“Energy consumption, CO2 emissions and economic growth in MENA countries”

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ENERGY CONSUMPTION, CO_2 EMISSIONS AND ECONOMIC GROWTH IN MENA COUNTRIES

Abstract

This study investigates the relationship between economic growth, final consumption, investment, energy use and CO_2 emissions in two groups of Middle East and North Africa (MENA) countries: Oil Poor Countries (OPC) and Oil Rich Countries (ORC). It is assumed and verified that the structural relationship between GDP growth, energy use and CO_2 emissions is different in these two groups of countries. FGLS panel estimations were carried out over the period 1974–2014. In ORC, no significant relationships are observed between energy use and GDP, whereas CO_2 emissions and GDP are positively linked. In OPC, there are opposite connections: a positive link between GDP and energy use, whereas the impact of CO_2 emissions on GDP tends to be negative. In both groups of countries, a positive and bi-directional link is observed between energy use and CO_2 emissions. The strength of this link is twice bigger in OPC than in ORC. This indicates that CO_2 reduction policies conducted through energy use control (quantitative and qualitative) will have higher effect in OPC than in ORC. This also shows that the relationships between economic growth, energy use and CO_2 emissions differ noticeably and structurally between OPC and ORC. These results provide new insights into the opportunities and threats faced by CO_2 reduction policies in OPCs and ORCs.

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INTRODUCTION

Increasing CO_2 emissions pose a serious threat to the environment, which is a common anxiety for both developing and developed countries (Zhang et al., 2015; Muhammad & Khan, 2019). Air pollution was ranked 5th highest risk factor of mortality in 2017 at the global level (HEI, 2019). In 1992, the World Development Report discussed in detail the relationship between the environment and economic activity. It was argued that their connection is not linear, but has an inverted U shape (World Bank, 1992, pp. 36-43). Grossman and Krueger (1993) developed similar analysis. These researchers initiated the idea that the relationship between economic growth and the environment may be divided into two stages. The first development stage uses intensively "free" inexpensive environmental resources. Through time, their depletion induces a social demand for stronger environmental policies and a rise in their costs, which stimulates the development of eco-friendly solutions. Consequently, this leads to a second stage of cleaner economic growth and possibly to an environmental recovery from the degradations initiated in the first stage of development. The relationship between the environmental pollution and economic growth, as well as energy consumption, has been an area of intense research. Many subsequent studies test these relationships

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and are now referred to as the Environmental Kuznets Curve (EKC[1]) approaches. They have investigated various types and causes of environmental degradations in many countries (Kaika & Zervas, 2013; Antonakakis et al., 2017; Acheampong, 2018; Mikayilov et al., 2018; Muhammad, 2019). However, the empirical confirmation of the relationships hypothesized by the EKC has remained ambiguous and controversial until now. The results differ according to the periods of time, the countries under study and the econometric methodologies. For example, Acheampong (2018) and Muhammad (2019) compare the relationship between economic growth, CO_2 emissions and energy use in different regions. They notice that the parameter estimates differ strongly according to the countries and the estimation methods. Furthermore, as stated by Davis and Caldeira (2010, p. 5690), accounting based on consumption reveals that a substantial part of the CO_2 emissions is traded internationally. Therefore, these emissions are not reported in the national emission inventories when statistics are based on production data. Assigning responsibility of these emissions for consumers may be a solution of compromise between the need of economic growth in the countries where the energy is produced (currently those countries that are rich in oil) and those who use it (oil poor countries).

This study aims to investigate the relationship between economic growth, final consumption, investment, energy use and CO_2 emissions. Several empirical analyses have already been conducted on a large scale of heterogeneous countries. Their findings are often very general and difficult to convert into relevant recommendations for the national public policies. Initially national and natural resource endowments are scarcely considered, whereas they may be seen as a critical incentive to engage into environmentally friendly policies. Regarding oil, which is a non-renewable natural resource with many potential substitutes, the main long-term problem faced by oil rich countries (ORC) may be an "apocalyptical run" for the appropriation of the benefits of their gradually ending oil reserves before the emergence of less expensive green substitutes. At the international market scale, these strategies may result in keeping oil prices relatively low until the total depletion of their natural reserves. Low oil prices reduce the incentives to invest in initially more expensive green energies and delay the reduction of CO_2 emissions by the oil poor countries (OPC). Poor countries often try to promote their international competitiveness through productivity gains obtained by cost reduction strategies rather than by innovation. They often specialize in low-tech markets driven by price competition. Consequently, in a poor country with poor oil endowment, investment decisions in green vs fossil energy production may have important consequences for their international competitiveness and long-term growth prospects. They may face the traditional tradeoff between early stage economic growth and environmental preservation hypothesized by the EKC. In all cases, the goal of OPCs and ORCs is to promote their "self-interest" through GDP growth.

The EKC raises the question of a link between growth and environmental degradation without explicitly considering the possible impact of the natural resource endowments. This work tries to address this question by focusing on the impact of countries oil endowments on the relationship between economic activities, energy use and environmental damages caused by CO_2 emissions. The first section briefly reviews the literature and explains the research process. The second section explains the methodology, describes the data and presents the results of the estimations. In conclusion, research limitations and implications are discussed.

1. LITERATURE REVIEW

Many studies examine the environmental impact of economic activities around the world through the lens of the EKC model (see, for example, Panayotou, 1993, 2003; Kaika & Zervas, 2013; Antonakakis et al., 2017; Gill et al., 2018; Mikayilov et al., 2018; Acheampong, 2018; Muhammad, 2019; Muhammad & Khan, 2019; Yao et al. 2019). According to Gill et al. (2018, p. 1636), in the early stages of the economic growth, especially when the primary production dominates, there is an abun-

1 The EKC is named for Kuznets (1955) who hypothesized that income inequality first rises and then falls as economic development proceeds.

