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Energy Use and Economic Growth in Morocco: A Maximum Entropy Bootstrap Approach

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ABSTRACT

This paper adds to the literature in the energy use-economic growth nexus, by analysing the relationship between GDP (Gross Domestic Product) per capita and energy consumption (EC) per capita in Morocco, following a bivariate framework using the Maximum Entropy Bootstrap (MEB) method, on a 1971-2021 time series. This method is particularly advantageous for the statistical analysis of non-stationary time series, eliminating the need for transformation to achieve stationarity, which proves to be problematic for evolutionary time series that change over time, hence affecting the results. The MEB gives more robust results even in the case of small samples. Our results are separated between the first six static models, which have demonstrated bidirectional causality, while the other six dynamic models showed different results, depending on the time-period, however most of them support the neutrality hypothesis. The results we obtained are reliable given the robustness of the MEB method. We suggest more studies to consider utilizing this method in this nexus considering multivariate framework.

Keywords: Energy Use-economic Growth Nexus, Maximum Entropy Bootstrap Method, Wald Test, Morocco, Renewable Energy Sources
JEL Classifications: O47, P18, P28

1. INTRODUCTION

It is irrefutable that energy was and is still an essential element for turning the wheels of the economy with its different sectors and fields. Thus, energy remains a vital economic asset for any economic action and daily activity, seeing its demand increase day after day, facing at the same time its limited resources that are constantly confronted by disappearance; adding to that, the harmful effects of fossil fuels combustion on the environment. The field of energy has recorded numerous changes throughout the years. Energy sources have evolved in an astonishing way since the 19th century with the introduction of coal as a new energy source, after the industrial revolution that came with the usage of steam engines and power plants that used coal as the main fuel (Rodrigue, 2020). Being such an invaluable commodity, the priority to study the impact of energy use and/or consumption (EC) on economic growth (GDP) was crucial for many countries. Countless studies and examinations had seen the day since the 1970s, with the aim of determining whether there is a relationship between energy use and GDP, and to specify the nature of this causal relationship and its direction.

The studies analysing the energy use-GDP nexus have mainly resulted in four outcomes (Atef Saad Alshehry, 2015), which we will be testing for in this paper. First, the no causality outcome, referred to as the neutrality hypothesis in the literature. This hypothesis states that energy use and economic growth are aliens to one another. Many studies found this result in the case of certain geographic zones. Second, is the feedback hypothesis; this hypothesis means that there is causality both ways and it is divided into two outcomes; the first is unidirectional causality from energy use to GDP, namely the growth hypothesis, and the second is unidirectional causality from GDP to energy use, referred to as the conservation hypothesis. The outcomes from the previous studies differ according to several factors; the geographic studied area, which could be a country, a region, or a group of countries. Another factor could be the method used to examine the relationship. Several studies analysing the same context have found different outcomes for the case of the same geographic zone, which draws our attention to the necessity of selecting the most adequate approach.

The energy use-GDP nexus has been the subject of several studies for the case of Morocco in the past two decades. However, being a country that is in constant change and growth, especially in the field of energy, it is imperative to update the analysis and examination of this link. Morocco, in the past few years, has concentrated on the evolution and enforcement of its renewable energy potential. Starting by the implementation of a significant number of policies and strategies aiming to ensure the orderly conduct and execution of the that have been launched since 2009, the date of the promulgation of the 13-09 law on renewable energies; and the national energy policy for 2030, which targets a 52% share of renewable energy in the energy mix by 2030 (Ministry of Energy, Mines and Environment, 2020).

To enhance the existing body of knowledge on the energy use-GDP nexus in Morocco, we have opted to employ a novel methodology not yet explored in the Moroccan context. The method we will work with is the Maximum Entropy Bootstrap approach (MEB), and the Wald test. Our chosen approach revolves around the Maximum Entropy Bootstrap and the Wald test. The MEB algorithm, an innovative econometric tool developed by Vinod (2006), draws inspiration from the Maximum Entropy principle pioneered by Jaynes (1957). This method proves particularly advantageous for the statistical analysis of non-stationary time series, eliminating the need for transformation to achieve stationarity. Vinod argues that this transformation proves to be problematic for evolutionary time series, which change over time, hence affecting the results. In fields such as medicine and social sciences, thinking and living creatures are always present, which makes assuming stationarity rather impractical given that human behaviour is delicate to initial settings (2006). Individuals and nations' economic behaviour is usually time-dependent, beginning with intrinsic initial conditions, each to take a specific route. Such evolving data are often not suitable to being transformed into stationary series, since it would intervene with its natural course. Hence, we decided that using the MEB for this study was the best course of action, in order to obtain more robust results.

The objective from this paper is to examine the relationship between energy use and economic growth, over the period 1971-2021, using the MEB approach, and Wald test. We use bivariate analysis for the variables energy use per capita and GDP per capita. The rest of the paper is structured as follows: Section 2 presents an ensemble of previous works in the same field. Section 3 gives a brief contextualization of the energy situation in Morocco. Section 4 presents methodology and data; the results and discussions are presented in section 5, and lastly, a conclusion in the section 6, in addition to some policy implications for the Moroccan context.

2. LITERATURE REVIEW

The theme of the connection between energy consumption and economic growth, or gross domestic product (GDP), has been the subject of numerous studies during the last few decades. One of the very first articles that treated this subject, and one of the ground-breaking studies, can be found in Kraft and Kraft (1978). The research found that unidirectional causality going from income to energy consumption, and not the opposite. These results were found regarding the post-war period, from 1947 to 1974 (1978). Following this publication, many studies were conducted on the same subject on different countries and regions of the world, in order to better determine and understand the nature of the relationship between energy consumption and economic growth, and see whether it exists at all in the first place. Studying the economic growth, renewable and non-renewable energy consumption nexus in Morocco, using the causality analysis in VAR model over the 1980-2019 period, revealed results that supported the neutrality hypothesis. El-Karimi (2022) found no significant causality between renewable energy consumption and economic growth, stating that there could likely exist an unreached threshold beyond which renewable energy consumption will begin to promote economic growth. He also found unidirectional causality in the case of economic growth to non-renewable energy that could be explained by the country's economic development (2022).

