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Carbon emissions - income relationships with structural breaks: the case of the Middle East and North African countries

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Abstract

This article revisits the CO\textsubscript{2} emissions-GDP causal relationships in the Middle East and North Africa (MENA) countries by employing Rossi (2005) instability-robust causality test. We show evidence of significant causality relationships for all considered countries within the instability context, whereas the standard Granger causality test fails to detect causal links in any direction, except for Egypt, Iran and Morocco. An important policy implication resulting from this robust analysis is that the income is not affected by the cuts in the CO\textsubscript{2} emissions for only two MENA countries, the UAE and Syria.

Keyword: income, CO\textsubscript{2} emissions, robust causality.

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1. Introduction

Global climate change particularly due to CO\textsubscript{2} emissions together with its obviously serious consequences on environment, human health and economic activity has recently become a critical issue to all global, regional and national policy decisions. According to the World Meteorological Organization (WMO) greenhouse gas bulletin of November 2012, carbon dioxide (CO\textsubscript{2}) is the single most important anthropogenic greenhouse gas in the atmosphere. Its relative contribution to the global radiative forcing caused by all long-lived greenhouse gases since 1750 is estimated at about 64\%. More importantly, it is responsible for 81\% of the increase in radiative forcing over the past five years. While the globally averaged CO\textsubscript{2} mole fraction attained a new record of 390.9±0.1 ppm in 2011 or 140\% increase compared to the level before the industrial revolution, the WMO Global Atmosphere Watch points out that half of this CO\textsubscript{2} emission remains in the atmosphere even though the absorption capacity of the natural environment (ocean and terrestrial sinks) has steadily increased. The continued increasing trend of the global carbon emissions in 2011 and 2012 makes dangerous climate change more certain. Another important issue over the recent years is that the inequality of carbon emissions between rich and poor countries has not much diminished (Padilla and Serrano, 2006)\footnote{Padilla and Serrano (2006) analyze the relationship between CO\textsubscript{2} emission inequalities and income inequalities across countries for the period 1971–1999 by employing the common tools used in income distribution analysis. They also show that income inequality has significant power in explaining the inequality in CO\textsubscript{2} emissions across countries.}
The reduction of CO$_2$ emissions is however a challenging task as it has direct impacts on industrial production and economic growth. Indeed, if the energy-related carbon emissions can be reduced by cutting the amount of energy used, the economic growth potential may be severely compromised, especially for developing countries which do not have enough money to invest in clean energy and/or to develop energy-efficient technologies. Thus, a vast literature in energy and ecological economics have investigated the relationships among energy consumption, carbon emissions and economic growth, and the majority of previous studies conclude on the complexity of this issue. Ozturk (2010) reviews the recent literature on the energy use-growth nexus and shows that no consensus neither on the existence nor on the direction of causality between the two variables of interest can be reached. Some studies find evidence of unidirectional causality running from energy consumption to growth (e.g., Stern, 2000; Oh and Lee, 2004; Ho and Siu, 2007), but the others reveal the unidirectional causality from growth to energy consumption (e.g., Zamani, 2007; Ang, 2008; Zhang and Cheng, 2009) or even no causality between these variables (e.g., Payne, 2009). The bidirectional causality between energy consumption and growth is found in, for example, Glasure (2002) and Belloumi (2009), while mixed results are reported by, among others, Soytas and Sari (2003), Lee (2006), and Chiou-Wei et al. (2008), among others. Similar divergence of the results holds for the literature on CO$_2$ emissions-growth nexus (e.g., Halicioglu, 2010; Jayanthakumaran et al., 2012). Various environmental degradation indicators have
also been examined in relation with economic growth and energy use (e.g.,
Coondoo and Dinda, 2002; Liu, 2005; Jaunky, 2011), but the results do not
provide unanimous conclusions on the validity of the EKC (Environmental
Kuznets Curve) hypothesis.\footnote{The EKC hypothesis postulates that envi-
ronmental degradation and economic develop-
ment are linked by an inverted U-shaped relationship according to which at low-income
levels we might see a positive relation between national income and pollution (e.g., carbon
dioxide, sulfur dioxide, nitrogen oxide and water pollutants), and at high levels of income
a negative relation between the two variables.} We review this line of literature in more detail
in Section 2.

