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# The effects of renewable energy and agriculture on $CO_2$ emissions in Morocco: An approach to S-VAR modelling:

# Les effets des énergies renouvelables et de l'agriculture sur les émissions de $CO_2$ au Maroc : Une approche à la modélisation S-VAR

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**Abstract**

This paper aims to assess the impact of agriculture and renewable energy on $CO_2$ emission in Morocco during the period 1990 - 2020. In this regard, using R Software, the Structural Vector Autoregressive model (SVAR) is estimated to identify the short-run relationship that links our variables. The causality analysis as defined by Granger shows the existence of a two-way causal relationship between agriculture, renewable energy and $CO_2$ emissions. The results obtained, from the impulse response function analysis shows that agriculture increases $CO_2$ emissions while renewable energy reduces it. Therefore, the Government of Morocco should encourage the use of renewable energy and strengthen the management of agriculture to curb climate change and achieve the goal of sustainable development.

**Keywords :** Agriculture ; Renewable energy ; $CO_2$ emissions ; Climate change ; SVAR

**Résumé**

Cet article vise à évaluer l'impact de l'agriculture et de l'énergie renouvelable sur l'émission de $CO_2$ au Maroc au cours de la période 1990 - 2020. À cet égard, en utilisant Logiciel R, le modèle Vecteur Autorégressif Structurel (SVAR) est estimé pour dégager la relation à court terme qui lie nos variables. L'analyse de causalité au sens de Granger montre l'existence d'une relation causale dans les deux sens entre l'agriculture, l'énergie renouvelable et les émissions de $CO_2$. Les résultats obtenus, tirés de l'analyse en fonctions des réponses impulsionnelles montrant que l'agriculture augmente les émissions de $CO_2$ tandis que l'énergie renouvelable la réduit. Par conséquent, le pouvoir public du Maroc doit encourager l'utilisation des énergies renouvelables et renforcer la gestion de l'agriculture pour enrayer le changement climatique et atteindre l'objectif du développement durable.

**Mots clés :** Agriculture ; Énergie renouvelable ; Émission de $CO_2$ ; Changement climatique ; SVAR

## Introduction

Climate change is the modification of atmosphere as a result of its chemical transformation by greenhouse gases. These gases, which are naturally present in the atmosphere, form a layer around the earth that allows it to retain its heat, the so-called greenhouse effect. The sun heats the earth, which then transmits some of its heat into space.

At the beginning of the 20th century, climate change issues are a complex problem worldwide, which, although environmental in nature, has repercussions on many issues such as poverty, economic development, population growth, sustainable development and resource management. To address climate change, $CO_2$ emissions must be reduced. In 1992, countries joined an international charter - the United Nations Framework Convention on Climate Change (UNFCCC) - to consider what could be done to reduce global warming and to address any unavoidable rise in temperatures. In 1995, within the framework of a decision known as the Berlin Mandate, the Convention's signatory countries began a round of negotiations to decide on stronger and more detailed commitments for industrialised countries. After two and a half years of extensive negotiations, the Kyoto Protocol was adopted in Japan on December 11, 1997. The Kyoto Protocol imposes a limit on the world's major economies on the total release of greenhouse gas (GHG) emissions. In 2015, the United Nations adopted the 17 Sustainable Development Goals (SDGs) to balance social, economic and environmental aspects. One of the SDGs was to take urgent action to address climate change and its impacts.

Morocco has also adopted a proactive and responsible approach in its fight against global warming, thanks to the strengthening of its institutional environment as well as the legal framework for the implementation of structuring climate-oriented programmes. These implementations are the result of a strong high-level political will deployed by the Moroccan Convention in terms of greenhouse gas emission reductions, as told in its Nationally determined Contribution.

The agricultural sector is one of the most important sectors in Morocco as it contributes significantly to the gross domestic product with a varying proportion from 13% to 20% depending on the year (Aattar & Elouardirhi,2022). In order to mitigate the effects of climate change, the agricultural strategy, and in full coherence beside the Moroccan policy to fight against climate change and the National Strategy for Sustainable Development, has adopted two key components, namely adaptation to climate change and mitigation of greenhouse gases. The adaptation effort has focused mainly on the control of irrigation water, while the mitigation effort has focused on the extension of plantations in order to increase the potential of carbon sequestration and reduce greenhouse gas emissions.