Asafu-Adjaye (2000) conducted a research on the same relationship on four Asian countries over the 1971-1995 period (India, Indonesia, Philippines and Thailand) using Granger Causality test and a Vector Error Correction Model (VECM). His results indicated a long run unidirectional causality from energy consumption to income for India and Indonesia, and a bidirectional causality for Thailand and the Philippines. His results also supported the neutrality hypothesis in the short run for India and Indonesia. The neutrality hypothesis suggests that energy consumption and economic growth are independent from one another, meaning there exists no link between the two. Bozkurt and Akan (2014) examined the same nexus as Pakistan in Turkey, using a cointegration test on a 1960-2010 time series. Their results showed that CO_2 emissions had a negative effect on economic growth, but energy consumption had a positive impact on it, for the Turkish case. George Hondroyiannis (2002) used a VECM model on a 1960-1996 time series in Greece and obtained results indicating a long run Granger causality between energy consumption and income. Wolde-Rufael (2009) investigated the relationship between energy use and income on panel data covering 17 African countries using the variance decomposition analysis on the period 1971-2004. Following his results, the neutrality hypothesis was rejected in 15 countries out of 17, which means there exists a relationship between the two variables in these countries. He also found that, in 11 out of the 17 countries, energy consumption is only a contributing factor to economic growth, not a fundamental one. Soufiane et al. (2021) studied the nexus between renewable energy consumption and economic growth in Morocco using the ARDL approach and Granger Causality over the 1990-2014 time series. They found that renewable energies have a positive impact on national GDP, and GDP on CO_2 emissions.

Shyamal and Bhattacharya (2004) used Engle-Granger cointergration on Indian data from 1950 to 1996 and the results showed bidirectional causality between the two variables. They also obtained the same results using Johansen multivariate cointegration approach. Ahmed and Long (2013) analyzed the energy use and economic growth linkage in Pakistan. They used an Auto-Regressive Distributed Lag model (ARDL) on time series from 1971 to 2008. Their work analysed the two variables with three others, CO_2 emissions, trade openness and population growth. They tested for the validity of the Environmental Kuznets Curve (EKC Hypothesis), which examines the relationship between income per capita and environmental degradation, as suggested by Stern (2004). They found that the EKC Hypothesis was invalid in the short run but valid in the long run. They also determined that population affects CO_2 emissions negatively. For the case of Malaysia, Begum et al. (2015) studied the linkage between energy use, CO_2 emissions, economic and population growth for their country. First they used and ARDL on the period 1970 to 1980 and found a negative relationship between economic growth and CO_2 emissions. Lastly, they used a Dynamic Ordinary Least Squares (DOLS) and a Sasabuchi-Lind-Mehlum U test (SLM-U) on the period 1980-2009 where they found that CO_2 emissions and economic growth had a positive relationship, and that the EKC hypothesis was invalid. Their results also revealed that there was a unidirectional causality from both energy use and economic growth to CO_2 emissions; however, the population growth had no impact on CO_2 emissions on the same period. Another study was conducted on 10 Middle Eastern countries analysing the energy use-GDP- CO_2 emissions nexus by Magazzino (2016), using a VAR on panel data covering the 1971-2006 time-period. The results Magazzino found were a negative impact of GDP on CO_2 emissions in the six Gulf Cooperation Council (GCC) member countries (Qatar, UAE, KSA, Bahrain, Oman and Kuwait). Jamaï Mouhtadi and Sadefo Kamdem (2019) investigated the energy consumption-economic growth-carbon dioxide nexus in Morocco by using the Johansen cointegration method. They concluded that there existed a long-run relationship between energy consumption, economic growth, and CO_2 emissions; and also a long run bidirectional causality between energy consumption and economic growth, and between energy consumption and CO_2 emissions. Which indicates that in the case of Morocco, the feedback hypothesis is supported (2019). Cherni and Abdelbaki (2017) studied the CO_2 emissions-economic growth-renewable energy use nexus in Tunisia by using the ARDL method on a 1990-2015 time series and they demonstrated that there was a bidirectional causality between income and RE consumption, and CO_2 emissions and income.

Multiple studies found different results regarding the relationship between energy use and income, to which are added other variables in some cases, to get a better grasp of this relationship. The variety of these results shows that energy use and economic growth are influenced by other variables such as CO_2 emissions, population growth, urbanization rates, and other variables. The origin of the energy source also plays a role in determining the influence of the energy consumption variable on economic growth and vice-versa. To prove this, Ito (2017) studied the relationship between renewable and non-renewable energy consumption, CO_2 emissions and income using multiple tools: the Pool Mean Group method (PMG), the Generalized Method of Moments (GMM) and an ARDL model on panel data of 42 countries, from 2002 to 2011. Through this study, he established that non-renewable energy use had a negative effect on income, while renewable energy use had a positive impact on income in the long run, as well as on CO_2 emissions. The results obtained by Ito reflect the expected outcome of the renewable energies usage on the CO_2 emissions around the world. The expansion of the implementation of renewable energy policies and the growth of their usage contributed significantly to the reduction of global CO_2 emissions (IEA, 2022). Enforcing the Moroccan literature in the energy consumption-economic growth nexus, El-Elkarimi and El-Ghini (2021) studied the relationship between the two variables employing the Toda and Yamamoto causality test on annual data from 1980 to 2016. They revealed support of the neutrality hypothesis as they found no significant causality between RE consumption and GDP. İnal et al. (2022) analysed the link using a panel LM[1] bootstrap cointegration test on 9 African oil-producing countries from the year 1990 to 2014 (2022). Their results revealed the absence of any significant effect of RE on economic growth, however, CO_2 emissions had a positive impact on three out of the nine countries (Algeria, Equatorial Guinea and Egypt).

Dong et al. (2018) conducted a panel data analysis on 128 countries from 1990 to 2014 to analyse the relationship between CO_2 emissions, renewable energy use, economic and population growth. They used a Cross Sectional dependence and slope homogeneity test (CS-DSH), and confirmed the existence of Cross Sectional significant dependence and homogeneity among the variables. They also tested for Dynamic common correlated effects mean group (CCEMG) and found that population and economic growth both have a significant positive impact on CO_2 emissions on the regional as well as on the global levels.