While past studies have permitted a good understanding of the dynamics
between carbon emissions and national income, most of them use linear and
nonlinear Granger causality tests which are not without drawbacks. This
methodology may effectively lead us to make misleading conclusions simply
because traditional Granger causality tests are not robust to potential struc-
tural instabilities contained in the underlying data (Rossi, 2005). To avoid
this problem, one can for example rely on the properties of nonstationary
series and make use of cointegration models that accommodate structural
breaks (e.g., Lee and Chang, 2005).

This article differs from the past literature in that it examines the causal
relationship between income and CO$_2$ emissions using the Granger-causality
regressions that explicitly take parameter instability into account. We are
particularly motivated by the apparent cyclical behavior of the considered
variables as well as by the structural change in the CO$_2$ variable, poten-
tially induced by sudden shifts in industrial structure and structural effects of reducing carbon emissions. Our empirical investigation is based on the instability-robust causality test of Rossi (2005) and focuses on a sample of twelve MENA countries. For instance, little is known about the CO₂ emissions-growth in MENA countries while the global warming has become an important global environmental challenge requiring the countries to reduce their carbon emissions. The investigation of the carbon emissions-growth nexus is all the more important that, like other developing countries, the ability of MENA countries as Kyoto Protocol signatories to reduce the global warming is quite complicated because they need to improve the standard of living for their inhabitants and this depends greatly on increased energy use per capita which usually has a high level of carbon emission intensity.

Using annual data of per capita GDP and carbon emissions, we show evidence of significant causality relationship between two variables for all considered countries in the presence of structural change, whereas no causality in any direction is detected by the standard Granger causality test, except for Egypt, Iran and Morocco. Overall, the results reveal a unidirectional causality running from GDP to CO₂ emissions for the UAE and Syria, running from CO₂ emissions to GDP for Algeria, Egypt, Iran Morocco, and Tunisia,

³Algeria, Bahrain, Egypt, Iran, Jordan, Lebanon, Morocco, Oman, Saudi Arabia, Syria, Tunisia, and United Arab Emirates (UAE)

⁴Some studies have examined the long-run link between CO₂ emissions and growth in the MENA region using cointegration and panel cointegration tests (Fodha and Zaghdoud, 2010; Al-Mulali, 2011; Arouri et al., 2012), but none of them considers directly the impact of instabilities on the causality between variables.
and a bidirectional causality for the remaining countries. These findings imply that the reduction in the CO$_2$ emissions by MENA countries does not harm the economic growth of only two countries, the UAE and Syria.

The remainder of the article is organized as follows. Section 2 briefly reviews the related literature on the causal relationship between income, energy use, and carbon emissions with a special focus on the potential impact of structural breaks. Section 3 presents the conventional framework of Granger causality test as a baseline approach for comparison and the instability-robust causality test of Rossi (2005). Section 4 reports our main empirical results. Policy implications of our findings are discussed in Section 6.

2. Literature review

As discussed in the introduction, CO$_2$ emissions must be significantly reduced in order to preserve the environmental quality. The use of low carbon-intensity energy sources, the development of clean energy and the reduction of conventional energy consumption are among the most frequently evoked solutions. While the former solutions are relatively a long-term target, energy consumption cuts may have harmful effects on economic growth and national income. In order to provide guidelines for appropriate policy actions, a number of studies have firstly examined the causal links between energy consumption and economic growth (e.g., Oh and Lee, 2004; Belloumi, 2009; Zhang and Cheng, 2009). Using various datasets and econometric techniques, past research has shown that the causality between these variables can be
unidirectional from one variable to another as well as bidirectional (Ozturk, 2010).

An important issue, not always solved appropriately by past research, is the potential impact of parameter instability on the obtained results. Some studies have attempted to take the possibility of structural breaks into account when modeling the energy-growth nexus (e.g., Lee and Chang, 2005; Chiou-Wei et al., 2008). It is common practice in previous works to employ the Zivot and Andrews (1992) unit root test allowing for structural break and the Perron (1997) structural change test to detect instability problems before testing for the causality. Other techniques such as the rolling window Granger causality test (Balcilar et al., 2010), the dummy variables (Fuinhas and Marques, 2012), and the Markov switching VARs (Fallahi, 2011) are also used to account for possible structural changes. Recent studies adopt more complex approaches. For example, Esso (2010) employs threshold cointegration technique to test the energy-growth relationships for seven African countries for the period 1970-2007 and finds evidence of cointegration relationship with structural break in five out of seven countries. Narayan and Smyth (2009), Apergis and Payne (2009), Lee and Chiu (2011), and Arouri et al. (2012), among others, have applied panel cointegration techniques with multiple structural breaks and panel data unit root tests with structural breaks to address the energy-growth issue.

