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The Relationship between Economic Growth and Energy Consumption Disaggregated by Sector: The Case of Morocco

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ABSTRACT

The type of relationship that can link energy with economic growth plays a major role in determining the macroeconomic policy of a country. Therefore, several studies have been carried out to derive econometric models to link energy consumption with gross domestic product (GDP). However, in these studies the energy consumption has been used in its global term, while this consumption includes all the economic sectors that use energy (residential, industry, transport, agriculture). Therefore, the objective of this work is to examine this relationship between the gross domestic product (GDP) and energy consumption but disaggregated by sector (residential, transport and industrial). And to validate our model we have taken the case of Morocco during the period 1997-2019, in order to draw the impact of each sector on economic growth. In order to test this causality, a Vector Error Correction Model (VECM) is applied instead of a Vector Autoregressive Model (VAR), using the Johansen cointegration technique. The results obtained showed that in the long run energy consumption by the transportation and residential sectors has a positive impact on GDP, while that of households has a negative impact.

Keywords: Energy Consumption, Economic Growth, Sector, Vector Error Correction Model, Cointegration, Johansen Causality
JEL Classifications: Q43, O40, Q40

1. INTRODUCTION

Energy is part of the economic development of each country, as it is a key source of economic growth, since many production and consumption activities require the use of energy as a basic element, which stimulates the efficiency of almost all sectors of the economy. Therefore, this relationship between economic growth or GDP and energy consumption has become an issue that attracts the attention of researchers around the world, who question the direction of causality between energy consumption and economic growth. Moreover, the nature of this causal relationship is of great importance for the definition and effective implementation of economic and energy policies of a country (Ozturk, 2010).

The empirical results of some of these researchers' works are very different and even contradictory, as they sometimes state that the growth of energy consumption directly causes the growth of GDP, or the opposite, thus a unidirectional causal relationship, sometimes bidirectional and in some cases a total absence of causality.

However, it is necessary to specify that the majority of these works have only approached the relationship between GDP and energy consumption in its total term, this seems to us not sufficient to study this relationship well, because the consumption includes all the economic sectors that use energy (residential, industry, transport, agriculture).

Therefore, the main purpose of this study is to determine and explore the interrelationships that may exist between economic growth (GDP) and energy consumption disaggregated by sector (residential, transportation and industrial). Most t of the work done by other researcher only concerns energy consumption in a general sense, the thing that was found in a previous study that we carried out "a state of the art" of the realized works (Tatou and Youssfi, 2022). And this does not seem to be sufficient to properly study this relationship, because consumption includes all the economic sectors that use energy (residential, industry, transport, agriculture.). In addition, among these sectors there are those that can be seen as productive sectors because their consumption contributes most to the formation of GDP, so this energy consumption can have a positive impact on economic growth. As well as other sectors considered as non-productive sectors since their consumption has a negative impact on growth. Our study then tries to study the impact of each of these sectors on the GDP.

However, this kind of reflection is very important according to the current situation of countries, where energy plays the role of an essential lever that ensures the attractiveness and competitiveness of a country's economy, and that pulls it upwards. Therefore, it is suggested that these sectors can be seen as key drivers of economic growth, but this assumption is only on the theoretical level. So based on this idea we will try to conduct this study with the aim of confirming or denying this assumption.

In order to evaluate our general model, we have taken the case of Morocco, using as variables the GDP and the energy consumption by each of the three energy sectors (residential, transport and industrial) between 1997 and 2019, where a Vector Error Correction Model (VECM) is applied instead of a Vector Autoregressive Model (VAR), using Johansen's co-integration technique.

2. PREVIOUS WORK

Kraft et al. (1978) did a seminal paper that was among the first works that looked at the relationship between economic growth and energy consumption. They showed the existence of a unidirectional causality between GNP growth and energy consumption in the US between 1947 and 1974. However, this paper was criticized by Akarca and Long in 1980, who noted that the choice of the period was wrong, because it was unstable since it included the first oil shock. Thus, this causal link between energy consumption and economic growth has given rise to several studies using different techniques and different country samples.

In addition, several empirical studies have been developed in other countries that have used other methods of econometric analysis (Wolde-Rufael, 2006; Chang and Wong, 2001; Stern, 2000; Asafu, 2000). Applying new techniques, a number of econometric studies have shown the existence of unidirectional or bidirectional causality, or so much as an absence of causality, but they have failed to provide an overall trend of countries at different levels of development or economic structures.