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dance of natural resource stock and, conversely, a limited generation of wastes because of a noticeable restriction of the economic activity. In the course of development through industrialization, there is a significant depletion of natural resources and the accumulation of waste. During this phase, there is a positive relationship between income, economic growth (per capita) and environmental degradation (per capita). However, the increased scarcity of the natural resources, the decline of unpolluted areas and goods lead to a rise in their relative prices. As economic growth continues and the larger service sector develops, combined with improved technologies and better information diffusion, the material basis of the economy tends to reduce. In turn, it results in a less damaging growth for the environment (Panayotou, 2003; Gill et al., 2018). Bilgili et al. (2015, p. 838) note that "…the validity of EKC does not depend on income level of individual countries of panel in which EKC hypothesis holds." However, Yao et al. (2019, p. 1350) argue that "…the developing countries could reach the turning point of an inverted U-shaped EKC at a relatively lower income level than their developed counterparts", particularly they benefit from a technological and social catching-up process. As a result, their EKC turning points can occur at a relatively low income. It is a result of the interaction between income and technology. This approach is against Mikayilov et al. (2018, p. 1565), who support that "…the EKC is usually held for the developed countries having a higher income than the developing countries." In the same line, Pillu (2009, p. 230) explores energy saving technologies in four main countries (France, Germany, Japan, and the USA) from 1978 to 2003. He reports "a strong and positive mechanism of energy prices variations on innovative activities measured in terms of the patent applications." The law of the energy prices plays a determinant role, which may sometimes be mitigated by technological opportunities. Fernández et al. (2018, p. 14) analyze the relationship between innovation and the CO_2 emission by assessing the extent to which the R&D expenditure affects CO_2 emissions in the United States, the European Union and China over the period 1990–2013. They show that R&D expenses are liable to contribute to reduce CO_2 emissions in developed countries. In another context, the overuse of the energy can lead to much higher CO_2 emissions.

Acheampong (2018) examines the dynamic causal interrelation between economic growth, carbon emissions and energy consumption in 116 countries spread over four different regions (Asia-Pacific, Caribbean and Latin America, MENA and sub-Saharan Africa) and over the period of 1990 and 2014. He finds that the economic growth does not cause the energy consumption in all these four regions and only causes CO_2 emission reductions in Caribbean and Latin America. He also demonstrates that the CO_2 emission has a positive causal effect on the economic growth in Asia-Pacific, Caribbean and Latin America and MENA countries, but has no causal effect in sub-Saharan Africa. It has only a negative causal effect on the energy consumption in MENA countries. On the one hand, he concludes that the energy consumption has a negative causal effect on the growth in Asia-Pacific, Caribbean and Latin America and MENA countries, but has a positive causal effect in sub-Saharan Africa. On the other hand, he concludes that the energy consumption has a negative causal effect on CO_2 emissions in Caribbean and Latin America and Sub-Saharan Africa countries and has a positive causal effect in MENA countries and no causal effect in Asia-Pacific countries (Acheampong, 2018).

Muhammad (2019) also examines the effects of economic growth, energy consumption, and CO_2 emissions on a panel of 68 countries over the period between 2001 and 2017 (the sample includes developed, developing and MENA countries). He compared the results obtained using different econometric methods: Seemingly Unrelated Regression (SUR), Generalized Method of Moments (GMM) and System Generalized Method of Moments (Sys GMM). He observes that economic growth influences energy consumption positively and significantly by SUR method and negatively and significantly by Sys GMM method in developed countries, positively and significantly in emerging countries (by SUR and GMM method), but negatively and significantly in MENA countries only by GMM method. He also shows that the effect of economic growth on the CO_2 emission is positive and significant in developed countries by SUR and GMM method and MENA countries by SUR and Sys GMM method, but is negative and significant in emerging countries by SUR and Sys GMM method. Additionally, the author shows that the impact of the CO_2 emission on the economic growth is positive and significant in developed countries, and is positive and significant in MENA countries by only dynamic models, but is negative and significant in emerging countries. He indicates that CO_2 emissions have a direct and significant impact on energy consumption in all developed, emerging and MENA countries by using the three methods of estimation. He notes that the impact of energy consumption on economic growth is positive and significant in developed countries by GMM method and in emerging countries by SUR and GMM method but is negative and roughly significant in MENA countries only by Sys GMM method. He emphasizes that the impact of energy consumption on the CO_2 emission is positive and significant in emerging and MENA countries by the three methods of estimation, but positive and significant in developed countries only by SUR and GMM method (Muhammad, 2019).

One possible reason explaining the diversity of results and their sensitivity to the econometric procedure may be that most studies implicitly consider that all the countries enjoy similar natural resource endowment and are engaged in similar growth regimes. The reality is much different: many key natural resources are unevenly distributed across countries. Countries with larger endowment usually exploit and export these resources to countries where the natural resource is scarcer. That international specialization may result in very different patterns of interaction between economic growth, investment, final consumption and pollution. From that point of view, the case of oil may be an interesting topic. That resource is unevenly distributed and its use has many harmful environmental consequences. Its production, transformation and consumption spread all over the world. One part of the harmful consequences of that business is internalized by each country[2] but some of them fall in the common pool; it is particularly the case of CO_2 emissions induced by oil. As a result, the direct relationship between GDP growth and polluting activities that is hypothesized by the EKC may not be easily applied to that kind of pollution.-

This study aims to contribute to this debate by measuring the impact of countries' oil degree of abundance on the connection between GDP growth, final consumption, investment, energy use and CO_2 emissions. Two samples of MENA countries are compared, namely Oil Rich MENA's Countries (ORC) and Oil Poor MENA's Countries (OPC). The hypothesis is that the nature and intensity of the relationship between economic activity and CO^2 emissions differs from OPC to ORC. If that hypothesis proves right, it will be an opportunity to discuss its implications from the point of view of environmental policymaking.

According to the above-mentioned literature and discussion it is expected that the intensity of the relationship between the economic vs energetic variables differs between OPC and ORC. Concerning the nature of the influential variables on GDP, it is known that a large part of the OPC national income results from energy consuming activities. On the contrary, in ORC, a large part of the national income comes from CO_2 emitting extractive activities. Consequently, it is expected that energy use should have a stronger impact on GDP growth in OPC than in ORC (H1 : "The impact of energy use on GDP is larger in OPC than in ORC"). In ORC, petrol rents result in a trade surplus that is not directly consumed but saved and invested abroad. Therefore, in ORC, GDP growth may not be associated with higher energy use. On the contrary, in oil importing OPC, it is assumed that GDP growth has a direct impact on the internal consumption that should result in higher energy use. Consequently, it is expected that the impact of GDP growth on energy use should be stronger in OPC than in ORC (H2 : "GDP growth has a stronger impact on energy use in OPC than in ORC). Concerning CO_2 emissions and their strong link with extractive activities, it is expected that there is a positive impact of CO_2 emissions on GDP growth in ORC, but no impact in OPC (H3: "In ORC, CO_2 emissions have a positive impact on GDP growth"; H3': "In OPC, CO_2 emissions have no impact on GDP growth"). Finally, in both groups of countries, a positive relationship between energy use and CO_2 emis-

2 Oil producing countries lose a non-renewable resource and often cause soil and water pollutions; countries that perform transformation generate localized air pollution and face industrial hazards; finally, the countries in which consumption occurs generate localized air pollution (in the form of fine particles).