As far as the carbon emissions reflect the quantity of energy used, past studies have also included the carbon emission variable directly in the empiri-
actual analysis of short- and long-run relationships with other economic variables, and examined in particular the EKC hypothesis. Our study is closely related to the strand of literature that investigates causal relationships between CO₂ emissions and economic growth following the increasing threat on the global warming (e.g., Azomahou et al., 2006; Soytas and Sari, 2009; Dinda, 2009; Pao and Tsai, 2010; Acaravci and Ozturk, 2010; Menyah and Rufael, 2010; Niu et al., 2011; Jayanthakumaran et al., 2012). These studies mainly find that there is a long-run stable relationship between carbon emissions and economic growth and that national income significantly affects carbon emissions. For example, Pao and Tsai (2010) document a long-run bidirectional Granger causality between income and CO₂ emissions for the BRIC countries. Acaravci and Ozturk (2010) find a long-run positive relationship between economic growth and CO₂ emissions for a sample of European countries using autoregressive distributed lag bounds testing approach of cointegration. Differently, Dinda (2009) documents the existence of unidirectional causality running from CO₂ emissions to income for OECD countries and from income to emissions for non-OECD countries. Halicioglu (2010) empirically examines the causal relationships between carbon emissions, energy consumption, income, and foreign trade for Turkish data over the period 1960–2005. Using the bounds testing to cointegration procedure, the author shows the existence of two forms of long-run relationships between the variables according to which carbon emissions are determined by the other variables in the first form, while all other variables affect the income
in the second form. Moreover, income is the most significant variable in explaining the carbon emissions which is followed by energy consumption and foreign trade. There is however evidence to suggest that economic growth has no impact on the CO₂ emissions in the US (Soytas et al., 2007).

To a larger extent, our research is also linked to previous studies that focus on the relationship between economic growth and CO₂ emissions in relation with the test of the EKC hypothesis. Coondoo and Dinda (2002) examine the relationship between CO₂ emissions and income for a group of 88 countries and find no credence to the EKC hypothesis. Their results are more or less supported by those of the majority of subsequent studies including, among others, Martinez-Zarzoso and Bengochea-Morancho (2004), Liu (2005), Lantz and Feng (2006), Akbostanci et al. (2009), and Boopen and Vinesh (2011). For example, Martinez-Zarzoso and Bengochea-Morancho (2004) find that CO₂ emissions tend to decline when income increases up to a certain level, and then there would be an increase of emissions at higher incomes. By estimating a simultaneous equation system in which national income and CO₂ emissions are jointly determined by country-specific levels of capital, labor and technology, Liu (2005) finds a negative link between CO₂ emissions and income. Akbostanci et al. (2009) found that Turkish data do not confirm EKC hypothesis using a panel data model. Boopen and Vinesh (2011) found that there was no reasonable turning point and thus no validity of EKC hypothesis for Mauritius over the period 1975-2009. On the contrary, Jaunky (2011) established the validity of an inverted U-shaped
relationship for Malta, Oman, Portugal and UK from a panel of 36 countries.

Overall, past studies on the CO2 emissions-growth nexus have not directly considered regime shifts in the Granger-causality test regressions. Our article contributes to this literature by resorting to the instability-robust causality test of Rossi (2005).

3. Methodology

This section presents our empirical procedure. We first introduce the standard Granger causality test as a baseline framework. To ease the comparison of results, the possibly long-term cointegrating relationship is not examined here because the Rossi (2005) instability-robust causality test is primarily based on regression relationships. We then present the Rossi (2005) competing approach and use the tests of Andrews (1993) and Rossi (2005) to check the robustness of the obtained results for causality.