In this paper, we aim to analyse and assess the impact of renewable energy and agriculture on $CO_2$ emissions for Morocco over the period 1990 – 2020, using the Structural Vector Autoregressive model. This study will help decision makers to set public policies regarding environmental degradation.

In order to properly conduct our study, Section 1 reviews the literature with a focus on the techniques used to analyse the $CO_2$ emissions determinants in emerging and developing economies. Section 2 presents the data analysis and some stylised facts, while Section 3 will discuss the data and the study empirical technique. The results discussion is presented in Section 4. Section 5 is a conclusion.

## 1. Overview of the empirical literature:

Over the past two decades, a large body of empirical work in the literature has intensively analysed the many factors explaining the evolution of $CO_2$ emissions. These factors include economic growth, renewable and non-renewable energy consumption, economic openness, transport, urbanisation and foreign direct investment in different countries as well as different periods.

**Jaunky (2011)** applied the Vector Error Correction Model (VECM) model for a panel of data from 36 high-income countries over the period 1980 and 2005. The results show for the whole panel, that a 1% increase in gross domestic product generates a 0.68% increase in $CO_2$ emissions in the short run and 0.22% in the long run. From another perspective, **Shafiei and Salim (2014)** analysed the effects of population, gross domestic product per capita, renewable and non-renewable energy, industrialisation and urbanisation on $CO_2$ emissions on a sample of 29 OECD (Organisation for Economic Co-operation and Development) countries over a period from 1980 until 2011 using the STIRPAT model. The results indicate that renewable energy consumption has a negative and significant effect on $CO_2$ emissions, while non-renewable energy consumption, population, GDP per capita, industrialisation and urbanisation have positive and significant effects in the long term.

Focusing on the African case, **Jebli and Youssef (2017a)** analysed the links between renewable energy, agriculture and $CO_2$ emissions in Tunisia over a period from 1980 - 2011 using the VECM model. They found that renewable energy decreases $CO_2$ emissions while agricultural activity increases $CO_2$ emissions. On the same line, and applying the same method, **Jebli and**

**Youssef (2017b)** they studied the environmental degradation of the 5 North African countries for the period 1980 to 2011. They concluded that increasing GDP and renewable energy consumption increases $CO_2$ emissions, while increasing agricultural activity reduces $CO_2$ emissions. Using the Autoregressive Distributed Lag (ARDL) methodology, **Jebli and Youssef (2017c)** investigated the factors influencing $CO_2$ emissions in Morocco for the period 1980 to 2013. Regarding the variables used, the authors distinguished renewable energy consumption per capita, $CO_2$ emissions, real gross domestic product, agricultural value added. They were able to draw from this analysis that Morocco needs to encourage the use of renewable energy to reduce $CO_2$ emissions.

In 2019, **Aydogan and Gülin** investigated the dynamic links between $CO_2$ emissions per capita, economic growth, agricultural value added, renewable and non-renewable energy consumption for a panel of E7 countries covering the period 1990-2014. It shows that E7 countries should continue to increase the share of renewable energy to improve the agricultural sector, thereby reducing fossil energy consumption for environmental improvement. In the same context, **Soleil, Tariq, Haris and Mohsin (2019)** used the ARDL model to examine the environmental effects of economic openness, economic growth and foreign direct investment in the South Asian Association for Regional Cooperation countries. Their results reveal that foreign direct investment and economic openness have a negative relationship on $CO_2$ emissions. In addition, economic growth increases $CO_2$ emissions.