The hypothesis of no causality or else neutrality has been supported as an example by the findings of Kpemoua (2016), Yildirım et al. (2014), and among the studies that support the hypothesis of bidirectional causality are those of Ozturk (2017), Mouhtadi and Kamdem (2019), Apergis and Payne (2012), Shahbaz et al. (2012), Fuinhas and Marques (2012), Mohammadi and Parvaresh (2014), Bloch et al. (2015). While the results for example of Harkat (2020), Saqib (2021) and Touitou (2021) support the hypothesis of unidirectional causality.

3. ENERGY CONSUMING SECTORS: PRODUCTIVE AND NON-PRODUCTIVE SECTORS

In all these works that we have seen in the previous part, we find that they study the energy consumption at the global level by all the sectors, without making a distinction between the different energy consuming sectors (Industrial, Residential, Transport.)...

Furthermore, it can be assumed that among these sectors there are those that have a positive impact on economic growth, as well as others that have a negative effect. For example, the industrial sector of an economy is among the largest consumers of energy, in addition it contributes the most to the formation of GDP, so this energy consumption can be assumed to have a positive impact on GDP.

There are other sectors that are not productive sectors but consume a large part of this energy, such as the residential sector, where households need energy to perform their daily activities.

3.1. Productive Sectors

The productive sectors, are the sectors that consume energy but producing other productive elements in the economy, such as industry, business, transportation.

- The industrial use of energy is what allows industries to draw resources to produce goods. Thus, the sector that consumes the most energy is industry, which accounts for nearly a third of this global consumption
- The energy consumed in the transportation sector represents the final energy used by all units in the transportation sector. Transport can use energy in various ways, mainly to run cars, planes, ships., as well as to produce these vehicles, and build roads, airports
- Energy consumption in the commercial sector includes institutional consumption, which represents the energy that allows companies, buildings., to serve the public
- The agricultural sector is also among the energy consumers, because the agricultural production relies heavily on energy consumption for crop irrigation, operation of machinery and generation of fertilizers. This consumption is divided into direct energy (oil products, gas, electricity) and indirect energy (energy used to produce, manufacture and transport products, buildings and equipment).

3.2. Non-productive Sectors

The non-productive sector can be considered any sector that consumes energy but for purposes that do not have a direct impact on the profile of economic growth, such as the residential sector, which uses energy that requires expenses that are expensive for the country, without producing something in return that will make up for this loss for the economy. This is a sector that looks like the energy consumption of households related to their residence, excluding institutional housing included in the commercial sector. Typical energy uses in this sector include: lighting, cooking, refrigeration, heating, ventilation and the use of various other appliances. These energy-intensive uses are highly dependent on the structure of the dwelling, the location, and the equipment used.

As can be seen in Figure 1, energy consumption by the residential sector is increasing over time at the global level, so this increase can have a direct effect on GDP, and the objective of our work is to determine whether this effect is positive or negative.

3.3. Energy Consumption by the Two Types of Sectors in Morocco

From Figure 2, it can be seen that transportation accounts for a large share of total energy consumption, 38% over the entire period. This is followed by the residential and industrial sectors, which account for 26% and 21% respectively. Therefore, these three sectors alone account for 85% of final energy consumption. This is the reason why in the following part of our work we will study the relationship between GDP and energy consumption by each of these three sectors.

4. VECM MODELING

4.1. Introduction to Some Existing Models

In order to model the influence of energy consumption on GDP, several econometric models have been developed, among which we quote for example:

$$LnGDPt=\beta_0+\beta_1\ LnENt+\beta_2\ LnCO2t+\beta_3\ LnINVt+\varepsilon_t \quad (1)$$

Where LnGDP is the logarithm of GDP per capita, LnEN is the logarithm of energy consumption per capita, LnCO2 is the logarithm of CO_2 emissions per capita, and LnINV is the logarithm of the investment rate (Mouhtadi and Kamdem, 2019).

$$Y_t= f\,(K_t, L_t, E_t) \quad (2)$$

Where Y is aggregate output or real GDP, K is the capital stock, L is the level of employment and E is total energy consumption (Wolde-Rufael, 2009).

$$Y_t= a_{0t} +b\_1\ X_t+b_2\ Z_t +\varepsilon_t \quad (3)$$

Where, Y is the gross domestic product of a country at a given date t (GDP), X is the consumption of electricity, Z is the consumption of oil products and ε is an error term (Belmokaddem et al., 2014).

As we noted in the first part, the works on this question vary in the results obtained as well as in the data and methods used, introducing different variables such as CO_2 emission, investment rate. But the major drawback of this work is that it addresses this relationship between growth and aggregate (total) energy consumption.