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sions is expected (H4: "In both groups of countries, CO_2 emissions stimulate energy use"; H5: "In both groups of countries, energy use induces higher CO_2 emissions").

2. METHODS

This study adopts the Cobb-Douglas production function to study five-way linkages between economic growth, final consumption, investment, energy use and CO_2 emissions. In this respect, the general form of the Cobb-Douglas production used by many authors (Acheampong, 2018; Muhammed, 2019; Muhammad & Khan, 2019) is as follows:

$$Y_{it} = AC_{it}^{\alpha 1i} K_{it}^{\alpha 2i} Eu_{it}^{\alpha 3i} CO2_{it}^{\alpha 4i} e^{\pi it}, \quad (1)$$

where Y is the output, A is a global constant, and π is the residual term assumed to be identically, independently and normally distributed. The returns to scale are associated with investment, final consumption, energy use and CO_2 emissions, which are drawn by α_1, α_2, α_3 and α_4, respectively.

The logarithmic transformation of the Cobb-Douglas production function (1) is given by:

$$\begin{aligned} \ln(Y_{it}) &= \ln(A) + \alpha_{1i} \ln(K_{it}) + \\ &+ \alpha_{2i} \ln(C_{it}) + \alpha_{3i} \ln(Eu_{it}) + \\ &+ \alpha_{4i} \ln(CO2_{it}) + \pi_{it}, \end{aligned} \quad (2)$$

where $\alpha_0 = \ln(A)$; the subscript; $i = 1, ..., N$ denotes the country and $t = 1, ..., T$ denotes the time period. Variable Y is per capita of the real GDP (constant 2010 USD); K is per capita of the gross capital formation (the constant 2010 USD); C is the per capita final consumption expenditure (constant 2010 USD); Eu and CO_2 denote the energy use (kg of oil equivalent per capita) and CO_2 emissions (metric tons per capita), respectively (see more information in Appendix A). All data are provided from the World Development Indicators[3].

The five-way linkages are examined using the following system of equations:

$$\begin{aligned} &\text{Eq1:} && Y_{it} = A_1 C_{it}^{\alpha 1i} K_{it}^{\alpha 2i} Eu_{it}^{\alpha 3i} CO2_{it}^{\alpha 4i} e^{\pi it}, \\ &\text{Eq2 :} && C_{it} = A_2 Y_{it}^{\varphi_{1i}} K_{it}^{\varphi 2i} Eu_{it}^{\varphi 3i} CO2_{it}^{\varphi 4i} e^{\delta it}, \\ &\text{Eq3:} && K_{it} = A_3 Y_{it}^{\theta_{1i}} C_{it}^{\theta 2i} Eu_{it}^{\theta 3i} CO2_{it}^{\theta 4i} e^{\varepsilon it}, \quad (3) \\ &\text{Eq4:} && Eu_{it} = A_4 Y_{it}^{\beta_{1i}} C_{it}^{\beta 2i} K_{it}^{\beta 3i} CO2_{it}^{\beta 4i} e^{\mu it}, \\ &\text{Eq5:} && CO2_{it} = A_4 Y_{it}^{\beta\omega_{1i}} C_{it}^{\omega 2i} K_{it}^{\omega 3i} Eu_{it}^{\omega 4i} e^{\gamma it} \end{aligned}$$

Eq1-3 represent the relationship between the traditional economic growth factors. They describe the causality between economic growth, investment and final consumption. In this context, Muhammad (2019) examines the effect of energy consumption and CO_2 emissions on economic growth. Mehrara and Musai (2013, p. 1) demonstrate the importance of economic growth for capital formation. Bretschger (2014, p. 1) finds a negative impact of energy use on investment in the physical capital and knowledge formation in the case of developed countries.

Eq4-5 represent the relationship between the energetic input required by economic activities and their environmental consequences in terms of CO_2 wastes (Acheampong, 2018; Muhammad, 2019).

The work carried out by Muhammad (2019) seems to provide a wide international overview. On the contrary, this study focuses on two groups of MENA countries and tries to identify their possible specificities. The first group consists of four oil rich countries (ORC) such as Algeria, Iran, Oman and Saudi Arabia. The second is composed of four oil poor countries (OPC): Tunisia, Israel, Morocco and Egypt. The data used in this study are taken from the World Development Indicators[4] from 1974 to 2014.

The data are analyzed using the STATA 13. Specification tests are performed to determine the appropriate estimation model for five panel data in the two groups of countries (Baltagi, 2013; Cameron & Trivedi, 2009; Fitrianto & Musakkal, 2016).

The Likelihood Ratio Test, the Breusch-Pagan LM test and the Hausman test are used to identify the individual specific effects (notably, the fixed ef-

3 https://databank.worldbank.org/source/world-development-indicators

4 http://databank.worldbank.org/data/reports.aspx?source=world-developmentindicators

fect and the random effect). It was deduced that the regression model should be an individual FE model for each of the five equations in the ORC (see Appendix C) and in OPCs (see Appendix D). The Breusch-Bagan test and the modified Wald test are also performed, respectively, to detect the existence of intra- and the inter-individual heteroscedasticity in the residuals of the individual FE model (Baum, 2001; Podestà, 2002). In the two groups of countries, it was deduced that the phenomenon of heteroscedasticity was present in five equations (see Appendices C and D). The Breusch-Pagan LM test is used to identify possible cross-sectional dependence in the error term between the studied entities (Baum, 2001). The errors exhibit a cross-sectional correlation in five equations concerning ORCs (see Appendix C) and OPCs (see Appendix D). Finally, a serial correlation is the cause for optimistic standard errors (Torres, 2007). To check for this complication, a Wald test is used which validates the presence of the first order autocorrelation in the five equations in the ORC (see Appendix C) but only in two equations (Eq2 and Eq3) in the OPC (see Appendix D).

The AR1 process may differ across the examined countries and cause panel specific AR1 (PSAR1) (Beck & Katz, 1995, p. 640). The restriction of a common autocorrelation parameter is reasonable when the individual correlations are nearly equal and the time series are short in relation to the StataCorp (2019, p. 204). Conversely, in the currently examined case, the time span is long (41 years) and the individual correlations are distinctive in different equations (see Appendix B). As a conclusion, the panel specific AR1 is chosen and the error structure is determined by the panel heteroscedasticity, the autocorrelation and contemporaneous correlation (HPAC) in five equations in ORC and only in Eq2 and Eq3 in OPC. However, it is determined by the panel heteroscedasticity and the contemporaneous correlation (HPAC) in Eq1, Eq4 and Eq5 in OPC.