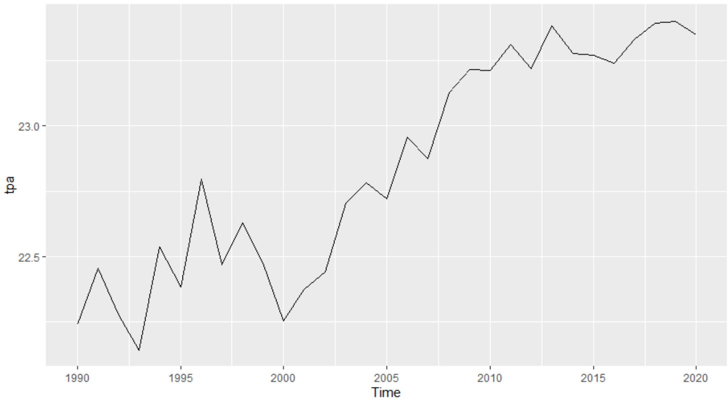
Recently, **Pilatowska, Geise and Włodarczyk (2020)** used the threshold vector autoregressive model (T-VAR) to see the impact of renewable energy consumption, nuclear energy and economic growth on $CO_2$ emissions in Spain over the period 1970-2018. The results indicate that nuclear and renewable energy consumption contribute to a reduction in $CO_2$ emissions, however, the increase in economic activity, lead to a larger increase in $CO_2$ emissions. Similarly, **Eyuboglu and Uzar (2020)** studied the determinants of environmental degradation. For this purpose, they used the variables: agriculture and renewable energy and $CO_2$ emissions. These were examined for seven countries over the period 1995-2014 through the VECM model. The major finding is that agriculture increases $CO_2$ emissions and renewable energy is a very important catalyst in reducing $CO_2$ emissions. Also, **Ridzuan, Marwan, Khalid, Helmi Ali and Tseng (2020)** investigated the relationships between $CO_2$ emissions and economic development, renewable energy, urbanisation and agricultural sub-sectors, such as crops, livestock and fisheries, in Malaysia for the period of 1978 - 2016 through the use of ARDL model. They found that urbanisation and agricultural sector deteriorate environmental quality and the use of renewable energy reduces the level of $CO_2$ emissions. On the other hand, **Oryani,Yoonmo, and Rezania (2020)** evaluated the impact of renewable electricity generation on economic growth and $CO_2$ emissions in Iran for the period 1980 - 2016 , using the structural vector autoregressive model (SVAR). Their results show that renewable electricity did not reduce $CO_2$ emissions.

Finally, we can also mention the study conducted by **Xuhua Hu, Najabat, Malik, Hussain, Fengyi and Nilofar (2021)** who investigated the effects of energy, economic openness and innovations on the environment of ASEAN countries for the period 1990-2014. To estimate the long-term relationship, they used P-VECM modelling. The results show that energy use and economic openness harm the environment by increasing $CO_2$ emissions.

## 2. Data analysis and stylized facts:

In this Section we present the evolution of agriculture, renewable energy and $CO_2$ emission over the period 1990 - 2020 in Morocco[1].

**Figure 1:** The evolution of agriculture in Morocco:

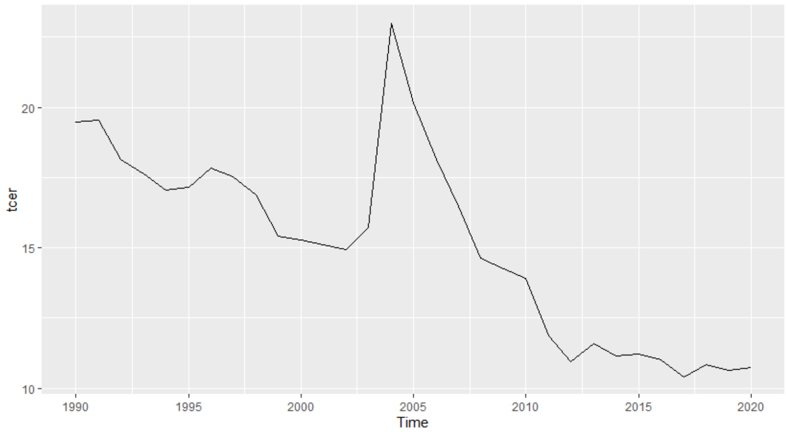



**Source:** Compiled by us from output of R software:

Agricultural production is globally low between 1990 - 2007, while it has improved between 2008 - 2020, due to the launch of the Green Morocco Plan in 2008. Agricultural production increased by an average of 52.02% over the period 2008 - 2020 compared to the previous period. In general, agricultural production has experienced a significant evolution from the year 2000 onwards due to the launch of the Moroccan agricultural development strategy.