3.1. Linear Granger causality test

The bivariate framework of the Granger (1969) causality test examines whether one time series is useful in forecasting another based on linear least squares predictors. This framework has been extensively used to investigate the linear causality between national income \( y_t \) and CO2 emissions \( x_t \), and it involves estimating a \( k \)-order linear vector autoregression model, \( \text{VAR}(k) \), as follows

\[
y_t = \alpha_0 + \alpha_i \sum_{i=1}^k y_{t-i} + \beta_i \sum_{i=1}^k x_{t-i} + \varepsilon_t
\]
\[ x_t = \alpha_0' + \alpha_i' \sum_{i=1}^{k} x_{t-i} + \beta_i' \sum_{i=1}^{k} y_{t-i} + \vartheta_t \]  

(2)

where \( y_t \) and \( x_t \) are stationary variables. \( k \) is the optimal lag order. The error terms, \( \varepsilon_t \) and \( \vartheta_t \), are assumed to follow a normal distribution with zero mean and a constant covariance matrix. The series \( y_t \) Granger causes \( x_t \) if the \( \beta_i' \) parameters are jointly significant, while \( x_t \) Granger causes \( y_t \) if the \( \beta_i \) parameters are jointly significant. There is evidence of bidirectional causal relationship between \( y_t \) and \( x_t \) when the \( \beta_i' \) and the \( \beta_i \) parameters are jointly significant.

3.2. Rossi (2005) instability-robust causality test

The Rossi (2005)'s instability-robust causality test applied to national income and carbon emissions is based on the following general regression model

\[ y_t = x_{t-1}' \beta_t + \varepsilon_t, \ t = 1, ..., T \]  

(3)

where \( x_{t-1} \) is a \((p \times 1)\) vector of explanatory variables. \( x_t \) and \( y_t \) alternatively play the role of income and CO₂ emissions. The Granger causality test we described above is only valid under the following assumptions: i) \( \{x_t, y_t\} \) are stationary and ergodic; ii) the variance-covariance matrix \( E(x_t x_t') \) is nonsingular; iii) \( E(x_t \varepsilon_t) = 0 \); and iv) \( \{x_t \varepsilon_t\} \) satisfies Gordin’s condition (Hayashi 2000, pp.402-403) and its long-run variance is nonsingular.\(^5\) Having relaxed

\(^5\)Let \( I_t = (x_t \varepsilon_t, x_{t-1} \varepsilon_{t-1}, ...) \) be the history of \( (x_t \varepsilon_t) \) at the time \( t \in \mathbb{Z} \). Roughly speaking, Gordin’s condition implies that the impact of \( I_{t-n} \) on the conditional expectation
these conditions, Rossi (2005) is interested in testing whether the variable $x_t$ has no predictive content for $y_t$ in the case where the parameters $\beta_t$ might be time-varying. In this article, we follow Chen et al. (2010) and focus on the case in which $\beta_t$ may shift from $\beta$ to $\beta' \neq \beta$ at some unknown points in time. While Rossi (2005) considers the general case of testing possibly nonlinear restrictions in models estimated by the Generalized Method of Moments (GMM), we confine the test to the simple case of no Granger causality restrictions in models whose parameters can be consistently estimated with Ordinary Least Squares (OLS) method. This procedure is advantageous in that it provides necessary consistency with the Granger-causality regressions implemented in this article.

Suppose that there is a sudden shift occurring at a particular point in time $\tau$. Let $\hat{\beta}_{1\tau}$ and $\hat{\beta}_{2\tau}$ denote the OLS estimators before and after the time of the shift, they are given by

$$
\hat{\beta}_{1\tau} = \left( \frac{1}{\tau} \sum_{t=1}^{\tau-1} x_{t-1} x_{t-1}' \right)^{-1} \left( \frac{1}{\tau} \sum_{t=1}^{\tau-1} x_{t-1} y_t \right),
$$

$$
\hat{\beta}_{2\tau} = \left( \frac{1}{T-\tau} \sum_{t=\tau}^{T-1} x_{t-1} x_{t-1}' \right)^{-1} \left( \frac{1}{T-\tau} \sum_{t=\tau}^{T-1} x_{t-1} y_t \right).
$$

Rossi (2005)’s test statistic used to decide between the null and alternative

---

\((x_t \epsilon_t)\) vanishes as \(n \rightarrow \infty\) and also that the conditional expectations of \((x_t \epsilon_t)\) do not vary too much in time (Hayashi, 2000, p.403).
Under the joint null hypotheses of no Granger causality and no time-variation in the parameters \((\beta_1 = \beta = 0)\), \(Exp - W^*\) has a non standard distribution whose critical values are tabulated in Table B1 of Rossi (2005). High values of \(Exp - W^*\) statistics will lead to reject the joint null hypotheses.
4. Empirical results

4.1. Data and analysis of stationarity

We use annual time series data of per capita GDP expressed in constant US$ 2000 and CO$_2$ emission measured in metric tons per capita for a sample of twelve MENA countries: Algeria, Bahrain, Egypt, Iran, Jordan, Lebanon, Morocco, Oman, Saudi Arabia, Syria, Tunisia, and United Arab Emirates (UAE). The study period is chosen with respect to the data availability for each country (see Table 1). Regarding the descriptive statistics, all first-differenced variable means are positive, except for the UAE. This finding suggests that per capita GDP and per capita CO$_2$ emissions have an increasing tendency in eleven out of twelve countries.