An individual fixed effect model correlates with the panel data. Estimations are performed using the feasible generalized least square (FGLS) method (Blackwell, 2005, p. 204). According to Podestà (2002, p. 14), “It is feasible to use FGLS method because it uses an estimate of variance-covariance matrix, avoiding the generalized least squares (GLS) assumption that Ω is known.” Reed and Ye (2011, p. 986) find that “the FGLS is the best overall estimator with respect to efficiency, but the worst when it comes to estimating confidence intervals. This means that researchers may have to use one estimator if they want the ‘best’ coefficient estimates, and another if they desire reliable hypothesis testing.” The estimations are examined individually on each of the five equations in the two groups of countries.

3. RESULTS AND DISCUSSION

In light of the above, Table 1 shows that the mean of all variables is greater in ORC than their counterparts in OPC. The level of CO_2 emissions is double in ORC. In addition, energy use is more volatile in ORC. However, it is less volatile in OPC in terms of the standard deviation (Std. dev).

Table 2 and Figures 1-4 clearly show that the common patterns are observed in both OPC and ORC: the links between ln$Y$ and ln$C$, ln$Y$ and ln$K$ and between lnEu and lnCO_2 are significantly positive and bidirectional. This means that there are strong positive interactions between GDP and its two main components such as the final consumption and investment. Except the link from lnEu to ln$K$, which is not significant in both groups, the connections between the economic variables (ln$Y$, ln$C$

Table 1. Descriptive data analysis

Variables	Obs.	ORC (Oil Rich Countries) Algeria, Iran, Oman, Saudi Arabia				OPC (Oil Poor Countries) Tunisia, Israel, Morocco, Egypt			
		Mean	Std. dev	Min	Max	Mean	Std. dev	Min	Max
LnY	164	9.10	.75	8.02	10.57	8.21	1.12	6.62	10.40
LnC	164	8.49	.82	7.29	9.88	8.01	1.10	6.75	10.16
LnK	164	7.78	.71	6.28	9.44	6.69	1.12	4.19	8.82
LnE	164	7.50	.81	5.17	8.84	6.61	.77	5.39	8.04
LnCO_2	164	1.87	.67	.65	2.96	.77	.79	–.47	2.29

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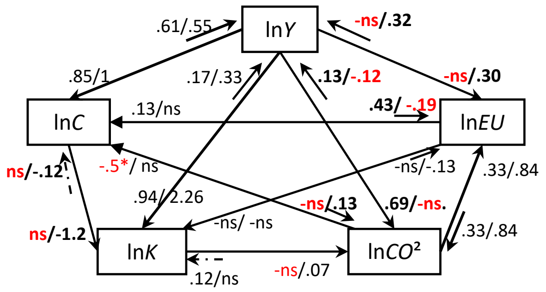

Figure 1. Graphical representation of main relationships between variables in ORC and OPC (figures: ORC/OPC)

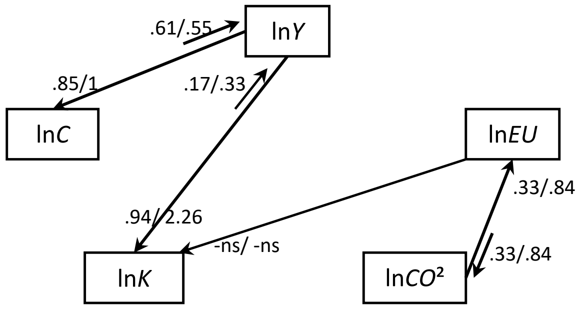

Figure 2. Similar links in ORC and OPC (same sign and same statistical significance – not necessarily the same size)

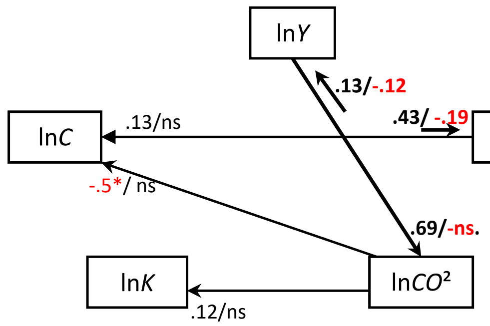

Figure 3. ORC specificities (different sign or significant in ORC but not significant in OPC)

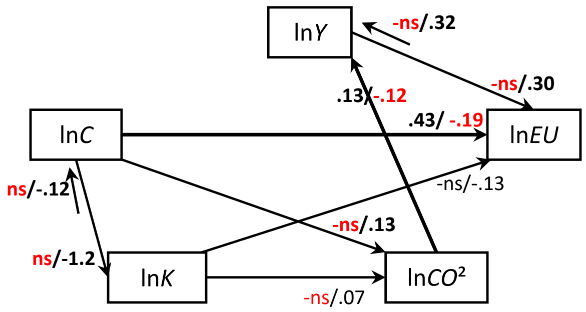

Figure 4. OPC specificities (different sign or significant in OPC but not significant in ORC)

Figures 1-4. Relationships between different variables in ORC and OPC (ORC figures/OPC figures)

and ln$K$) and the energetic ones (lnEu and lnCO_2) differ strongly. Many relationships with opposite signs are observed in OPC and ORC, basically related to the links between economic and energetic variables. The relationship between ln$C$ and ln$K$ differ strongly between OPC and ORC, which certainly reflects very different underlying productive structures.