To remedy this problem, we will try to break down energy consumption by sector, namely: the industrial sector, the transport sector and the residential sector.

4.2. Presentation of our Model

In this section we will attempt to define the causal relationships between economic growth and energy consumption disaggregated by sector (industrial, transportation and residential). For as already mentioned, there are productive and non-productive sectors, hence the need to study the sectors separately in order to know the impact of each independently on GDP.

In line with the empirical energy literature, we will use energy consumption and GDP to specify a long-run relationship between the variables that will be mentioned next. The long-run relationship can be expressed as the following econometric model:

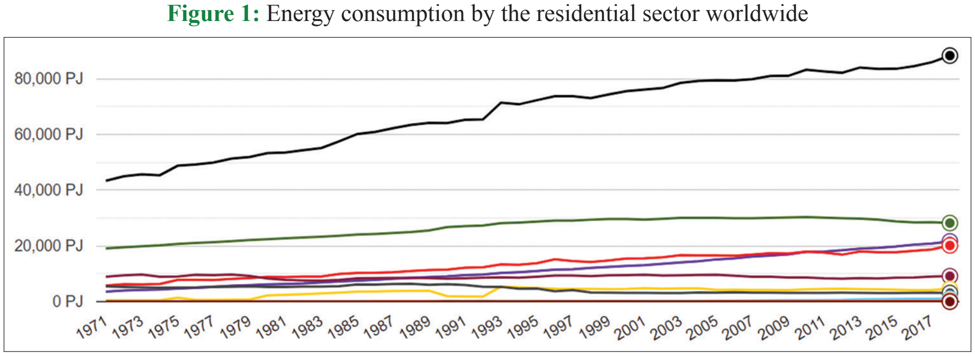
$$GDP_t = f\,(IND_t, MNG_t, TRSP_t)$$

Where GDP_t represents gross domestic product, IND is energy consumption by the industrial sector, MNG is energy consumption by households, TRSP is energy consumption by the transportation sector, and $\mathcal{E}_t$ represents the error correction term.

4.3. Data and Variables

Our empirical study focuses on Morocco, and the main variables of the analysis are GDP and energy consumption by each of the three energy sectors (residential, transportation and industrial) over the period 1997 and 2019. GDP is expressed in million dollars (constant US$), and energy consumption by the three sectors in TJ (terajoules) (Figure 1 gives a graphical representation of the different variables).

Figure 1: Energy consumption by the residential sector worldwide



Source: IEA (2018), "World energy balances," *IEA World Energy Statistics and Balances* (database)

The data are extracted from several sources such as: The World Bank, the Ministry of Energy, Mines, Water and Environment, and the Office des Changes, the United Nations Energy Balances. All the variables have been transformed into logarithm, this step is important to verify the partial characteristics of the short and long term elasticities of the model.

4.3.1. Representation of the variables used

- GDP: Real gross domestic product
- MNG: The energy consumption by households (represents the residential sector)
- TRSP: The energy consumption by the transport sector
- IND: The Energy consumption by the industrial sector.

The graphical analysis of the different series used in this study allows us to detect the various components of a time series. From these graphical representations, as illustrated in Figure 3 it is possible to detect an upward trend in the energy consumption of the three sectors over the observed period. This seems to indicate that there is an equilibrium or co-integration relationship between the series.

4.4. Methodology

In order to test this causal relationship, we will first test the stationarity of the series using the Augmented Dickey-Fuller method (ADF), and then we will use the Johansen cointegration test. Finally, we will examine the long-term relationships between the variables based on the vector error correction model (VECM).

4.4.1. Correlation tests

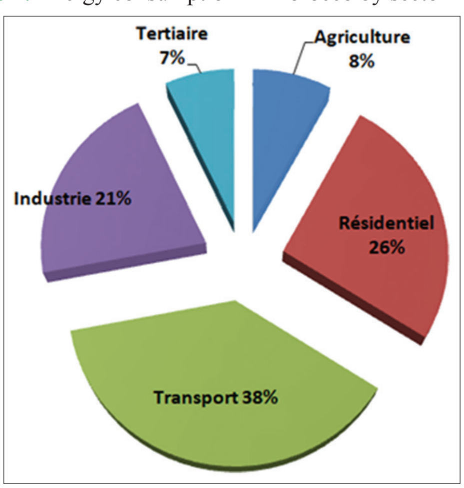
Before performing the stationarity tests, it is necessary to evaluate the existing correlations between the different variables of this study, as shown in Table 1.

A reading of the correlation matrix reveals that the energy series are strongly correlated with the GDP variable.