Since the Granger causality test requires the use of stationary variables in the bivariate system, commonly-used unit root tests including the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests are performed to check the stationarity of the studied variables. The results presented in Table 1 indicate that both the income and CO$_2$ series of all individual countries are nonstationary in levels, but stationary in their first differences. The stationary property of the differenced series is thus suitable for further statistical analysis with the Granger causality test and Rossi (2005) test robust to instabilities.

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6 Data are obtained from the World Development Indicators.
7 For concision purpose, we do not report the complete summary statistics here, but they can be made entirely available under request addressed to the corresponding author.
4.2. Causality analysis

4.2.1. Granger causality test

We use the AIC criteria to determine the appropriate lag lengths for each country’s CO₂ emission-income VAR model. Table 2 reports the results of the Granger causality test. Accordingly, the null hypothesis that changes in CO₂ emissions do not cause changes in GDP cannot be rejected for all MENA countries at the 5% level. There is a slight evidence to support the causality from CO₂ to GDP in Egypt at the 10% level. It is thus not possible to reduce emissions without sacrificing national income as reduction in CO₂ emissions can cause Egyptian output to decline. On the other hand, the null hypothesis of Granger noncausality from changes in GDP to changes in CO₂ emissions is rejected for Iran and Morocco at the 5% level. Hence, a decrease in carbon emissions will bring without impeding economic growth, but the inverse is not true for Iran and Morocco.

Summarizing all, the findings from the Granger causality test suggest that CO₂ emission cuts are not hurting economic growth of MENA countries,
except for Egypt where CO\textsubscript{2} emissions may have a slight effect on GDP. Fluctuations in the GDP may cause significant changes in CO\textsubscript{2} emissions for Iran and Morocco.

Table 2: Results of Granger causality tests

<table>
<thead>
<tr>
<th>Country</th>
<th>H\textsubscript{0}: GDP does not cause CO\textsubscript{2}</th>
<th>H\textsubscript{0}: CO\textsubscript{2} does not cause GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algeria</td>
<td>0.3556</td>
<td>0.6908</td>
</tr>
<tr>
<td>Bahrain</td>
<td>0.4977</td>
<td>0.1667</td>
</tr>
<tr>
<td>Egypt</td>
<td>0.0906\textsuperscript{c}</td>
<td>0.0551\textsuperscript{c}</td>
</tr>
<tr>
<td>Iran</td>
<td>0.0073\textsuperscript{a}</td>
<td>0.9023</td>
</tr>
<tr>
<td>Jordan</td>
<td>0.5060</td>
<td>0.4748</td>
</tr>
<tr>
<td>Lebanon</td>
<td>0.3073</td>
<td>0.1295</td>
</tr>
<tr>
<td>Morocco</td>
<td>0.0224\textsuperscript{b}</td>
<td>0.4739</td>
</tr>
<tr>
<td>Oman</td>
<td>0.3593</td>
<td>0.5486</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>0.8583</td>
<td>0.9875</td>
</tr>
<tr>
<td>Syria</td>
<td>0.9255</td>
<td>0.1785</td>
</tr>
<tr>
<td>Tunisia</td>
<td>0.2015</td>
<td>0.3818</td>
</tr>
<tr>
<td>UAE</td>
<td>0.5861</td>
<td>0.7671</td>
</tr>
</tbody>
</table>

Notes: this table reports the p-values of the Granger causality tests. \textsuperscript{a}, \textsuperscript{b} and \textsuperscript{c} indicate the rejection of the null hypothesis at the 1%, 5% and 10% levels, respectively.