Several statistical and econometric methods were employed to get a better understanding of the nature of the relationship between energy consumption and economic growth. Multiple studies supported the "growth hypothesis", like Greece, India, Turkey, ECO[2] member countries; meaning that energy consumption does indeed cause a higher level of output, as Kenneth Barroga argued, which will consequently mean that the studied zone (country or region) will need to stay away from energy conservation policies because they will have a negative impact on its economy (Kenneth Barroga, 2018). Other studies supported the "conservation hypothesis" which reflects a unidirectional causality running from economic growth to energy use; this means that implementing energy conservation policies would have desirable effects on the economy in these regions (2018). These results were obtained in Bangladesh, Tunisia and North Africa, among others. In addition, there were cases where the analyses showed causality both ways between the two variables; these cases include Thailand, Philippines, India and Tunisia.

1. Lagrange Multiplier
2. Includes Afghanistan, Azerbaijan, Iran, Kazakhstan, Kyrgyzstan, Pakistan, Tajikistan, Turkey, Turkmenistan and Uzbekistan.

Despite the fact that hundreds of studies were done in the field of energy use and economic growth, the analyses did not stop, for many changes occur in both variables especially that of energy use, not to mention the geographical context, since our two variables vary from one country/region to the other. The energy sector is in constant alteration in many regions of the world, with the use of REs that became more prevalent, and the discovery of new sources of energy like the Green Hydrogen and nuclear fusion, among others (Wisconsin Center for Environmental Education, 2020).

Adebayo (2020) used a Wavelet coherence approach on a 1971-2018 time series to examine the link between CO_2 emissions, energy use and economic growth in Thailand and found a unidirectional causality from economic growth to CO_2 emissions, and bidirectional causality between the latter and energy consumption. Akorede and Afroz (2020) in Nigeria also examined the same relationship while adding the urbanization variable, employing a Granger causality test and an ARDL. They found that urbanization and energy use have bidirectional causality; and unidirectional causality from energy use, economic growth and urbanization to CO_2 emissions in the short run. Their results also prove the existence of unidirectional causality from urbanization and economic growth to CO_2 emissions in the long run. Tran (2022) studied the relationship between energy usage, CO_2 emissions, economic growth and green finance while employing a cointegration test, an ECM and Granger causality on Vietnamese data from 1986 to 2018. His results showed the existence of cointegration amongst the variables and unidirectional causality from RE to CO_2 emissions.

The majority of these studies support either the growth hypothesis or the conservation hypothesis, while only few support the neutrality hypothesis. For example, in the case of Turkey, the study conducted by Bozkurt and Akan (2014), used a cointegration test and found that energy use had a positive impact on economic growth, thus supporting the growth hypothesis. Similar results were also found in the case of Morocco, Tunisia, Egypt and many other African countries [(Soufiane et al., 2021), (Cherni and Abdelbaki, 2017), (Ibrahiem, 2015)]. The cointegration test requires data to be stationary which equally means transforming it from its original form, thus affecting the results. However, in the case of Turkey, Yalta (2011) examined the relationship and found no significant linkage between energy consumption, reflecting the absence of any causal relationship between the two variables. He examined the time series with four different periods, and all amounted to the same result of no causality. Yalta proposed the Maximum Entropy Bootstrap (MEB) to address the inconsistent results on GDP-EC nexus in Turkey. This method is recognised for its efficiency in providing reliable results even on short duration samples, and it does not require the data to be stationary, as mentioned earlier in the introduction (2011).

In the context of Morocco, the unresolved inquiry pertains to determining the specific causal relationships between Gross Domestic Product (GDP) and Energy Consumption (EC) that should be employed for the formulation of policy recommendations. Furthermore, it is noteworthy that there exists a paucity of empirical studies addressing this particular subject within the Moroccan context.

3. THE ENERGY EVOLUTION IN MOROCCO

Morocco is a country faced with the absence of conventional fossil energy resources (petroleum, coal…) and a heavy dependence on imports, which covered more than 90% of energy needs. As a developing country, Morocco has experienced continuous growth in energy demand since the beginning of the 20th century, associated with industrialisation, the overall development of the economy and the improvement of living standards (Dupret et al., 2016). Over the past 25 years, demand has grown by an average of 6-7% year.

As energy is an essential factor in the functioning of the economy, Morocco, like most countries, whether industrialized or developing, has long been engaged in several efforts to achieve energy independence through the implementation of several policies and strategic decisions. It had begun to take its first successful steps a few years ago, starting with the creation of an adequate and appropriate legislative and regulatory framework to accompany many of its present and future projects. The Moroccan authorities have implemented a purposeful and ambitious strategy, the main objective of which is the development of renewable energies (2010). Morocco has truly provided itself with the means to succeed in its ambitions and is beginning to reap the first fruits of this strategy, among others.

In the part of Morocco administered by France under the protectorate, concessions for production (small hydroelectric plants, steam boilers or diesel engines) and distribution were granted to private companies in the country's main cities. The Moroccan Water, Gas and Electricity Distribution Company (SMD) was created in 1914 (2016). In 1920, the situation started taking another direction marked by the large-scale exploitation of phosphate deposit, one of the most essential in the world, which the Kingdom possesses. The transportation of such huge amounts of phosphate required setting a railway network. On the other hand, the shortage and poorness of local coal led to the use of electricity for traction, which gave a decisive impulse to the production of electrical energy. This is where the hydroelectric power came into place. Morocco is known for its strategic geographical location, as it is surrounded by two massive water sources: the Atlantic Ocean and the Mediterranean Sea. It is also characterised by its temperate climate, which provides it with a significant and regular precipitation that differs from one region to another, filling the many dams and micro-hydro plants spread throughout the Kingdom (Planete Energies, 2016).

King Hassan II implemented the policy of dams since the 1930s after numerous studies in order to find a solution to the phenomenon of drought cycles that the country was experiencing at the time. The Bin El Ouidane dam was built in 1953, after 14 years of effort, in the narrowing of the Oued El Abid, the most important tributary of the Oum Er-Rbia (Planete Energies, 2016). This project was carried out mainly produce electrical energy, irrigation, drinking water supply, etc. The surface area of the reserve lake is estimated at 3800 hectares. Today, this dam is considered a very diverse biological, ecological and environmental heritage in the region. It provides an annual electricity production of 287 GWh following the installation of a capacity of 135 MW. King Hassan II intensified the efforts taken to build barrages to secure one million of hectares irrigated, and to supply the population with drinkable water all around the Kingdom (2016).