Eq1 indicates that the GDP's fluctuations (ln$Y$) are positively explained by those in the final demand (ln$C$) and the gross capital formation (ln$K$) in the two groups of countries. This is in line with the national accounting perspective. In the MENA countries, the coefficient associated with ln$C$ is more important than that of ln$K$. It is over triple in oil rich countries (0.613 vs 0.179). It indicates

Table 2. Estimation results

Explanatory variables	Economic activity						Energy and CO²			
	Eq 1: ln$Y$		Eq2: ln$C$		Eq3: ln$K$		Eq4: lnEU		Eq5: lnCO_2	
	ORC	OPC	ORC	OPC	ORC	OPC	ORC	OPC	ORC	OPC
ln$Y$	–	–	.855***	1.053***	.944***	2.268***	–.038	.303***	.690***	–.078
ln$C$	.613***	.550***	–	–	–.024	–1.222***	.430**	–.197***	–.051	.136***
ln$K$	.179***	.335***	.012	–.124***	–	–	–.010	–.130***	–.054	0.073***
LnEu	–.003	.329***	.133***	.040	–.094	–.168	–	–	.336***	.849***
LnCO_2	.138***	–.122*	–.057*	.012	.123*	.050	.424**	.989***	–	–
Cons	2.286**	–.547	–.365	–.023	–.204	–1.066	3.501**	5.811**	–6.061***	–5.779***
Wald chi2(4)	816***	45,454***	452***	27,309***	148***	1,535***	263***	40,193***	576.7***	38,630***

Note: *** significant level (p≤ 1%); ** significant level (p≤ 5%), * significant level (p≤ 10%).

that in the MENA countries, economic growth is more sensitive to the domestic final demand than to investment behaviors.

Interestingly, it is observed that the variables ln*Eu* and $\ln CO_2$ have opposing impacts in OPC and ORC. Ln*Eu* has a positive and significant effect on ln*Y* in OPC but not in ORC. The positive impact of ln*Eu* in OPC is in line with the fact that energy is an input into many production processes and consumption activities such as transportation or cooking. In the economies where the service sector[5] accounts for a low proportion of GDP, the energetic intensity of business activities in OPC is certainly higher than that in ORC that are specialized in oil exports rather than in energy intensive activities such as agriculture or industry. In ORC, the impact of $\ln CO_2$ on ln*Y* is positive, whereas it is usually considered as a waste resulting from the economic activities (production and consumption) rather than as an input of the GDP. This may be explained by the fact that oil extraction is an important source of CO_2 emissions through the process of flaring (Masnadi et al., 2018, p. 851). Consequently, the CO_2 emission may appear as a precursor of the sales (and GDP) in ORC, which results in a positive relationship between $\ln CO_2$ and ln*Y*. Conversely, in OPC, the impact of $\ln CO_2$ tends to be negative. This is certainly explained by the fact that in OPC the CO_2 emission mainly results from the oil imports whose impact on the GDP is mechanically negative. The conclusion is that OPC and ORC may face very different incentives to engage in CO_2 reduction policies: CO_2 increase promotes GDP of ORC, whereas it may be associated with a decrease in GDP in OPC due to fossil energy imports. It is also clear that OPC need energy to sustain their development, whereas in ORC energy consumption is not a key incentive for their economic growth.

Eq2 signifies a positive and significant impact of GDP on final consumption in MENA countries. A slight crowding-out effect of the investment on the final consumption ($\ln K \rightarrow \ln C = -.124$) is observed in OPC, which is not observed in, ORC. This is certainly due to the fact that ORCs usually enjoy a trade surplus and a benefit from large financing capacities. On the contrary, OPCs usually face tight constraints on their trade balance, which leads to reduced financing capacity. Concerning the impact of energy use and CO_2 on consumption, it is noticed that there are large differences between ORC and OPC. In ORC, fluctuations in final consumption are preceded by others in energy use ($\ln Eu \rightarrow \ln C = .133$). This is certainly explained by the behavior of consumers who need more transportation (and energy) to sustain their purchasing process. This phenomenon is not significant in OPC. This is certainly because energy is mainly used in the production processes.

Eq3 shows that in OPC and ORC, ln*Y* has always a positive and significant effect on ln*K*. However, it is as twice as larger in OPC (2.268) than in ORC (.944). This suggests that there is probably an initial situation of under-equipment in OPC and that there is a major incentive for the investment in the aggregated demand. However, the reverse impact of *K* on *Y* is weak; undoubtedly, this is due to the equipment imports in OPC and ORC ($\text{Ln}K \rightarrow \text{Ln}Y = .335$ and $\text{Ln}K \rightarrow \text{Ln}Y = .179$, respectively). The OPC final consumption has a significantly negative impact on investment ($\text{Ln}C \rightarrow \text{Ln}K = -1.222$). The crowding-out effect is absent in ORC. This is certainly due to the mentioned situation of the lack of financial capacities in OPC. As Wen (2006, pp. 378-379) suggests, "such a crowding-out effect is more likely in situations of the temporary demand shocks and the weak returns to scale in the production technology. However, if the demand shocks are sufficiently persistent, then even in the absence of increasing returns to scale investment can be pro-cyclical and highly volatile". The intuition is mainly associated with the anticipated higher future demands after the shock can only be met by higher savings financed by the lower level of consumption when the access to the international financial markets is limited. The results show that in OPC, investment is neither determined by the energy use nor by CO_2 emissions, whereas in ORC, CO_2 emissions would stimulate the investment. This is not related to the implementation of environmental policies to combat CO_2 emissions from oil extraction and refining activities, as the reverse link (from ln*K* to ln*EU*) is not significant in these countries. Consequently, the positive effect of CO_2 emissions on investment results from

5 https://databank.worldbank.org/reports.aspx?source=2&series=NV.SRV.TOTL.ZS&country=# In 2014 the average share of the service sector in the OECD countries value added was 69%, whereas it was between a minimum of 42.9% in Algeria and a maximum of 58.2% in Tunisia.

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the impact of the physical volume of oil extraction and refining activity on the adjustment of the production capacities of the national suppliers of the oil sector.

In Eq4, the variable ln*Y* has a positive and significant effect on ln*Eu* only for OPCs. It is coherent with the fact that they must use energy for agriculture and industry, whereas the service sector is weakly developed. Nevertheless, for ORCs, most of their GDP comes from oil sales, whose prices and volumes are highly volatile and critical to global markets. Consequently, GDP fluctuations in ORC are not strongly related to the national level of energy consumption. It is noticed that the effect of final consumption is positive and significant on energy use in ORC. However, this effect becomes negative and significant in OPC. This is probably explained by the higher per capita income in ORC than that in OPC. According to Zhang et al. (2015, p. 881), "the higher income is associated with the consumption baskets that are more intensive in energy (transportation, housing, food, …)" (see also Lenglart et al. (2010). The consequence would be that in ORC, the link between consumption and energy use would be stronger and more positive than in OPC. The effect of the variable ln*K* remains negligible on ln*Eu* in ORC, but it is negative and significant in OPC. In OPC, investment significantly decreases energy use, which is consistent with the idea of the energy saving investment and the embodied technological change in the countries characterized by a low level of technology[6] and high labor intensity (Henry et al., 1988). As shown by Muhammad (2019), a positive impact of CO_2 emissions on energy use is observed in the MENA countries[7]; it is stronger in OPC than in ORC. This may be accounted for the fact that in ORC, the variability of CO_2 emissions is partly due to the domestic oil consumption and partly to the process of flaring undertaken during the oil extraction, which is driven by the foreign oil demand rather than the domestic energy use. Consequently, the relationship between CO_2 emissions and the domestic energy use is weaker in ORC than in OPC, where domestic energy use fluctuations are mainly determined by domestic quantities of the oil uses causing CO_2 emissions.