4.2.2. Instability-robust Granger causality test

Detection of structural change: Policy decisions, business cycles as well as sudden changes in the demand and supply of energy are important sources of structural changes in the time-paths of economic growth and carbon emissions, which directly affect their short- and long-run relationships. The Andrews (1993) QLR (Quandt Likelihood Ratio) test for stability with unknown breakpoints is thus used to check whether structural break is present in the
We consider two regression models where the changes in GDP and the changes in CO₂ emissions alternatively play the role of dependent variable. In principle, these two models have the same coefficient of determination, and thus, when applying the Andrews’ test, is expected to achieve the same break dates. In practice, these two regressions form the basis for studying the bidirectional causality between variables. If the evidence of structural change is confirmed by the above-mentioned test of break-point detection, the Rossi (2005)’s instability-robust causality test is used to assess the statistical strength of the causality with respect to the direction of impact identified by the stability test.

Table 3: Andrews (1993)’s QLR test for instabilities

<table>
<thead>
<tr>
<th>Country</th>
<th>Break date</th>
<th>SupLR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algeria</td>
<td>2001</td>
<td>3.5444</td>
</tr>
<tr>
<td>Bahrain</td>
<td>2004</td>
<td>11.9981**</td>
</tr>
<tr>
<td>Egypt</td>
<td>2001</td>
<td>2.2092</td>
</tr>
<tr>
<td>Iran</td>
<td>2002</td>
<td>5.5754</td>
</tr>
<tr>
<td>Jordan</td>
<td>2003</td>
<td>31.4553***</td>
</tr>
<tr>
<td>Lebanon</td>
<td>2005</td>
<td>14.9924**</td>
</tr>
<tr>
<td>Morocco</td>
<td>2001</td>
<td>5.6308</td>
</tr>
<tr>
<td>Oman</td>
<td>2002</td>
<td>19.4011***</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>2002</td>
<td>17.3362***</td>
</tr>
<tr>
<td>Syria</td>
<td>2001</td>
<td>15.6945***</td>
</tr>
<tr>
<td>Tunisia</td>
<td>2001</td>
<td>9.9094</td>
</tr>
<tr>
<td>UAE</td>
<td>2003</td>
<td>55.8088***</td>
</tr>
</tbody>
</table>

Notes: we test the stability of \((\beta_{0t}, \beta_{1t})\) in the following regression: \(\Delta CO2_{t+1} = \beta_{0t} + \beta_{1t}\Delta GDP_{t}\). ***, and ** indicate the rejection of the null hypothesis of stability at the 1% and 5% levels, respectively.

\(^8\)The QLR is also known as Andrews’ sup-\(F\) statistic.
Table 4: Andrews (1993)'s QLR test for instabilities

<table>
<thead>
<tr>
<th>Country</th>
<th>Break date</th>
<th>SupLR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algeria</td>
<td>2001</td>
<td>10.6336*</td>
</tr>
<tr>
<td>Bahrain</td>
<td>2004</td>
<td>223.3433***</td>
</tr>
<tr>
<td>Egypt</td>
<td>2001</td>
<td>24.348***</td>
</tr>
<tr>
<td>Iran</td>
<td>2002</td>
<td>21.0864***</td>
</tr>
<tr>
<td>Jordan</td>
<td>2003</td>
<td>50.1007***</td>
</tr>
<tr>
<td>Lebanon</td>
<td>2005</td>
<td>197.7884***</td>
</tr>
<tr>
<td>Morocco</td>
<td>2001</td>
<td>14.7287**</td>
</tr>
<tr>
<td>Oman</td>
<td>2002</td>
<td>18.3580***</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>2002</td>
<td>157.6914***</td>
</tr>
<tr>
<td>Syria</td>
<td>2001</td>
<td>1.39</td>
</tr>
<tr>
<td>Tunisia</td>
<td>2001</td>
<td>52.6012***</td>
</tr>
<tr>
<td>UAE</td>
<td>2003</td>
<td>8.1369</td>
</tr>
</tbody>
</table>

Notes: we test the stability of \((\beta_0, \beta_1)\) in the following regression: \(\Delta GDP_{t+1} = \beta_0 + \beta_1 \Delta CO_2_t\). ***, **, and * indicate the rejection of the null hypothesis of stability at the 1%, 5%, and 10% levels, respectively.