Later on, as part of the policy of liberalization and integration into the international economy, the liberalization of the energy sector started in 1994 to encourage the development of independent energy production under a maximum capacity of 10 MW within a contract with the ONEE (Office National de l'éléctricité et de l'Eau Potable) (ONEE, 2020).

Regarding distribution and refining, the privatisation of all the SNPP[3] companies was completed in 1996 and the two refineries that the country had (SAMIR[4] and SCP[5]) were sold in 1998 to the Corral Petroleum Group, which merged them in June 1999 (2016). However, and according to energy experts (Saoury, 2019), this privatization/selling of the SAMIR was one of the most flawed decisions ever made in Moroccan history yet. The refinery was a primordial actor in guaranteeing energy security in the country as it supplied Moroccans with good value for money for its hydrocarbons. The SAMIR provided a little over 60% of the national needs of hydrocarbons and more than 143% of airplane fuel, which means it had a surplus that could be exported as well as other oil products (Fuel oil, Bitumen, Paraffin, etc.) (Challenge, 2015).

In December 2015, the liberalization policy knew another change where the combustibles prices were determined by demand and supply (Moussaoui, 2015). In principle, this action constitutes an important opportunity for Moroccan economy; nevertheless, it has shown some downsides; most dangerous of all was the inconvenient timing that coincided with the shutdown of the unique domestic supplier of combustibles, SAMIR. This incident was a big risk facing the supply that would eventually lead to high prices (H24info, 2022).

As the consumption of energy had grown greater with the growth of the population across the globe, along with industrial activities that require intensive energy production and consumption, Morocco, since the 2000s, had introduced numerous legislative regulations in the renewable energy sector (RE). The main goal was to promote renewable energy production as part of the energy transition, to contribute in the preservation of the environment to prevent further harm (AMEE, 2016).

The development of renewable energies was a key point in the new energy policy. In 1982, the Centre for the Development of Renewable Energies (CDER) was established (Elouadi, 2002). The first strategy that the Centre implemented was to bring the rate of renewable energies in the energy mix to 10% by 2010. The Centre later on became the Moroccan Agency of Energy Efficiency (AMEE). However, the first legal regulation that went towards the development of this technology was the Law n° 13-09 for renewable energies. It was initiated under the Royal Directives of His Majesty the King Mohammed 6 to prioritize the development of renewable energy and sustainable development (Ministry of Energy Transition and Sustainable Development, 2010). This law makes it possible to fill the legal gaps in the field of renewable energy and to encourage investment and meet several challenges, for it embodies the commitments made by the public authorities in this field.

MASEN (Moroccan Agency for Sustainable Energy), one of the country's responsible organisms that take charge of implementing RE's projects, alongside ONEE, has for its main mission taking charge of the establishment and execution of projects related to solar energy, and that within the framework of the national strategy to achieve 52% of RE in the national installed capacity by 2030, by the construction of projects concerning not only solar energy, but every unit of electricity production coming from all known national renewable energy sources (wind and hydro), in order to secure access to clean electricity on the national scale (MASEN , 2019). The aforementioned organisms are in charge of conducting research and studies in the field to identify the capacity of the said production, in order to build the needed infrastructure necessary to realizing the suggested projects as well as the financial requirements (Minister of Energy, 2016).

4. METHODOLOGY AND DATA

4.1. Methodology

In this article, the modelling strategy adopted is the bivariate approach. To examine the existence of causality between energy consumption and economic growth, we use the Wald test, and the Maximum Entropy Bootstrap (MEB or meboot) method initiated by Vinod (2006). The MEB method has numerous advantages; for one, it allows analysis on non-stationary data, avoiding all structural changes in data, meaning that even if the data is non-stationary, the analysis can still be done without going through the steps of making it stationary by transformations such as differencing or de-trending, that shape-destroy the original series.

In the conventional bootstrapping theory, an ensemble, denoted as Ω, is considered a representation of the population from which the observed time series is derived, as stated by Lahiri (2003). The MEB procedure, which was introduced by Vinod and Lopez-de-Lacalle (2009), generates a substantial quantity of replicates (for instance, J=1000) that serve as elements of Ω. These replicates are used for inference and are created through an algorithm specifically designed to adhere to the ergodic theorem, which states that the grand mean of all ensembles approximates the sample mean. The Ω that is constructed preserves the fundamental shape and time-dependence structure of the autocorrelation function (ACF) and the partial autocorrelation function (PACF) of the original time series, as per the findings of Vinod and Lopez-de-Lacalle (2009).

Despite the prevalent use of bootstrapping, its comprehension is not always universal. In practical applications, the implementation of bootstrapping often presents challenges and its effectiveness may not align with common perceptions. Certain bootstrap methodologies are straightforward to apply and exhibit exceptional performance under specific circumstances. However, in other

3. Société Nationale des Produits Pétroliers
4. Société Anonyme Marocaine de l'Industrie du Raffinage
5. Société Chérifienne des Pétroles

scenarios, the efficacy of bootstrap methods may be compromised and the selection among alternatives can pose difficulties. This is particularly evident in the context of highly dependent or evolving time series data, as noted by Davidson and Hinkley (1997).

The recently developed technique called the MEB is a more general method than bootstrapping, since it does not assume stationarity and does not need possibly questionable differencing operations. It has several advantages over conventional methods, including that it does not use any simulated errors based on the assumed reliability of a parametric model, it does not need to assume that the conditional mean of the dependent variable given a realization of regressors in standard notation is linear, it is robust against heteroscedastic errors, and the estimation process is relatively simple (2006).