[1] Data source : World Bank.

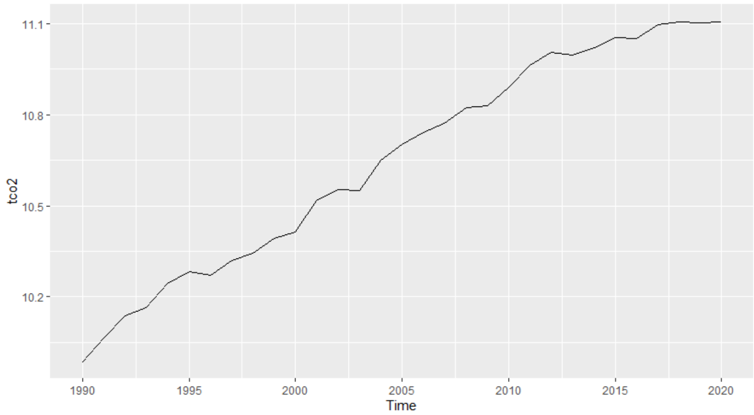
**Figure 2:** The evolution of renewable energy consumption in Morocco:




**Source:** Compiled by us from output of R software:

From Figure 2, we can notice that the evolution of renewable energy consumption is marked by a decrease throughout the period 1990 - 2003. In 2004, the consumption of renewable energy increased (23%) due to the use of renewable energy by the National Office of Electricity (NOE), which provided electricity to 80% of rural areas until 2008. Renewable energy dropped in the period 2005 - 2010 and then remained stable until 2020.

**Figure 3 :** The evolution of $CO_2$ emission in Morocco:




**Source:** Compiled by us from output of R software:

Along the period 1990 - 2020, the emission of $CO_2$ has experienced a continuous growth despite the public policies adopted by Morocco.

**Table 1 :** The correlation matrix:

| | Agriculture | Renewable energy | $CO_2$ emission |
|---|---|---|---|
| Agriculture | 1 | -0,788 | 0,950 |
| Renewable energy | -0,788 | 1 | -0,815 |
| $CO_2$ emission | 0,950 | -0,815 | 1 |

**Source:** Compiled by us from output of R software:

Studying the correlation, it emerges that the variables are strongly correlated with each other. However, there is a relatively strong and opposite direction correlation between renewable energy and $CO_2$ emission and a relatively strong and same direction correlation between agriculture and $CO_2$ emission.

**Table 2 :** Descriptive statistics:

| Variable | Min | Moyenne | Médiane | Sd | Max |
|---|---|---|---|---|---|
| Agriculture | 4137182826 | 9089383707 | 7958963285 | 14559378607 | 3646880878 |
| Renewable energy | 10,41 | 15,11 | 15,26 | 23 | 3,4 |
| $CO_2$ emission | 21730 | 44797.66 | 44490 | 66680 | 15174.56 |

**Source:** Compiled by us from output of R software:

On average, Morocco produces 9089383707 MAD in the agricultural sector and consumes 15.11% of renewable energy. The average $CO_2$ emission in Morocco is 44797.66 Kt. By relating the standard deviation to the mean, we can conclude that all variables are highly dispersed.

## 3. Data and research methodology:

According to the existing literature that studies the dynamic relationship between renewable energy consumption and $CO_2$ emissions, it has been done mainly through the channel of macro-econometric models. Sims (1980) proposed an alternative to the macro-econometric model, the vector autoregressive model. This model does not rely on identification assumptions. One of the criticisms directed to the VAR model is that it is completely non-theoretical in the strict sense, with no consideration for the hypothesis of contemporaneous effects between variables. Economists point out that the classical VAR model is unable to capture and explain economic dynamics as a response to these criticisms. Blanchard and Wotron (1986) and Ben marke and Sims (1986) constructed the structural vector autoregressive model (S-VAR).