Eq 5 shows that the main determinant of CO_2 emissions in ORC is GDP (.690) and then the level of *Eu* (.336). This means that these countries are still in the first phase of the EKC, where an increase in GDP degrades the environment (in terms of the CO_2 at least). Combined with the compositional effect, the scale one (due to specialization in polluting industries) dominates and accelerates the environmental degradation. This finding supports the analysis of Mikayilov et al. (2018, p. 1565), who show that "the EKC usually holds for most of the developed countries but usually not for developing economy". In OPC, however, the impact of GDP on CO_2 emissions is not significant; the main incentives of CO_2 emissions are the level of *Eu* (.849) (whose impact is as twice as larger than those in ORC), final consumption (.136) and then investment (.073). In OPC, a small but positive and significant impact of final consumption and investment on CO_2 emissions is also observed. It is possibly due to the growth of a demand inclined towards goods with higher CO_2 emissions or energy use ratios. In OPCs with initial poor infrastructures and rapid demographic growth, such as Tunisia and Morocco, a large part of the demand in goods investment is made out of the new infrastructures and residential, commercial, and industrial buildings. Building activities lead to higher cement demand and production, which is a major source of CO_2 emissions that are not only due to energy use but also to the chemical process involved in the production of cement (Andrew 2019, p. 1675). In addition to cement, other industrial activities generate non-fossil fuel CO_2 emissions: mineral products, chemical products, and metal products. In 2016, their contribution to CO_2 emissions in China was, for example, 5% (Cui et al., 2019, p.1). The non-energy use of oil is also a source of the CO_2 that is not directly related to the energy use such as the production of petrochemical feedstocks, lubricants, solvents, and bitumen (Patel et al., 2005; Krtková et al., 2019). Consequently, an increase in the intermediate and final demand for these products may have a positive influence on CO_2 emissions without any significant impact on the energy use. In OPC, this may be explained by a negative impact of investment and final consumption on energy use combined with a positive impact on CO_2 emissions.

6 The level of technology is defined by the World Bank as a Research and Development Expenditure (% of GDP). Technology levels are 0.53, 0.61, 0.71 and 0.6, respectively, in Algeria, Egypt, Morroco and Tunisia. However, technology levels are higher, 1.67, 2.19, 2.8 and 3.04, respectively, in the United Kingdom, France, the United States and Germany (WDI, 2017).

7 On the contrary, Acheampong (2018) reports a negative relationship.

CONCLUSION

Internationally, energy availability is one of the major drivers of growth. However, in the last century, most of the energy used in the world came from non-renewable sources, which in turn resulted in huge CO_2 emissions. Consequently, several research papers have recently tried to study the relationships between economic growth, final consumption, investment, energy use and CO_2 emissions at the international, regional and local levels. However, few have explicitly made comparisons between ORCs and OPCs. The value of the comparison lies in its relevance from an environmental policy perspective. In these two groups of countries, very different patterns of interconnections between economic variables and energy and CO_2 variables are observed. Panel FGLS estimations indicate that in all the MENA countries under investigation, the link between energy use and CO_2 emissions is bi-directional and strongly positive. However, it is nearly as twice as higher in OPC than in ORC. Accordingly, environmental policies aimed at loosening the link between energy use and CO_2 emissions should have a stronger environmental impact on OPC than on ORC. This is taking the form of programs of substitution of fossil energies by renewable energies and the promotion of more efficient methods of the energetic conversion and CO_2 capture.

It is also observed that in ORC, GDP is not associated with the level of energy use. This is strongly and positively related to CO_2 emissions. Besides, CO_2 emissions in ORC would also have a positive correlation with GDP, which is explained by the huge amounts of CO_2 generated through oil extraction and refinery with no connection to the energy use. This results in a low level of incentive to fight CO_2 emissions and may potentially have adverse consequences for the economic growth if the development and the implementation of the greener processes result in higher production costs. Therefore, specific CO_2 policies will have to be developed for ORC with the aim to weaken the link between CO_2 emissions and GDP. It takes the form of a new technology promotion in the oil industry but with a macro-economic diversification (IMF, 2003). The second option may be the best one in the long perspective, since it increases macroeconomic resilience in case of any cropping-up of oil crisis and future depletion of the reserves.

Regarding the OPC, a bi-directional relationship between GDP and the level of energy use is observed, whereas CO_2 emissions show a tendency to reduce GDP (the reverse link is negative but not significant). The negative link between CO_2 emissions and economic growth creates a positive incentive in favor of the CO_2 emission reduction programs through the promotion of renewable energy and the switch to technologies with higher energetic return (Johnstone et al., 2008, p. 19). In these countries, investment and final consumption have a negative impact on energy use. This is clearly the result of a shift in consumer and investment behaviors in favor of new energy saving goods and technologies. Despite that negative impact on energy use, a slight positive impact of final consumption and investment on CO_2 emissions is also observed. This could have been the result of evolution in demand that favors activities with higher levels of non-energy use of oil and/or higher non-oil CO_2 emissions. Unfortunately, this study does not offer evidence for that hypothesis.

Highlights

- The relationship between economic growth and the environment varies strongly between OPC and ORC MENA countries.
- In ORC, there is no significant relationship between energy use and GDP, but there is a positive bi-directional link between CO_2 emissions and GDP.
- In OPC, there is a bidirectional positive link between GDP and energy use, whereas the impact of CO_2 emissions on GDP is negative.
- In ORC and OPC, the link between energy use and CO_2 emissions is bi-directional and strongly positive.

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APPENDIX A

Table A1. Definitions of the World Development Indicators used in the study

Source: World Bank (2020).