4.2. Statistical Models

This study will be conducted following bivariate models between the two variables, GDP per capita GDP_t and EC per capita EC_t. The models are as follows:

$$EC_t = a_1 + a_2\, GDP_{t-p} + e_t \quad (1)$$

$$GDP_t = a_1 + a_2\, EC_{t-p} + e_t \quad (2)$$

$$EC_t = a_1 + a_2\, EC_{t-1} + a_3\, GDP_{t-p} + e_t \quad (3)$$

$$GDP_t = a_1 + a_2\, GDP_{t-1} + a_3\, EC_{t-p} + e_t \quad (4)$$

e_t represents the error/residual term, *t* and *p* represent time and lags respectively. To correctly conduct the analysis using meboot, we worked with the R software using several packages starting with the *meboot* package, which runs the MEB method, *lmtest* for linear regression models, which are models one through six, and *dynlm* for dynamic ones, which are models 7-12. Most importantly, the *hdrcde* package for highest density regions (HDR) graphics is used to show the samples distributions for our a_i coefficients ($i = 2,3$). We also used the same software to conduct the Wald test.

With p=0,1,2, we obtain 12 model equations from the first four expressed above, and they are as follows:

To analyse the existence of a relationship between the two variables and its direction, confidence intervals for the parameter are computed based on the 1000 samples we have from the *meboot* package (original data included), for the case of energy use as dependent variable and GDP as independent variable, and vice versa, which are represented in models 1-6.

In the rest of the models (7-12) in Table 1, the same variables are incorporated in lagged forms (with lags 0, 1 and 2) in the equations in order to obtain more robust and accurate estimates for coefficient a_3 (Wilkins, 2017), and confidence intervals for coefficient a_3 are calculated for the same end goal. Therefore, the null and alternative hypotheses are as follows:

$$H_0{:}a_i = 0;\ H_1 : a_i \neq 0 \text{ with } i = 2,3$$

The null hypothesis H_0 means that there is no relationship between the two variables. In the case where the null hypothesis is rejected, meaning zero is not included in the confidence interval, in other words, the corresponding coefficient is non-null, then the exogenous variable explains the dependent variable.

The next section presents the study's results with detailed explanations for all 12 models in 3 different times series, the first is the whole period from 1971 to 2021, the second time period (TP1) from 1971 to 1996, and the last one (TP2) from 1997 to 2021.

4.3. Data

This section describes the data and the variables we decided to work with in this empirical analysis. The variables that we chose to study, following the existing literature, are energy use per capita measured in Kgoe[6], and GDP per capita measured in local Moroccan currency, MAD. The time series under study is an annual dataset for Morocco running from 1971 to 2021, obtained from the World Bank, and the World Development indicators. The values are transformed into logarithmic form during the analysis to present better interpretation.

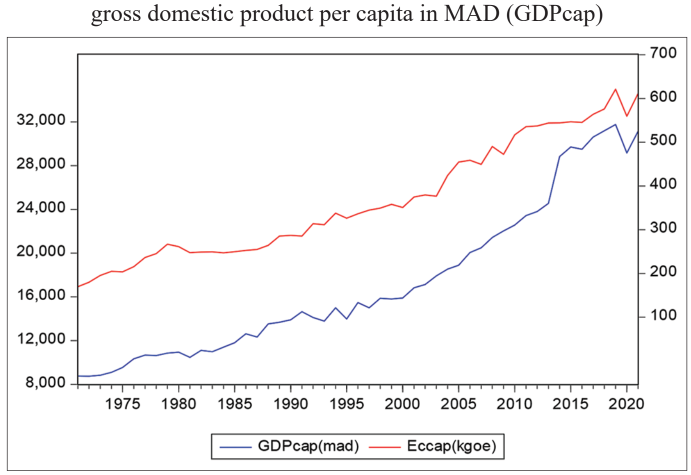
To get a better view on the data, we represent it in graphic form to highlight the trends of both series and see if they show signs of correlation in this form.

6. Kilogram of Oil equivalent

Table 1: 12 Model equations subject of the study

Model 1	$EC_t=a_1+a_2\, GDP_t+e_t$
Model 2	$EC_t=a_1+a_2\, GDP_{t-1}+e_t$
Model 3	$EC_t=a_1+a_2\, GDP_{t-2}+e_t$
Model 4	$GDP_t=a_1+a_2\, EC_t+e_t$
Model 5	$GDP_t=a_1+a_2\, EC_{t-1}+e_t$
Model 6	$GDP_t=a_1+a_2\, EC_{t-2}+e_t$
Model 7	$EC_t=a_1+a_2\, EC_{t-1}+a_3\, GDP_t+e_t$
Model 8	$EC_t=a_1+a_2\, EC_{t-1}+a_3\, GDP_{t-1}+e_t$
Model 9	$EC_t=a_1+a_2\, EC_{t-1}+a_3\, GDP_{t-2}+e_t$
Model 10	$GDP_t=a_1+a_2\, GDP_{t-1}+a_3\, EC_t+e_t$
Model 11	$GDP_t=a_1+a_2\, GDP_{t-1}+a_3\, EC_{t-1}+e_t$
Model 12	$GDP_t=a_1+a_2\, GDP_{t-1}+a_3\, EC_{t-2}+e_t$

Figure 1: Energy use per capita in KGOE (ECCAP) (right axis) and gross domestic product per capita in MAD (GDPcap)



Source: World Development Indicators

Figure 1 shows that both time series have an ascending trend and are strongly correlated. Morocco has recorded a constant rise of its energy consumption throughout the last 30 years, with a strong rise in the last two decades. This growth is due to several reasons, one of which is the demographic growth, that increased by 50.89% between 1990 and 2021, and 37.32% between 1996 and 2021 (World Bank, 2022). Moreover, during this time, Morocco has been living a transitional period marked by a notable evolution of new technologies such as the digitalisation concerning many sectors, and the unmatched potential of renewable energies, that gained a crucial momentum in the last 20 years. This transition makes the country one of the top countries in the world with such potential especially regarding attraction of foreign investors. Their attraction enables the economy to prosper, creating more job opportunities, improving infrastructure and enhancing the country's ranking globally, as well as improving the international links with several countries such as India, Canada, the United States, and Japan. Improving these aspects had a positive effect on the national economy as it proved to be a key enhancer of it, and its indicators have recorded a remarkable progress during the last two decades (2016). According to the High Commission for Planning, it has been noted that economic activity has been part of a long-term growth cycle, i.e. almost 54 successive quarters of increase (since 2003), in contrast to the 1990s, which were characterised by short cycles of growth (HCP, 2013). Overall, the Moroccan economy has had a continuous growth cycle in the last two decades until the Covid-19 pandemic that took place in 2020, which explains the two decreases in the graph. The Moroccan government is doubling its efforts to recover from the pandemic's repercussions and regain its initial pace of growth.