4.4.2. Unit root test (ADF)

The first step in our analysis is to check the stationarity of the series studied and their orders of integration, which is the objective of Table 2. This step is fundamental because the use of non-stationary series in a regression can lead to inefficient coefficients, non-optimal predictions and invalid significance tests.

Figure 2: Energy consumption in Morocco by sector in 2020



Source: AMEE: Agence marocain pour l'efficacité énergétique

The values of the t-statistics compared to the critical values (at 1%, 5% and 10%), confirm the presence of unit root in the series, so they are all non-stationary. In addition, the variables can be made stationary by differentiation or by filtering.

The results of the Augmented Dickey Fuller test (ADF) represented in Table 3, indicate that the four variables are stationary in first difference, then they are integrated of order 1 or I(1).

4.4.3. Cointegration analysis

After defining the order of integration of the variables, the next step is to check for the existence of cointegration between these series. The cointegration tests are considered as a continuation of the stationarity tests, they allow to verify that the integrated variables of the same order have a strong possibility of having a cointegrating relationship. Therefore, to test the cointegration

Table 1: The correlation matrix of the variables

t-statistique	GDP	Households	Industry	Transport
GDP	1.00	-	-	-
Households	0.57	1.00	-	-
Industry	0.82	0.39	1.00	-
Transport	0.94	0.69	0.67	1.00

GDP: Gross domestic product

Table 2: Augmented Dickey-Fuller unit root test

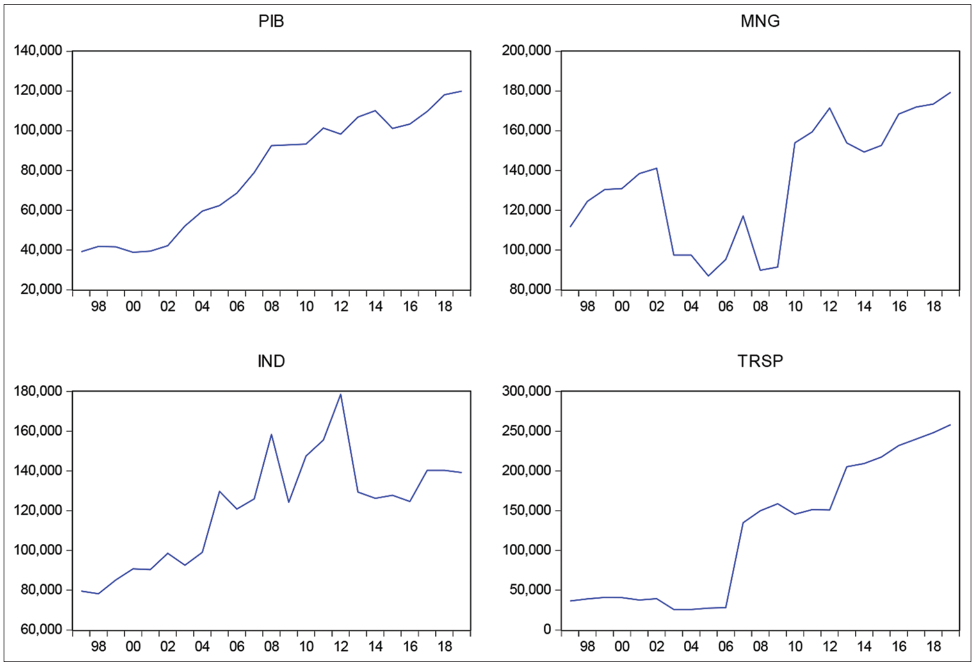
Variables	Test de Dickey Fuller Augmenté (ADF)		
	1[a]	2[b]	3[c]
En niveau			
GDP	1.714	1.399	2.849
MNG	1.520076	1.356729	0.454248
IND	1.589643	2 .07022	0.266017
TRSP	2.490517	1.143113	1.418596
En première Différence			
ΔGDP	−0.28178	2.220319	−2.87292
ΔMNG	0.649781	0.597080	−4.548628
ΔIND	−0.79740	1.017237	−6.461910
ΔTRSP	0.626695	1.676500	−3.864382

[a]Model with constant and trend, [b]Model with constant only, [c]Model without constant and trend. ADF: Augmented Dickey-Fuller, GDP: Gross domestic product

Table 3: Johansen cointegration test

Rank test (trace)			
Number of cointegration	Eigen value	Trace statistic	5% critical value
None*	0.9802	126.579	47.856
At most 1*	0.7186	47.962	29.797
At most 2*	0.5863	22.595	15.494
At most 3*	0.2189	4.942	3.841
Rank test (maximum Eigen value)			
Number of cointegration	**Eigen value**	**Max-Eigen statistic**	**5% critical value**
None*	0.9802	78.617	27.584
Atmost 1*	0.7186	25.366	21.131
Atmost 2*	0.5863	17.653	14.264
Atmost 3*	0.2189	4.943	3.841

Figure 3: Graphical overview of the variables



between these variables and determine the number of relationships that may exist, we will apply the Johansen test.