Indicator name	Source note
GDP per capita (constant 2010 USD)	"GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant 2010 U.S. dollars." World Bank (2020), entry NY.GDP.PCAP.KD
Gross capital formation (constant 2010 USD)	"(formerly gross domestic investment) consists of outlays on additions to the fixed assets of the economy plus net changes in the level of inventories. Fixed assets include land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings. Inventories are stocks of goods held by firms to meet temporary or unexpected fluctuations in production or sales, and "work in progress." According to the 1993 SNA, net acquisitions of valuables are also considered capital formation. Data are in constant 2010 U.S. dollars." World Bank (2020), entry NE.GDI.TOTL.KD
Final consumption expenditure (constant 2010 USD)	"Final consumption expenditure (formerly total consumption) is the sum of household final consumption expenditure (formerly private consumption) and general government final consumption expenditure (formerly general government consumption). Data are in constant 2010 U.S. dollars." World Bank (2020), entry NE.CON.GOVT.KD
Energy use (kg of oil equivalent per capita)	"Energy use refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport." World Bank (2020), entry EG.USE.PCAP.KG.OE
CO_2 emissions (metric tons per capita)	"Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring. Source: Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States." World Bank (2020), entry EN.ATM.CO2E.PC
Population, total	"Total population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship--except for refugees not permanently settled in the country of asylum, who are generally considered part of the population of their country of origin. The values shown are midyear estimates. Source: World Bank staff estimates from various sources including census reports, the United Nations Population Division's World Population Prospects, national statistical offices, household surveys conducted by national agencies, and Macro International." World Bank (2020), entry SP.POP.TOTL

APPENDIX B

Table B1. Panel-corrected: rhos

ORC	Eq1	Eq2	Eq3	Eq4	Eq5	OPC	Eq1	Eq2	Eq3	Eq4	Eq5
Algeria	0.849	.923	.925	.697	.547	Tunisia	–	.903	.817	–	–
Iran	0.658	.596	.834	.826	.882	Israel	–	.613	.763	–	–
Oman	0.593	.714	.633	.846	.809	Morocco	–	.776	.820	–	–
Saudi Arabia	0.701	.739	.516	.817	.742	Egypt	–	.870	.777	–	–

APPENDIX C. OIL RICH COUNTRIES (ORC)

1. TESTING FOR FIXED EFFECTS (F-TEST)

The hypotheses to be tested are:

H0: *All individual intercepts = 0 ($\alpha_i = 0$ in the regression model $Y_{it} = \alpha_i + x_{it}^{'}\beta + \varepsilon_{it}$).*
H1: *Individual intercepts ≠ 0.*

Value	Eq1	Eq2	Eq3	Eq4	Eq5
F(3, 156)	7.31	26.93	18.27	16.92	15.21
Prob. > F	0.00	0.00	0.00	0.00	0.00

Here, the p-value is small enough (at < 0.01 level) to reject the null hypothesis (*H0*) in five equations. So there is a significant fixed effect (FE), and the FE model is thus preferred than a Pooled OLS model.

2. TESTING FOR RANDOM EFFECTS (BREUSCH-PAGAN LM TEST)

The hypotheses to be tested are:

H0: *All individual specific variance components = 0 (α_i = 0 in the regression model $Y_{it} = x_{it}^{'}\beta + \left(\alpha_i + \varepsilon_{it}\right)$.*

H1: *Individual specific variance components ≠ 0.*

Value	Eq1	Eq2	Eq3	Eq4	Eq5
Chibar2(01)	0.00	0.00	0.00	0.00	0.00
Prob. > chibar2	1.00	1.00	1.00	1.00	1.00

Here, the p-value is big enough (at > 0.05 level) to accept the null hypothesis (*H0*) in five equations. Thus, the random effect is not significant, and the Pooled OLS model is thus preferred to the random effect.

After testing for individual specific effects (fixed effect and random effect), it can be deduced that the regression model should be an individual FE model verified by the Hausman test.

3. TESTING BETWEEN FE AND RE (HAUSMAN TEST)

The hypotheses to be tested are:

H0: *Individual specifics are random: $E(\alpha_i + \varepsilon_{it}/x_{it} = 0)$.*
H1: *Individual specifics are fixed.*

Value	Eq1	Eq2	Eq3	Eq4	Eq5
chi2(4)	25.59	64.64	52.46	74.97	47.31
Prob. > chi2	.00	.00	.00	.00	.00

Here, the p-value is big enough (at < 0.05 level) to reject the null hypothesis (*H0*) in five equations. Therefore, the effects are fixed and the regression model should be an individual FE.

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4. TESTING FOR INTRA AND INTER INDIVIDUAL HETEROSCEDASTICITY (BREUSCH-PAGAN TEST AND MODIFIED WALD TEST)

- Intra-individual heteroscedasticity (Breusch-Pagan test)

The hypotheses to be tested are:

H0: *The variance of the error is constant over time for each individual* ($\sigma_{it}^2 = \sigma^2 \, \forall \, i,t$, $\sigma_{it}^2 = \sigma_i^2 \, \forall \, t = 1,.,k$, *and* $\sigma_i^2 = \sigma^2 \, \forall \, i = 1,\ldots,N$).

H1: *The variance of the error changes over time.*

Value	Eq1	Eq2	Eq3	Eq4	Eq5
F(4, 159)	118.16	111.81	118.57	78.83	105.10
Prob > F	0.00	0.00	0.00	0.00	0.00

Here, the p-value is small enough (at < 0.01 level). This leads to a strong rejection of the null hypothesis (*H0*) in five equations for any confidence level. Therefore, there is a phenomenon of intra-individual heteroscedasticity.

- Inter individual heteroscedasticity (modified Wald test)

The hypotheses to be tested are:

H0: *The variance of the error is the same for all individuals* ($\sigma_i^2 = \sigma^2 \, \forall \, i = 1,\ldots,N$).
H1: *The variance of the error changes between individuals.*

Value	Eq1	Eq2	Eq3	Eq4	Eq5
chi2 (4)	40.23	138.17	4.67	182.17	27.48
Prob>chi2	0.00	0.00	0.32	0.00	0.00

Here, the overall statistic $\chi^2(N)$ has a $p = 0.0000 > 5\%$ only in Eq3. This leads to the acceptance of the null hypothesis (*H0*) for any confidence level. Therefore, a phenomenon of inter individual heteroscedasticity is absent in Eq3 but is present in other four equations.