In Table 3, we report the structural break dates for the causal relation from GDP to CO\(_2\) emissions. Structural change is detected for seven out of twelve countries with respect to the Andrews’ QLR test. As to the causal relation from CO\(_2\) emissions to GDP, the results in Table 4 indicate the presence of structural change in ten out of twelve countries. On the whole, we found a noticeable proportion of significant structural changes occurring in the two inverse regression models. This evidence clearly supports the use of instability-robust causality test. We also find identical break dates in some countries (2001 for Algeria, Egypt, Morocco, Syria, and Tunisia, and 2002 for Iran, Oman, and Saudi Arabia), suggesting that MENA countries may have been exposed to similar dynamics and structural breaks in economic,
technological, and institutional patterns. These structural instabilities may be explained by the occurrence of several past events such as the world’s economic recession in the early 2000s typically caused by the 1997-1998 Asian financial crisis and the collapse of the dot-com bubble during 2000-2001 in the United States, the 2003 Iraq war, and the change in OPEC pricing mechanism to target zone pricing as announced by the OPEC president, Ali Rodriguez, in March 2000 (Hammoudeh, 2003).

Results of Rossi (2005) instability-robust causality test: Table 5 reports the results of the causality tests in the presence of structural change. The p-values reported for these tests are obtained by linear interpolation from a simulation of 5,000 Monte Carlo replications over a dense grid. The causality is found to be highly significant for both causal directions and for all countries experiencing structural breaks. These findings clearly contrast the standard Granger causality test according to which the causality running from GDP to CO$_2$ emissions is only significant in two countries at the 5% level (Egypt and Morocco), and the inverse causal direction is only marginally found in one country at the 10% level (Egypt).

Rossi (2005) explains this discrepancy of test conclusions with those of the standard Granger causality test by the effect of structural breaks in the underlying data. Since the linear Granger causality test explicitly assumes no structural change, the instability of the model parameters straightforwardly calls into question the obtained results and can lead to misleading conclusions about the causality between system variables. For instance, Bianchi
(1995) and Salman and Shukur (2004), among others, show that the standard Granger causality tests can give misleading results if significant structural change occurs.

Table 5: Results of Rossi (2005)'s Granger-causality test robust to instabilities

<table>
<thead>
<tr>
<th>Countries</th>
<th>Regression model: $\Delta CO_{2t+1} = \beta_{0t} + \beta_{1t}\Delta GDP_t$</th>
<th>p-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bahrain</td>
<td>0.0000$^a$</td>
<td></td>
</tr>
<tr>
<td>Jordan</td>
<td>0.0000$^a$</td>
<td></td>
</tr>
<tr>
<td>Lebanon</td>
<td>0.0000$^a$</td>
<td></td>
</tr>
<tr>
<td>Oman</td>
<td>0.0093$^a$</td>
<td></td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>0.0093$^a$</td>
<td></td>
</tr>
<tr>
<td>Syria</td>
<td>0.0092$^a$</td>
<td></td>
</tr>
<tr>
<td>UAE</td>
<td>0.0095$^a$</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Countries</th>
<th>Regression model: $\Delta GDP_{t+1} = \beta_{0t} + \beta_{1t}\Delta CO_{2t}$</th>
<th>p-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algeria</td>
<td>0.0069$^a$</td>
<td></td>
</tr>
<tr>
<td>Bahrain</td>
<td>0.0000$^a$</td>
<td></td>
</tr>
<tr>
<td>Egypt</td>
<td>0.0057$^a$</td>
<td></td>
</tr>
<tr>
<td>Iran</td>
<td>0.0074$^a$</td>
<td></td>
</tr>
<tr>
<td>Jordan</td>
<td>0.0000$^a$</td>
<td></td>
</tr>
<tr>
<td>Lebanon</td>
<td>0.0000$^a$</td>
<td></td>
</tr>
<tr>
<td>Morocco</td>
<td>0.0067$^a$</td>
<td></td>
</tr>
<tr>
<td>Oman</td>
<td>0.0076$^a$</td>
<td></td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>0.0099$^a$</td>
<td></td>
</tr>
<tr>
<td>Tunisia</td>
<td>0.0000$^a$</td>
<td></td>
</tr>
</tbody>
</table>

Notes: This table reports the p-values of the test examining the null hypothesis of no Granger causality ($H_0: \beta = \beta = 0$) that is robust to parameter instabilities. $a$, $b$, and $c$ indicate the rejection of the null hypothesis at the 1%, 5%, and 10% levels, respectively.

