Nexus between Energy Consumption, Economic Development, and CO2 Emissions: Empirical Evidence from Morocco

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Abstract:

Existing literature that assesses the nexus between economic development, primary energy consumption, and CO_2 emissions has been a point of interest for many scholars. Yet, there is no such existing literature that targets assessing such relationship for the case of Morocco. The following contribution determines the long run relationship between these variables using an autoregressive distributive lag model (ARDL) bound test that is developed by Pesaran et al. (2001). Findings indicate that there is a significant co-integration between the variables of interest, meaning that the long run relationship between them exists. Findings also show that energy consumption has direct positive effect on economic growth but it may have larger negative effect on economic growth indirectly through higher carbon dioxide emissions.

Key words: GDP, Energy consumption, CO_2 emissions, Long run relationship, ARDL Bound test, Co-integration, Morocco

JEL: O13, P28, P48, Q43

Introduction:

Energy sources are consumed by many end-users that are mainly: electricity sector, industrial sector, transportation sector, and household sector. Primary energy consumption plays an important role in economic growth and economic development in many economies. Yet, this paper focuses its analyses on Morocco. The contribution of Harkat (2020) assesses the energy-growth nexus, and empirical findings indicate that in the case of Morocco, a unidirectional causality between energy consumption and GDP exists and is initiated from the latter variable. This means that Morocco supports the conservation hypothesis, which indicates that policies related to the reduction of primary energy consumption will negatively impact economic growth (Harkat, 2020)

Another important factor in the energy-growth nexus relates to assessing the relationship between the economic development and the CO2 emissions resulted from the increase or decrease of primary energy consumption in many economies. This problematic was not addressed for the Moroccan economy.

In the case of Morocco, descriptive statistics in 2016 indicate that the CO2 emissions resulted from primary energy consumption come mainly from the electricity sector with a percentage of 39%, followed by the transportation sector, industrial sector, residential and commercial buildings sector, and finally from the agriculture sector, with the corresponding rates of 31%, 13%, 12%, and 5%, respectively. In addition to that, descriptive statistics indicate that CO2 emissions have increased by over 181% from 1990 to 2006, and are still increasing drastically (IEA, 2019).

The Moroccan government was subject to participating in COP 22 as well as the ones that followed, which led to making action plans for different reforms that consist of transitioning to clean energy (mainly in the power sector). Still, CO2 emissions are noticed to be increasing between 2006 and 2016, with the same coefficient (if not a higher one) as the one for the period between 1990 and 2006 (IEA, 2019).

For this, the current paper aims at assessing the long-run relationship between economic development that is represented by GDP, primary energy consumption, and CO2 emissions. This is to support the existing action plans taken by the Moroccan government, and provide incentives to policy makers about which type of energy sources and energy-related infrastructures to be taken into consideration for different types of consumers.

The rest of the paper is organized as follows. The next section presents a brief literature review in the field of the relationship amongst economic growth or development, primary energy consumption, and CO2 emissions, followed by the data and method section. After this latter, empirical results will be presented while the last section concludes the paper.

Literature review:

Many scholars and researchers have been interested on assessing the relationship between energy consumption, economic development, and CO2 or gases emissions to address environmental issues, policy analysis, or sustainable growth (Sek, 2017). But the existing literature divides this field into three main groups (e.g. Amadeh and Kafi, 2015; Bozkurt and Akan, 2014; Acaravci and Ozturk, 2010).

The first group of researchers target analyzing the relationship between economic growth or economic development, and environmental pollution by testing the Environmental Kuznets Curve (EKC) hypothesis for different economies (e.g. Franklin and Ruth, 2012; and Karakas, 2014; and Charfeddine and Ben Khediri, 2015). Concerning the second group, they focus on analyzing the relationship between economic growth and energy consumption. Examples of these contributions were cited in the contribution of Harkat (2020). Finally, and concerning the last group, they investigate the combination of the first and second group.

Most of the contributions that assess the relationship between the three variables of interest report the existence of a co-integrating relationship in their model (Sek, 2017). For Bloch et al. (2012) and Jafari et al. (2012), analyses indicate that both GDP and energy consumption contribute to a positive effect on CO2 emissions. But for Omri (2013), empirical findings indicate that there is a positive impact from GDP on CO2 emissions while there is a negative impact from financial development and capital on CO2 emissions in MENA regions.

Concerning Alam et al. (2014), findings show that both financial development and energy consumption cause CO2 emissions to increase in Malaysia. But for Sek (2017), analyses used different techniques that account for linear co-integration and threshold co-integration – Enders-Siklos (ES) test, and results indicate that there is a long run relationship between GDP, energy consumption, and CO2 emissions. This latter variable impacts the GDP negatively.