5. TESTING FOR CROSS-SECTIONAL CORRELATION (BREUSCH-PAGAN LM TEST)

The hypotheses to be tested are:

H0: *The error terms are not correlated across entities.*
H1: *The error terms are correlated across entities.*

Value	Eq1	Eq2	Eq3	Eq4	Eq5
chi2(6)	34.44	29.44	41.75	52.65	17.62
Prob. > chi2	0.00	0.00	0.00	0.00	0.00

Here, the overall statistic $\chi^2((N(N-1))/2)$ has a $p = 0.0000 \leq 5\%$ in five equations. This leads to rejection of the null hypothesis for any confidence level. Consequently, the errors exhibit cross-sectional correlation in five equations.

6. TESTING FOR AUTOCORRELATION WITHIN UNITS (WALD TEST)

The hypotheses to be tested are:

H0: *No first-order autocorrelation.*
H1: *There is first-order autocorrelation.*

Value	Eq1	Eq2	Eq3	Eq4	Eq5
F(1, 3)	170.83	48.29	29.52	26.03	10.17
Prob. > F	0.00	0.00	0.01	0.01	0.04

P value ≤ 5% in five equations. This leads to rejection of the null hypothesis and validation of the presence of first-order autocorrelation in five equations. Appendix D. Oil Poor Countries (OPC)

7. TESTING FOR FIXED EFFECTS (F-TEST)

The hypotheses to be tested are:

H0: *All individual intercepts = 0 ($\alpha_i = 0$ in the regression model $Y_{it} = \alpha_i + x_{it}^{'}\beta + \varepsilon_{it}$).*
H1: *Individual intercepts ≠ 0.*

Value	Eq1	Eq2	Eq3	Eq4	Eq5
F(3, 156)	103.76	50.46	9.57	73.96	3.96
Prob. > F	0.00	0.00	0.00	0.00	0.00

Here, the p-value is small enough (at < 0.01 level) to reject the null hypothesis (*H0*) in five equations. So there is a significant fixed effect (FE) and the FE model is thus preferred than a Pooled OLS model.

8. TESTING FOR RANDOM EFFECTS (BREUSCH-PAGAN LM TEST)

The hypotheses to be tested are:

H0: *All individual specific variance components = 0 ($\alpha_i = 0$ in the regression model $Y_{it} = x_{it}^{'}\beta + \left(\alpha_i + \varepsilon_{it}\right)$.*

H1: *Individual specific variance components ≠ 0.*

Value	Eq1	Eq2	Eq3	Eq4	Eq5
chibar2(01)	0.00	0.00	0.00	0.00	0.00
Prob. > chibar2	1.00	1.00	1.00	1.00	1.00

Here, the p-value as big enough (at >0.05 level) to accept the null hypothesis (*H0*) in five equations. Thus, the random effect is not significant and the Pooled OLS model is thus preferred to the random effect.

After testing for individual specific effects (fixed effect and random effect), it can be deduced that the regression model should be an individual FE model verified by the Hausman test.

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9. TESTING BETWEEN FE AND RE (HAUSMAN TEST)

The hypotheses to be tested are:

H0: *Individual specifics are random:* $E(\alpha_i + \varepsilon_{it}/x_{it} = 0)$.
H1: *Individual specifics are fixed.*

Value	Eq1	Eq2	Eq3	Eq4	Eq5
chi2(4)	233.01	67.85	29.78	64.36	12.48
Prob. > chi2	.00	.00	.00	.00	.01

Here, the p-value as big enough (at < 0.05 level) to reject the null hypothesis (*H0*) in five equations. Therefore, the effects are fixed and the regression model should be an individual FE.

10. TESTING FOR INTRA AND INTER INDIVIDUAL HETEROSCEDASTICITY (BREUSCH-PAGAN TEST AND MODIFIED WALD TEST)

- Intra-individual heteroscedasticity (Breusch-Pagan test)

The hypotheses to be tested are:

H0: *The variance of the error is constant over time for each individual* ($\sigma_{it}^2 = \sigma^2 \, \forall i,t$, $\sigma_{it}^2 = \sigma_i^2 \, \forall t = 1,.,k$, *and* $\sigma_i^2 = \sigma^2 \, \forall i = 1,\ldots,N$).

H1: *The variance of the error changes over time.*

Value	Eq1	Eq2	Eq3	Eq4	Eq5
F(4, 159)	288.13	275.60	288.42	286.89	286.76
Prob. > F	0.00	0.04	0.00	0.00	0.00

Here, the p-value is small enough (at < 0.01 level). This leads to the strong rejection of the null hypothesis (*H0*) in five equations for any confidence level. Therefore, a phenomenon of intra-individual heteroscedasticity is present.

- Inter individual heteroscedasticity (modified Wald test)

The hypotheses to be tested are:

H0: *The variance of the error is the same for all individuals* ($\sigma_i^2 = \sigma^2 \, \forall i = 1,\ldots,N$).
H1: *The variance of the error changes between individuals.*

Value	Eq1	Eq2	Eq3	Eq4	Eq5
chi2(4)	12.66	282.79	12.15	74.71	2.04
Prob. >chi2	0.01	0.00	0.01	0.00	0.72

Here, the overall statistic $\chi^2(N)$ has a $p = 0.0000 \leq 5\%$ in Eq1, Eq2, Eq3 and Eq4. This leads rejection of the null hypothesis (*H0*) for any confidence level in these equations. Therefore, a phenomenon of inter individual heteroscedasticity is present in the four first equations but absent in Eq5.

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11. TESTING FOR CROSS-SECTIONAL CORRELATION (BREUSCH-PAGAN LM TEST)

The hypotheses to be tested are:

H0: *The error terms are not correlated across entities.*
H1: *The error terms are correlated across entities.*

Value	Eq1	Eq2	Eq3	Eq4	Eq5
chi2(6)	15.431	27.27	32.66	17.36	13.27
Prob. > chi2	0.01	0.00	0.00	0.00	0.03

Here, the overall statistic $\chi^2((N(N-1))/2)$ has a $p = 0.0000 \leq 5\%$ in five equations. This leads rejecting the null hypothesis for any confidence level. Consequently, the errors exhibit cross-sectional correlation in five equations.

12. TESTING FOR AUTOCORRELATION WITHIN UNITS (WALD TEST)

The hypotheses to be tested are:

H0: *No first-order autocorrelation.*
H1: *There is first-order autocorrelation.*

Value	Eq1	Eq2	Eq3	Eq4	Eq5
F(1, 3)	4.24	39.22	26.87	3.36	3.45
Prob. > F	0.13	0.00	0.01	0.16	0.16

P-value ≤ 5% only in Eq2 and Eq3. This leads to rejecting the null hypothesis and validating the presence of first-order autocorrelation only in Eq2 and Eq3.

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