Our S-VAR takes the following primitive form:

$$AY = \tau_0 + \sum_{i=1}^{p} \tau_i Y_{t-1} + e_i$$

Where $Y_i$ is the vector of variables to be explained;

$Y_{t-1}$ is the vector of explanatory variables;

$\tau_i$ is the vector of coefficients to be estimated;

$t = 1; 2; 3 \ldots; T$ is the time;

$p$ is the optimal number of lags determined according to the information criteria;

$A$ is the matrix of contemporaneous effects which captures the instantaneous or simultaneous effects between variables;

and $e_i$ is the vector of random disturbances representing specification errors and the effects of omitted variables.

In this paper, we apply the long-run restrictions method proposed by Blanchard and Quah (1989). The long-run structural innovation in the form of a matrix can be represented as follows:

$$\begin{pmatrix} 1 & a_{12} & a_{13} \\ a_{21} & 1 & a_{23} \\ a_{31} & a_{32} & 1 \end{pmatrix} \begin{pmatrix} CER \\ AGR \\ CO_2 \end{pmatrix} = \begin{pmatrix} \varepsilon^{CER} \\ \varepsilon^{AGR} \\ \varepsilon^{CO_2} \end{pmatrix}$$

Where $\varepsilon^{CER}$ represents the pulse of renewable energy consumption, $\varepsilon^{AGR}$ indicates the pulse of agriculture and $\varepsilon^{CO_2}$ represents the pulse of carbon dioxide emissions.

The data used for estimating the model coefficients come from the database published by the World Bank. They are annual and cover the years 1990-2020. Three variables are used in this study:

**Table 3:** Data sources:

| Variable | Unit of measurement | Source | Notation |
|---|---|---|---|
| $\boldsymbol{CO_2}$ emission | Kilo Tonne (Kt) | The World Bank | $CO_2$ |
| Agriculture | Dirham (MAD) | The World Bank | AGR |
| Renewable energy consumption | Percentage (%) | The World Bank | CER |

**Source:** The Word Bank:

In order to reduce the variability of the data, they have been converted to logarithmic form, except for renewable energy consumption.

## 4. Review of empirical results:

We will estimate our model using a Structural Vector Autoregressive model (S-VAR) to identify the short-run relationship that links the variables. The study of the stationarity of a stochastic process is mandatory for the estimated model to be reliable. To study the stationarity, we use the Augmented Dickey-Fuller test.

**Table 4:** Unit root tests:

| Time series | Order of integration retained by the ADF test | Type |
|---|---|---|
| $L\_CO_2$ | I (1) | DS |
| CER | I (1) | DS |
| L_AGR | I (1) | DS |

**Source:** Compiled by us from output of R software:

The ADF test confirms the fact that the L_AGR, L_CER and L_$CO_2$ are all first order integrated and also of Difference-Stationary (DS) type.

Before proceeding with the estimation of the model, it is important to determine the optimal number of lags, in order to have a good estimation of the model. This optimal number of lags is determined using a set of information criteria. The latter must be minimal for the number of delays to be optimal.

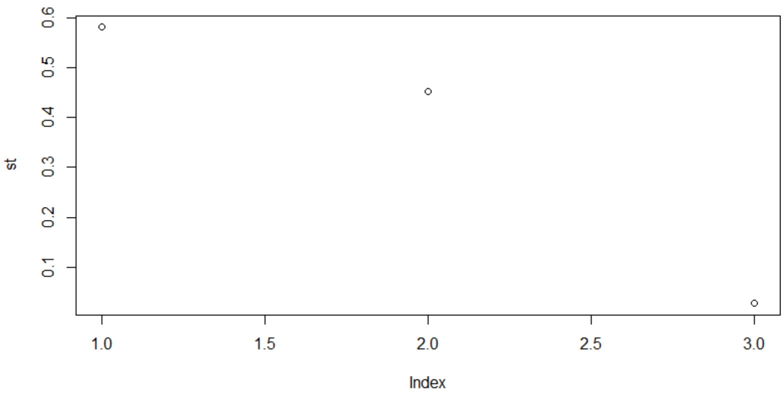
**Table 5 :** The choice of the optimal number of lags:

| AIC(n) | HA(n) | SC(n) | FPE(n) |
|---|---|---|---|
| 1 | 1 | 1 | 1 |

**Source:** Compiled by us from output of R software:

As we can see, the previous output indicates that the optimal number of lags indicated by the criteria AIC, FPE, SC and FPE is equal to 1, and since we are working under a finite sample, we allow ourselves to choose the criterion, hence, the number of delays to be retained is 1. After determining the optimal number of lags we can then estimate the Vector Autoregressive model using the R Software. We proceed by plotting the inverse of the roots associated with the Autoregressive part of each of the variables to ensure the stability of our VAR model.

**Figure 4 :** Stability of a VAR model:




**Source:** Compiled by us from output of R software:

The representation of the inverse of the roots of the characteristic polynomial of the model shows that they are below the unit circle (below 1). Hence, the stability of the model is ensured. We validate the model by tests of homoscedasticity and autocorrelation of errors.

**Table 6 :** Diagnostic test of a VAR model:

| Test | Objectif | P-value |
|---|---|---|
| ARCH | Heteroscedasticity | 0,97 |
| Portemanteau | Autocorrelation of errors | 0,77 |

**Source:** Compiled by us from output of R software:

We proceed with a test of heteroscedasticity. The value of the probability (P-value) indicated in the previous table is equal to 0.97, it is well above 0.05, so we do not reject the null hypothesis. Hence, the residuals are homoscedastic.

The P-value shown is equal to 0.77, it is well above 0.05, so we do not reject the null hypothesis, hence the absence of error autocorrelation. Thus, by validating the two previous tests, we can validate our VAR model. At this point, we can estimate our structural vector autoregressive model.

The causality test in the sense of Granger gives some insight into the link between agriculture, renewable energy and the emission of $CO_2$ in terms of causality. This test illustrates that agriculture, renewable energy cause the emission of $CO_2$ in the short run.

**Table 7:** Causality test in the sense of Granger:

| Hypothesis | P-Value |
|---|---|
| AGR cause $CO_2$ | 0,001 |
| CER cause $CO_2$ | 0,04 |

**Source:** Compiled by us from output of R software:

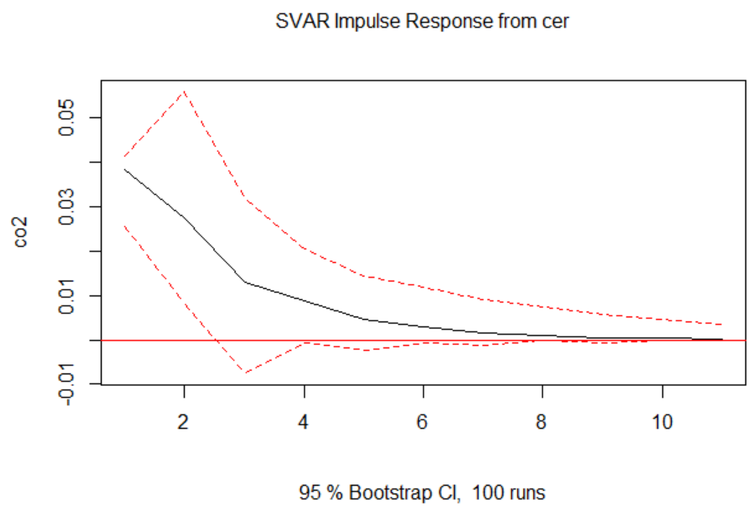
The causality test in the sense of Granger shows from an overall view that the causality is significant between the variables studied.

Indeed, the results show that agriculture causes the emission of $CO_2$ in Morocco in the short term, since the p-value is less than 0.001 (we therefore reject the null hypothesis stating that agriculture does not cause the emission of $CO_2$ in the short term).