Overall, the results presented in Table 5 reveal a unidirectional causality running from GDP to CO$_2$ emissions for Syria and the UAE, thus supporting the "conservation hypothesis" that reducing CO$_2$ emissions by energy
conservation policies will not generate harmful effects on economic growth. Next, significant bidirectional causality between CO₂ emissions and GDP is found in five countries including Bahrain, Jordan, Lebanon, Morocco, Oman and Saudi Arabia. This finding implies that CO₂ emissions and economic growth are jointly determined and affected at the same time and that it is not easy to get rid of an optimal policy. Finally, we find a significant unidirectional causality running from CO₂ emissions to GDP for Algeria, Egypt, Iran, Morocco, and Tunisia. That is, energy conservation may lead to damage economic growth in these countries. As far as CO₂ emissions are driven by energy consumption⁹ our results contrast, to a large extent, those of Wolde-Rufael (2005) who find causality running from GDP to energy consumption for Algeria and Egypt, and no causality for Tunisia. They are also inconsistent with those of Al-Iriani (2006) who documents a causality running from GDP to energy consumption for Bahrain, Oman, Saudi Arabia, and the UAE. The findings of Mehrara (2007) are similar to ours in that the author provides evidence of a unidirectional causality running from GDP to energy use for the UAE. Note finally that Al-mulali (2011) documents, from a panel data perspective for the MENA countries, a bidirectional Granger causality between oil consumption, CO₂ emissions and the GDP, which is only detected in five out of the twelve MENA countries we consider after

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⁹ Arouri et al. (2012) study the relationship between CO₂ emissions, energy consumption, and real GDP for 12 MENA countries over the period 1981–2005 and find, from recent bootstrap panel unit root tests and cointegration techniques, that energy consumption has a positive correlation with CO₂ emissions.
structural instabilities are accounted for.

5. Conclusion

A large body of literature has been devoted to the investigation of the causal relationship between energy variables and national income, but only a few studies have addressed this issue in the context of parameter instability, especially for the developing countries in the MENA region. Recently, some studies have considered the instability in CO$_2$ emissions-income nexus using unit root and cointegration tests allowing for structural breaks (e.g., Arouri et al., 2012), but they mainly focus on the long-run relationships. Our article attempts to fill this gap by exploring the causality relationships between GDP and CO$_2$ emissions for twelve MENA countries through the use of the instability-robust causality test of Rossi (2005). This empirical framework permits us to avoid the drawback of the standard Granger-causality that becomes inefficient in the presence of structural breaks in the underlying data.

Our results indicate that the standard Granger causality test fails to detect the dynamic causal links between GDP and CO$_2$ emissions for almost all countries, meanwhile the Rossi’s test robust to instabilities reveal a number of interesting insights. Indeed, when structural change is accounted for, we find a bidirectional causality in six out of twelve countries (Bahrain, Jordan, Lebanon, Morocco, Oman and Saudi Arabia), a unidirectional causality running from GDP to CO$_2$ emissions for two countries (Syria and the UAE),
and a unidirectional causality running from CO$_2$ emissions to GDP for five countries (Algeria, Egypt, Iran, Morocco, and Tunisia).

While the global warming has become an important global environmental challenge facing the world, the MENA countries are expected to reduce their greenhouse gas emissions (especially CO$_2$ emissions), the policy implications of the above-mentioned findings are likely to be country-specific. The reason is that the CO$_2$ emissions reduction may have an economic cost for some MENA countries. Effectively, countries such as Syria and the UAE may adopt a policy of energy conservation to comply with their potential binding obligations without compromising their economic growth as changes in CO$_2$ emissions exert no significant on income. Any reduction of carbon emissions is, however, a challenging task for countries where the causality runs from CO$_2$ emissions to income because any restrictions on energy consumption may adversely affect income. In this scheme of things, forcing CO$_2$ emission cuts will have a detrimental impact on economic growth for these countries. A longer commitment period for CO$_2$ reductions is therefore expected so that these countries can firstly promote their economic growth. Otherwise, they will have no intention to sign any international environmental treaty. Similar implications hold for countries where a bidirectional causality between GDP and CO$_2$ emissions exists. Nonetheless, the trade-off between growth and environmental degradation is more complex as growth patterns also affect carbon emissions.
Acknowledgment: The first author thanks Barbara Rossi for helpful clarifications on the code used in Rossi (2005).

References


[38] Liu, X., 2005. Explaining the relationship between CO2 emissions and national income; the role of energy consumption. Economic Letters 87, 325-328.


