers that have to decide in which kind of renewable to invest.

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