Furthermore, the test shows that renewable energy causes the emission of $CO_2$ in the short run. Indeed, the p-value related to the renewable energy variable is less than 0.04, so we accept the alternative hypothesis, i.e., renewable energy causes the emission of $CO_2$ in the short run.

The impulse response function is present over a 10-year time horizon. The vertical axis shows the percentage of the approximate change in the variable $CO_2$ following a shock to renewable energy consumption and agriculture.

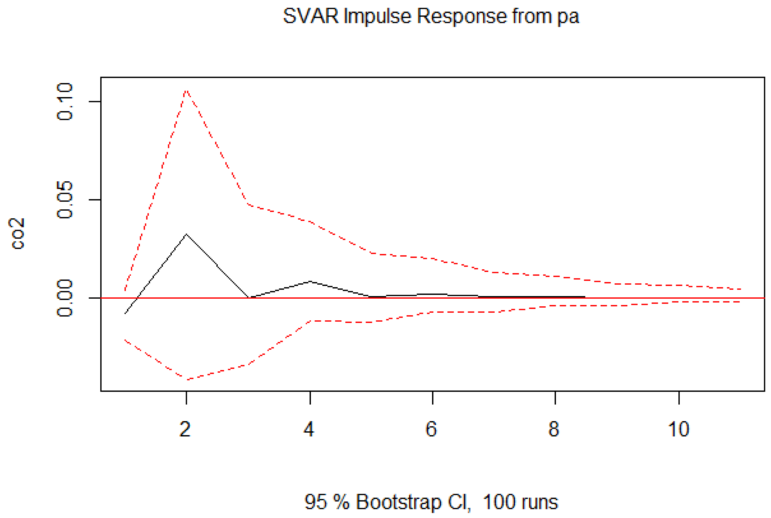
**Figure 5 :** The response of $CO_2$ emission following a shock to renewable energy:




**Source:** Compiled by us from output of R software:

An increase in renewable energy consumption acts negatively on the emission of $CO_2$. Indeed, the $CO_2$ emission show an instantaneous decrease following the increase in renewable energy consumption and which is almost extended over the 6 years of the simulation exercise.

**Figure 6:** The response of $CO_2$ emission following a shock to agriculture:




**Source:** Compiled by us from output of R software:

An increase in the production of agriculture results in an instantaneous increase in the emission of $CO_2$. This increasing evolution of $CO_2$ emission peaks around the 2 -year before converging to the stationarity path around the 5$^{th}$ year.

**Conclusion and Recommendation:**

Environmental degradation has become a major global problem due to the increase of $CO_2$ emissions in the last decade. Therefore, researchers and public authorities are making a special effort to stop environmental degradation. In this context, attempts to explain the main determinants of $CO_2$ emissions are progressing gradually. In the environmental economics literature, social, macroeconomic and sectoral factors are in the forefront to explain $CO_2$ emissions.

The objective of this work is to identify the effects of agriculture and renewable energy on $CO_2$ emission, using a Structural Vector Autoregressive model. This work reveals important information about the interaction of each variable with another that provides recommendations to Moroccan public policy makers for effective environmental public policy making and economic planning, taking into account environmental issues, energy conservation, and agriculture for sustainable growth.

The results of the econometric analysis reveal that agriculture is a sector that could play an important role in the $CO_2$ emission. So, it should be rethought to reduce the emission of $CO_2$. Therefore, we emphasize the recommendation that Moroccan policy makers should follow the model of States with developed agriculture based on ecological farming systems and less environmentally aggressive technologies.

Moreover, the results of the study also suggest that renewable energy is a key to reducing $CO_2$ emissions. As a recommendation, Moroccan authorities should encourage the consumption of renewable energy, and in particular clean renewable energy such as solar and wind, as it improves agricultural production and helps to combat global warming by reducing $CO_2$ emissions.

Given the importance of the subject, the same study can also be conducted in the regional framework. Future researchers can also use multi-sectoral models to capture the various economic interactions, including sectoral interactions, namely the computable general equilibrium model.

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