Other contributions analyzed group of countries by analyzing them one by one using the ARDL bounds testing approach, and results were different for each group of countries (e.g.

Acaravci and Ozturk, 2010). These different results are mainly due to data, estimation approaches, omitted variables bias, and country characteristics (Ozturk, 2010; and Yang and Zhao, 2014).

The following section will present the method used to assess the long run relationship between GDP, primary energy consumption, and CO2 emissions.

Data and methods:

The current paper assesses the relationship between the gross domestic product – GDP (USD using purchasing power parity rates), primary energy consumption – EC (Quad Btu), and carbon dioxide emissions – CO2E (MMtons) in Morocco. For the first variable, GDP, it is used as a proxy measure for economic development, while the last variable, CO2E, it is used as a proxy measure for environmental degradation. Concerning the GDP variable, it was extracted from the World Bank, while both EC and CO2E, they were extracted from the Energy Information Administration (EIA). These variables cover the period between 1990 and 2016, and were all transformed to their logarithm form.

This paper analyzes the relationship between GDP, EC, and CO2E on the long run using a co-integration test. For this, the investigation was divided into three main parts, where the first step accounts for conducting a unit-root test using the Augmented Dickey Fuller (ADF) test (Kim & Choi, 2017). It is observed that the time series are non-stationary, which makes them characterized as having different means in different point in time, with a variance that increases with the sample size (Harris and Sollis, 2003). This highly likely leads to a spurious regression that makes the t-statistics values of the coefficients very significant. In addition to that, it makes the coefficient of determination close to zero, and makes the value of the Durbin Watson (DW) test very low. All of this might lead to increasing the frequency of Type I error (Granger and Newbold, 1974).

For this, this study uses the autoregressive distributive lag model (ARDL) bound test, which is an advanced approach to test for the existence of the long run relationship between the variables of interest (Pesaran et al., 2001). This method is used because GDP, EC, and CO2E have ambiguous order of integration (e.g. GDP I(1), EC I(0), CO2E I(0)), which is not acceptable in other approaches.

The ARDL representation of the long run relationship between the transformed logarithmic variables can be constructed such as:

$$\partial\log(GDP_t) = \lambda_0 + \lambda_1\Delta\log(EC_{t-1}) + \lambda_2\Delta\log(CO2E_{t-1}) + \lambda_3\partial\log(EC_{t-i}) + \lambda_4\partial\log(CO2E_{t-i}) + \varepsilon_t$$

In the above model, ∂ is the second difference, Δ is the first difference, λs are the long run and short run coefficients to be tested using the following set of hypotheses:

- H_0: $\lambda_0 = \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = 0$, that indicates the no co-integration;
- H_A: $\lambda_0 \neq \lambda_1 \neq \lambda_2 \neq \lambda_3 \neq \lambda_4 \neq 0$, that confirms the existence of a co-integration.

The next step is to calculate the F-statistic with its corresponding critical values (Narayan, 2005). If the F-statistics exceeds the upper bound, H_0 is rejected, and H_A is accepted. If the F-statistics falls within the bounds, it indicates that the test is inconclusive. But if the F-statistics falls below the lower critical value, it implies that there is no co-integration.

Results:

As it was discussed in the methods section, the first step is to determine the stationarity of the time series variables using the ADF test. Table 1 summarizes the ADF test results for the variables taking into account the intercept, the intercept and trend, or none of them. Findings indicate that for the log(GDP) variable, the data is not stationary at level and first difference, and only becomes stationary on the second difference. But for both log(EC) and log(CO2E), the data is not stationary at level, but becomes stationary at I(1). This confirms the selection of the ARDL method selection, since the time series variables have conflicting order of integration.

Table 1: ADF test results

	ADF statistics								
Variables	Levels			First differences			Second differences		
Includes	Intercept	Trend and intercept	None	Intercept	Trend and intercept	None	Intercept	Trend and intercept	None
Log(CO2E)	-0,14 (0,93)	-2,01 (0,57)	3,70 (0,99)	-4,41*** (0,00)	-4,30*** (0,01)	-3,15*** (0,00)	-7,24*** (0,00)	-4,32** (0,01)	-7,39*** (0,00)
Log(EC)	-0,43 (0,89)	-1,59 (0,77)	3,28 (0,99)	-4,56*** (0,00)	-4,44*** (0,01)	-2,67*** (0,01)	-0,51 (0,87)	-0,90 (0,93)	-0,59 (0,44)