5. RESULTS AND DISCUSSION

In this section, we present the results obtained from the Wald Test, to illustrate the existence (or absence) of causality between EC and GDP. Later on, we will present the HDR graph results, which illustrates the confidence intervals (CI) bounds' values, for the three confidence levels: 90%, 95% and 99%, and compare the results obtained from the methods, while highlighting the MEB method that gives results that are more reliable statistical-wise.

We will discuss the first six models (1-6) separately since they are different from the models 7-12.

5.1. Wald Test Results

To analyse the relationship between energy use per capita and GDP per capita, we first started by investigating causality using the Wald test. Our results are presented in Table 2:

Table 2 elucidates the existence of causality in both directions; models 1-3 show unidirectional causality from GDP to energy use, as the p-value is smaller than the 5% level in all time-periods. Models 4 to 6 also illustrate unidirectional causality from energy use to GDP this time, with a $P < 0.05$ on all three time-intervals.

The results obtained for models one through six in all time-periods is consistent with the existing literature that supports both the

Table 2: Values of Chi-squared statistic from the Wald test (without bootstrap) method

Models	1971-2021	TP1: 1971-1996	TP2: 1997-2021
Model 1	P(> X2) = 0.0	P(> X2) = 0.0	P(> X2) = 0.0
Model 2	P(> X2) = 0.0	P(> X2) = 0.0	P(> X2) = 0.0
Model 3	P(> X2) = 0.0	P(> X2) = 0.0	P(> X2) = 0.0
Model 4	P(> X2) = 0.0	P(> X2) = 0.0	P(> X2) = 0.0
Model 5	P(> X2) = 0.0	P(> X2) = 0.0	P(> X2) = 0.0
Model 6	P(> X2) = 0.0	P(> X2) = 0.0	P(> X2) = 0.0
Model 7	P(> X2) = 0.00068	P(> X2) = 0.0023	P(> X2) = 0.02
Model 8	P(> X2) = 0.033	P(> X2) = 0.015	P(> X2) = 0.24
Model 9	P(> X2) = 0.027	P(> X2) = 0.0081	P(> X2) = 0.12
Model 10	P(> X2) = 0.0077	P(> X2) = 0.18	P(> X2) = 0.0058
Model 11	P(> X2) = 0.23	P(> X2) = 0.71	P(> X2) = 0.18
Model 12	P(> X2) = 0.011	P(> X2) = 0.22	P(> X2) = 0.18

Table 3: Results of the MEB method for a_2 estimates, models 1-6

Model 1-6		1971–2021	1971–1996	1997-2021
1	$CI_{99\%}$	(0.7981, 1.0031)	(0.3499, 1.557)	(0.2570, 1.167)
	$CI_{95\%}$	(0.8295, 0.9724)	(0.5197, 1.349)	(0.3569, 1.065)
	$CI_{90\%}$	(0.8443, 0.9581)	(0.5810, 1.277)	(0.4128, 1.008)
2	$CI_{99\%}$	(0.7850, 0.9967)	(0.2649, 1.544)	(0.2661, 1.1360)
	$CI_{95\%}$	(0.8161, 0.9667)	(0.4520, 1.308)	(0.3548, 1.0460)
	$CI_{90\%}$	(0.8303, 0.9532)	(0.5266, 1.220)	(0.4138, 0.9865)
3	$CI_{99\%}$	(0.7716, 0.9814)	(0.2578, 1.402)	(0.2781, 1.0743)
	$CI_{95\%}$	(0.7972, 0.9576)	(0.4202, 1.229)	(0.3528, 0.9984)
	$CI_{90\%}$	(0.8157, 0.9427)	(0.4757, 1.171)	(0.4095, 0.9419)
4	$CI_{99\%}$	(0.9050, 1.177)	(0.3907, 1.528)	(0.1856, 2.700)
	$CI_{95\%}$	(0.9404, 1.143)	(0.5283, 1.288)	(0.6729, 1.795)
	$CI_{90\%}$	(0.9627, 1.114)	(0.5825, 1.215)	(0.7859, 1.667)
5	$CI_{99\%}$	(0.8922, 1.179)	(0.3105, 1.471	(0.3149, 2.168)
	$CI_{95\%}$	(0.9285, 1.142)	(0.4905, 1.239)	(0.7000, 1.666)
	$CI_{90\%}$	(0.9493, 1.116)	(0.5538, 1.165)	(0.7990, 1.558)
6	$CI_{99\%}$	(0.8832, 1.172)	(0.2517, 1.444)	(0.4258, 1.894)
	$CI_{95\%}$	(0.9178, 1.132)	(0.4465, 1.189)	(0.7097, 1.584)
	$CI_{90\%}$	(0.9366, 1.110)	(0.5164, 1.108)	(0.7841, 1.506)

growth and the conservation hypotheses, which suggest that energy use causes a larger amount of output (GDP), and GDP causes more use of energy, respectively, for the case of Morocco. This can be explained by the fact that the Moroccan government has seen its domestic energy production increase in a fast rate; especially in the last 15 years with the improvement and evolution of renewable energy policies that enabled the implementation of several projects in the RE domain, which strongly encouraged other countries to choose Morocco as a source of clean energy. This in turn has helped the country's GDP to increase with the energy bill recording a slight reduction (Ministry of Energy, Mines and Environment, 2020).

5.2. The Maximum Entropy Bootstrap Method's Results

In this section, we present the results obtained using the MEB approach on the same time series used in the Wald test over the same three time-intervals.

We present the results in a table to facilitate reading them, and we provide the HDR graphics' intervals of the estimates for models one to six in Table 3; and estimates for models seven through twelve in Table 4 over the three time-periods.

Figure 2 shows the HDR confidence intervals' graphs for models 8-12 respectively, on 3 confidence levels (90%, 95% and 99%) for both timeframes TP1 and TP2, with β_2 and β_3 representing a_2 and a_3 respectively in our models.