Before performing the cointegration test, it is necessary to first determine the number of lags. In our case, the optimal number of lags chosen to minimize the choice criteria is P = 2.

According to the results of the Johansen test, we can say that the analysis of the trace and the maximum eigenvalue allows us to reject the null hypothesis of the absence of cointegration at the threshold of 5%, and on the other hand we accept the hypothesis that shows the existence of four cointegrating relationships between the variables.

4.5. Estimation of the VECM Model

Since the series are cointegrated, a VECM is established to study the short and long term causality. There are two steps to read a VECM model, in the first one we analyze the long term part which is used to study the significance of the variables in LT, while in the second part we determine the significant variables but in ST.

In the long term part all the values are significant. Then the estimation of the long term cointegration relation is given by the formula above:

$$GDP_t = 0.377IND_t + 0.346TRSP_t - 0.375\ MNG_t + 40281{,}22$$

4.5.1. Autocorrelation test of residuals

The test probabilities for autocorrelation indicate values >0.05. Therefore, the test is not significant, so we reject the null hypothesis which indicates an autocorrelation of the residuals.

4.5.2. Test of normality of residuals

The probability associated with the Jarque-bera statistic is >0.05, so we do not reject the null hypothesis. Hence, the residuals follow a normal distribution.

4.5.3. Heteroscedasticity test of the residuals: White's test

The probability associated with the test statistic is 0.374 is >0.05, so we can say that there is no heteroscedasticity of errors.

4.6. Analysis of Results

In the short run, we find that GDP depends only on the constant, while for the other variables their coefficients are not significant and therefore do not influence our endogenous variable in the short run.

In the long run, we find that GDP depends positively on energy consumption for the transportation sector with a weight of 0.346 and for the industrial sector with a weight of 0.377, and negatively for the household sector with a weight of 0.375.

The negative value of the coefficient associated with the household sector can be explained by the heavy energy bill that the country must support for this sector without any return.

For a better management of energy consumption, the only thing that can be said is that it is necessary to reduce energy consumption in the household sector to reduce its negative effect on GDP. On the contrary, as soon as the household consumption exceeds 45% of the global consumption, the latter (the global consumption) will have a negative effect on the GDP.

In the same way it is necessary to develop both the industrial and the transport sector in such a way that they use more energy and so we will have a positive effect on the GDP.

5. CONCLUSION

Different tests were conducted to analyze the relationship between energy consumption by the three sectors and economic growth (GDP) in Morocco. Johansen's approach showed the existence of a cointegration relationship which made the realization of a vector error correction model (VCEM) possible. The results of this model based on Johansen's approach indicate that in the long run energy consumption by the transport sector has a positive impact on the gross domestic product, but that of households has a negative impact. While in the short run, GDP depends positively on energy consumption by the industrial sector, with a negative but insignificant error term, indicating the absence of a restoring force towards equilibrium.

This result leads us to question the energy consumption situation in Morocco, and suggests that there is excessive energy consumption in the unproductive activities of the economy. Such as the consumption of households which has a negative impact on the economic growth in the long term, because this consumption is dedicated to purposes (Housing, heating, lighting, personal transport) which do not enter the economic activity thus do not have a direct impact on the GDP. As well as this sector consumes energy that requires means and expenses that are expensive for the country, especially if it relies on imported energy resources that are very expensive, without producing in return something that will make up for this loss for the economy.

Therefore, improving the energy efficiency of households can have positive impacts on the whole economy, so the state must implement policies that aim to raise awareness of households to reduce their consumption which is very expensive for the state.

However, industry and transport have a positive impact on economic growth. For the good development of economic activities can have a great obstacle which is the distance and the spatial constraints, but the transport allows to overcome this problem. In addition, in large cities as well as small villages, the economy needs transportation to participate in the global market, and to ensure national and international trade.

As in Morocco, industry in all areas supports thousands of jobs and contributes millions of dollars to the GDP.

Therefore, an important policy implication of this analysis is that energy can be seen as an element that limits GDP growth in Morocco. Hence the need to implement laws that enhance energy efficiency in the use of energy sources, fight against waste, reduce the burden of energy costs on the national economy and promote sustainable development.

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