Log(GDP)	-1,42 (0,55)	-1,31 (0,86)	1,19 (0,93)	-1,35 (0,59)	-0,70 (0,96)	-0,05 (0,65)	-12,95*** (0,00)	-3,49* (0,06)	-13,23*** (0,00)
Critical values									
LCO2E @ 1% level	-3,71	-4,36	-2,66	-3,72	-4,37	-2,66	-3,74	-4,47	-2,66
LCO2E @ 5% level	-2,98	-3,60	-1,95	-2,99	-3,60	-1,96	-2,99	-3,64	-1,96
LCO2E @ 10% level	-2,63	-3,23	-1,61	-2,63	-3,24	-1,61	-2,64	-3,26	-1,61
LEC @ 1% level	-3,72	-4,37	-2,66	-3,72	-4,37	-2,66	-3,86	-4,57	-2,70
LEC @ 5% level	-2,99	-3,60	-1,96	-2,99	-3,60	-1,96	-3,04	-3,69	-1,96
LEC @ 10% level	-2,63	-3,24	-1,61	-2,63	-3,24	-1,61	-2,66	-3,29	-1,61
LGDP @ 1% level	-3,79	-4,47	-2,67	-3,77	-4,47	-2,67	-3,75	-4,47	-2,67
LGDP @ 5% level	-3,01	-3,64	-1,96	-3,00	-3,64	-1,96	-3,00	-3,64	-1,96
LGDP @ 10% level	-2,65	-3,26	-1,61	-2,64	-3,26	-1,61	-2,64	-3,26	-1,61

Concerning the ARDL bounds testing approach results, they are summarized in table 2. Empirical findings indicate that the F-statistics falls above the upper bound of the critical values under 1%, 5%, and 10% significance, which leads to concluding that there is an existing long run relationship between the GDP and the other dependent variables.

Table 2: ARDL Bound test for co-integration

Variables	**F-statistics**	**Co-integration**
F(LGDP/LEC, LCO2E)	9,59***	Cointegration
Critical value	Lower Bound	Upper Bound
1%	6,43	7,51
5%	4,34	5,42
10%	3,77	4,54

Notes: *** Statistical significance at 1% level; ** Statistical significance at 5% level; * Statistical significance at 10% level. The lag length k=1 was selected based on the Schwarz criterion (SC).

The selected ARDL model is summarized in Table 3. Findings indicate that all the coefficients are statistically significant under a 1% significance level, except for CO2E variable. This latter is significant under a 5% significance level. All of this leads to concluding the significance of the following model:

$$Log(GDP) = 0.02 + 0.56Log(EC) - 0.20Log(CO2E)$$

The above model indicates that the long run relationship between GDP and EC is positive, as it has resulted in a positive coefficient, while the long run relationship between GDP and CO2E is negative, as it has resulted in a negative coefficient.

Table 3: ARDL selected model (Log(GDP) is the independent variable)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0,02	0,00	13,40	0,00
Log(EC)	0,56	0,09	6,32	0,00
Log(CO2E)	-0,20	0,08	-2,38	0,03

Conclusion and discussion:

The current contribution examines the long run relationship between economic development, primary energy consumption, and carbon dioxide emissions using the ARDL bound testing approach of co-integration in Morocco over the period between 1990 and 2016. The bounds F-test for co-integration test yields evidence of the existence of a long run relationship between the variables of interest.

The contribution of Harkat (2020) aligns with this contribution's findings, as it confirms the existence of this relationship using a unidirectional causality between GDP and EC. This latter contribution indicates that any increase in GDP causes an increase in energy consumption. However, and while findings show that energy consumption has a direct positive effect on the Moroccan GDP, results also indicate that energy consumption can have larger negative effect on GDP indirectly through higher carbon dioxide emissions.

The Moroccan national energy strategy has a roadmap to transition to low carbon energy systems, to reach a 52% of installed power capacity from renewable sources, to increase energy efficiency, as well as many objectives (IEA, 2019). Yet, and in order to achieve these objectives, the Moroccan government needs to take further steps and some necessary measures that will accompany this strategy. These steps and measures can be:

- Drafting and enforcing laws that will have as a purpose monitoring the quality of the primary energy consumed, and auditing the treatment process of its emissions. E.g. setting higher tax rates on coal with the lowest quality.
- Introducing new natural gas infrastructures, as natural gas has lower CO2 emissions compared to other types of primary energy.
- Replacing old technologies that had depreciated with more efficient one for industrials and power sectors.

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