The results from Table 3 show that there is bidirectional causality in all six models and over all three time-periods, on the 90%, 95% and 99% confidence levels, as the null hypothesis is rejected against the alternative one, meaning that zero does not belong to the confidence intervals obtained above. These results are similar to those obtained using the Wald test approach, regarding the same models (1 to 6) which support the feedback hypothesis, and it is consistent again with the aforementioned literature. Referring to Figure 1, we find that energy use and economic growth (expressed by GDP per capita in the graph) both have an upward trend and are strongly and positively correlated, which explains the results we obtained from both approaches on the six first models over the three time periods.

The results obtained in Table 4 from the MEB method concerning the models seven through twelve are quite thought-provoking. We notice that there are different outcomes depending on the period and the confidence level, as it is also apparent in Figure 2 for HDR graphs. Looking closely at, we see that TP2 mostly shows results of no causality, and especially on the 99% and 95% confidence levels. All confidence intervals in TP2 have zero in them, which reflects the non-rejection of the null hypothesis, meaning there is no causality, except for model 7 and 10 at the 90% level.

Focusing on the results from TP2 on the 99% level, which is the highest, shows that there is consistency with the findings obtained using the classic Wald test technique. Considering the two methods and their outcomes on the third time period (1997-2021), we determine that the findings support the neutrality hypothesis that points to the absence of causality between our two target variables. Our focus on TP2 is because it is the most recent, and that Morocco's major changes occurred during this period. However, this does not prevent the study of the other periods from being a requirement for comparison sake and at the same time to avoid omitting breaks, which is why we have opted for the analysis of the three periods.

The finding of non-existence of causality over the period 1997-2021 using the MEB approach were predictable, depending on the existing literature using the same approach in other regions, like in the case of Turkey (Yalta, 2011). However, for the case of Morocco, different studies found various results, some of which found that there is causality between the variables, while others supported the neutrality hypothesis. As we mentioned in the literature review, (Soufiane et al., 2021) and (Mouhtadi and Kamdem (2019) both proved the existence of causality between energy use and GDP, employing the ARDL model, and Johansen cointegration respectively. On the other hand, El-Karimi (2022) found no causality between RE use and GDP, and El-Elkarimi and El-Ghini (Elkarimi and Ghini, 2021) research revealed the absence of causality between energy use and GDP, thus supporting the neutrality hypothesis. They worked with a VAR model, and Toda and Yamamoto causality test, respectively.

Therefore, to our knowledge, the examination of the energy use-economic growth nexus has never been done using the Maximum Entropy Bootstrapping method for the case of Morocco.

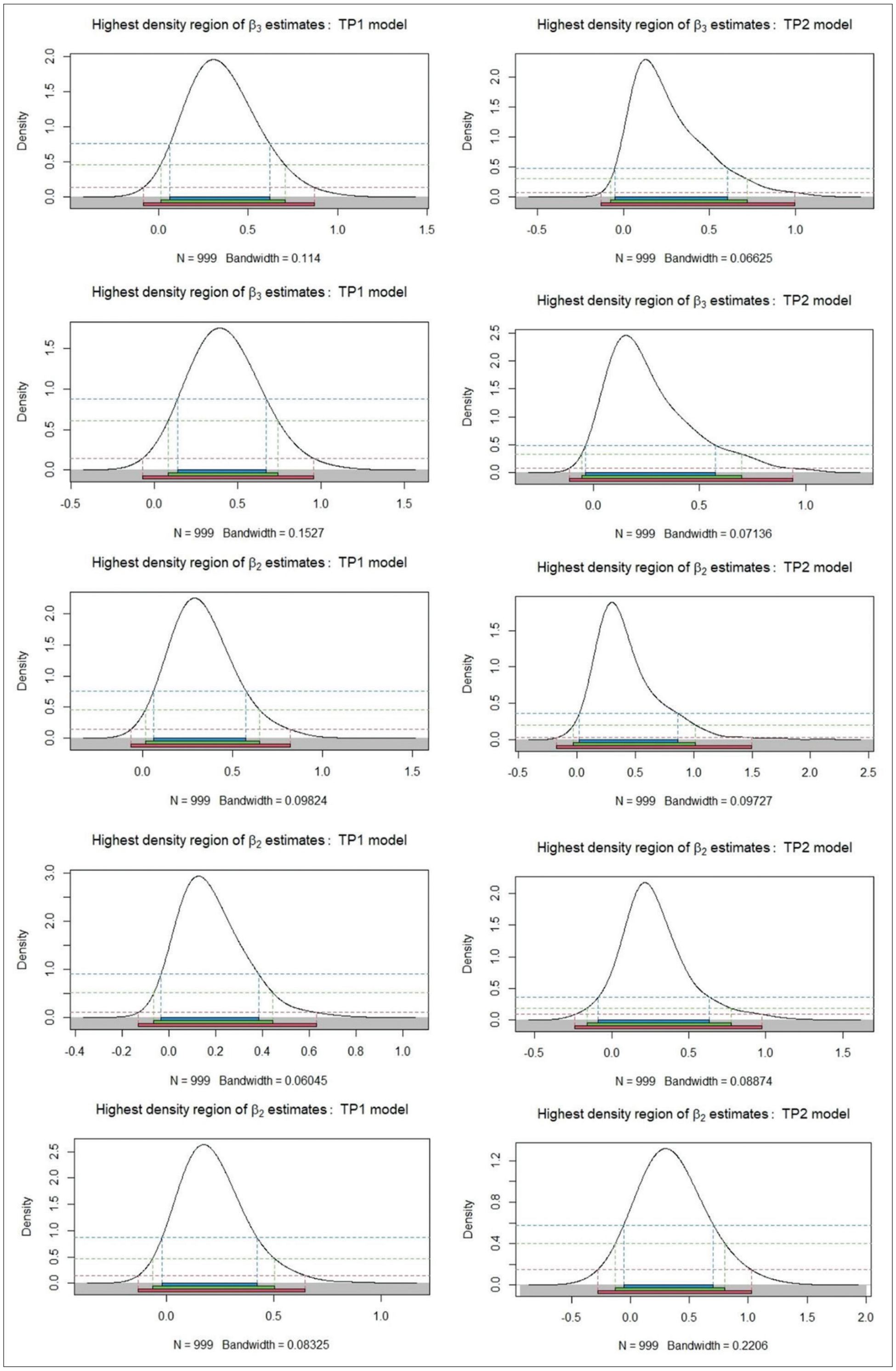
To further explain our findings, we refer to the previous studies that found similar results. El-Karimi (2022) believed that the non-causality result was due to the existence of a certain unmet threshold beyond which RE consumption will stimulate economic growth. El-Elkarimi and El-Ghini (2021) also stated that their results could be explained by the inadequate exploitation of the RE industry in Morocco. Both authors agreed on the importance of enhancing the renewable energy sector taking into account the remarkable potential that Morocco has.

Our results showed no causality in the 1997-2021 period. This period is characterized by the evolution of the RE network in multiple regions of the country, more particularly since 2009 with the enactment of the 13-09 Law that insists on the reinforcement of this important asset. Nevertheless, the results show that these

Table 4: Results of the MEB method for a_3 estimates, models 7-12

Model 7-12		1971–2021	1971-1996	1997-2021
7	$CI_{99\%}$	(0.02256, 0.5707)	(0.01972, 0.8850)	(−0.075377, 0.8657)
	$CI_{95\%}$	(0.06866, 0.5117)	(0.11602, 0.7110)	(−0.007221, 0.7281)
	$CI_{90\%}$	(0.08944, 0.4851)	(0.15761, 0.6501)	(0.031670, 0.6442)
8	$CI_{99\%}$	(−0.07021, 0.5579)	(−0.08437, 0.8690)	(−0.12983, 0.9955)
	$CI_{95\%}$	(−0.01571, 0.4630)	(0.01057, 0.7056)	(−0.07378, 0.7187)
	$CI_{90\%}$	(0.01705, 0.4070)	(0.06252, 0.6208)	(−0.05054, 0.6047)
9	$CI_{99\%}$	(−0.041414, 0.5858)	(−0.07048, 0.9566)	(−0.11520, 0.9389)
	$CI_{95\%}$	(0.005347, 0.4764)	(0.08415, 0.7412)	(−0.05625, 0.6970)
	$CI_{90\%}$	(0.032012, 0.4196)	(0.13915, 0.6732)	(−0.03723, 0.5745)
10	$CI_{99\%}$	(−0.098015, 0.7086)	(−0.06739, 0.8233)	(−0.17130, 1.4948)
	$CI_{95\%}$	(−0.002874, 0.5503)	(0.01509, 0.6489)	(−0.02689, 1.0163)
	$CI_{90\%}$	(0.051032, 0.4747)	(0.06034, 0.5747)	(0.02259, 0.8681)
11	$CI_{99\%}$	(−0.095263, 0.5622)	(−0.12958, 0.6312)	(−0.23838, 0.9762)
	$CI_{95\%}$	(−0.023198, 0.4018)	(−0.06278, 0.4452)	(−0.16200, 0.7728)
	$CI_{90\%}$	(0.009832, 0.3409)	(−0.03223, 0.3850)	(−0.08734, 0.6334)
12	$CI_{99\%}$	(−0.068335, 0.6261)	(−0.13018, 0.6446)	(−0.2801, 1.0265)
	$CI_{95\%}$	(−0.008597, 0.4649)	(−0.06453, 0.5025)	(−0.1277, 0.7997)
	$CI_{90\%}$	(0.021774, 0.4138)	(−0.02019, 0.4224)	(−0.0576, 0.7041)

Figure 2: HDR confidence intervals' graphs[7] for models 8 to 12 respectively, on 3 confidence levels (90%, 95% and 99%) for TP1 and TP2[8]



efforts are not yet enough to act as catalyst for economic growth, which is why it is crucial to further strengthen this sector. The absence of causality could also be due to the evolution of other sectors such as the services sector and tourism, which recorded a significant growth since 1990s, and represents up to 50% of the GDP (Statista Research Department, 2022).

7. HDR graphs for models 1 to 7 for all three time periods are available upon request.
8. β_2 & β_2 representing α_2 & α_3 respectively in our models.

6. CONCLUSION

During the last few years, Morocco has engaged in several strategic decisions and policies that allowed it to record a significant evolution. It has become the sixth largest African economy by GDP (Purchasing Power Parity, PPP) according to the IMF, and the 61st worldwide (IMF, 2023). Through this paper, we analyse the relationship between energy use and economic growth in Morocco using two methods, the Wald test and the Maximum Entropy Bootstrap (meboot) approach, on 12 model equations over the 1971-2021 period. As we have mentioned earlier, the meboot method represents multiple advantages, such as the elimination of the obligation of transforming the data, and its consistency in small samples. Another benefit would be that the meboot has not yet been conducted in the case of Morocco, and this represents our research gap.

Our study revealed interesting results. The first six models, which are the linear regression equations have shown the same result of bidirectional causality following both methods, and on all confidence levels, over all three time frames. These results uphold the feedback hypothesis, as found by Mouhtadi and Kamdem (2019), thus implying the interdependent relationship between the two variables, which means that investing in the energy sector would be beneficial for the advancement of the economy; the other way around holds as well. However, the dynamic models, which are represented in equations 7 through 12, show different findings, which differ from one time-period to the other. For example, model 7 shows causality from GDP to energy use in the whole time-period and in TP1, however, it shows no causality in the TP2 (1997-2021). Models 8 and 9 also demonstrate no causality over the 1997-2021 period. On the other hand, models 11 and 12 illustrate no causality between GDP and energy use over all time-periods, except once on the 90% confidence level over the whole time-period. Overall, the neutrality hypothesis is strongly supported through models 7-12, and more particularly over the period TP2, which comply with the findings of El-Elkarimi and El-Ghini (2021). However, they collide with other results that were found in other studies but used different methods, as mentioned in the literature review; most of which are methods that require data transformation in case of non-stationarity, among others, as is the case for Soufiane et al. (2021). in the Moroccan case, and Cherni and Abdelbaki (2017) for Tunisia.

Given the reliability of this method, we suggest that further analysis in the energy use-GDP nexus is conducted using the MEB. Considering the addition of more relevant variables such as urbanization, energy consumption by sector, or integrating more countries with similar characteristics to serve as a comparative tool, which would enable policymakers to identify shortcomings and key strengths for their countries, and decide the most efficient course of action to improve the economic situation.

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