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## Financial development and macroeconomic sustainability: modeling based on a modified environmental Kuznets curve

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1                                   **Financial development and macroeconomic sustainability:**  
2                                   **Modeling based on a modified environmental Kuznets curve**  
3

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17   **Abstract**

18   Sustainability has become an important and widely applied concept in the environmental economics  
19   literature. Despite the numerous studies employing an environmental Kuznets curve (EKC) this model  
20   has been critiqued for its incompleteness. This article builds a modified EKC model to examine the  
21   contribution of financial development for achieving sustainable development. Using data for 14  
22   selected [Middle East and North Africa \(MENA\)](#) countries during 1990-2017, the empirical results  
23   show that [the EKC hypothesis is valid for per capita CO<sub>2</sub> emissions and ecological footprint](#). The  
24   results provide evidence also of the presence of linear and non-linear relationships between financial  
25   development and non-sustainability and indicate that financial development is likely to have a small  
26   long-term impact on sustainable development. This suggests that current efforts aimed at protecting  
27   the environment and achieving sustainability will be ineffective given the extent of the problem.  
28

29   **Keywords:** Financial development; Sustainable development; Modified EKC-model  
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## 36 **1. Introduction**

37 Meeting the sustainable development goals (SDGs) has become a global issue. It has  
38 been suggested that their achievement will require a well-developed financial sector to  
39 stimulate economic growth, determine efficient resource allocation, and contribute to  
40 protecting the environment by financing viable and environmentally friendly projects. Several  
41 studies suggest that lack of a well-developed financial sector is a major barrier to sustainable  
42 development (e.g. Painuly and Wohlgemuth, 2006; García, 2013; Kayani et al., 2020).  
43 Drawing on this research, we contribute to this debate by examining how financial  
44 development contributes to macroeconomic sustainability in the MENA countries.

45

46 The present paper has three motivations: (i) the importance of the financial sector from a  
47 sustainability perspective, (ii) the strong need for the MENA economies to achieve  
48 sustainable development, and (iii) the need for the MENA countries to accelerate their energy  
49 transition and acknowledge the importance of the financial sector in advancing economic  
50 growth and enhancing sustainability.

51 First, financial development is essential for promoting stable and strong economic  
52 growth (Benhabib and Spigel, 2000; Ross, 2004; Thorsten et al., Ross 2004; Federici and  
53 Caprioli, 2009). The financial sector allocates capital among economic sectors and contributes  
54 to the management of risk. It provides investors with the capital needed to invest in the  
55 production of goods and services. However, there is considerable room for financial  
56 development in the MENA countries. For instance, in Algeria and Egypt, there is a high  
57 proportion of the population that does not have a bank account and a large proportion of the  
58 financial transactions in the MENA countries are made in cash. In their approach to  
59 addressing sustainable development issues such as climate change, global warming, and  
60 environmental pollution, policymakers could exploit this potential for financial development.

61 Second, environmental sustainability has been high on policy agendas since 2010.  
62 Most MENA countries signed the Paris agreement during COP 21 and need now to  
63 implement more environment-friendly policies. Taking advantage of financial development to  
64 implement such policies would be an innovative way to improve the situation in these  
65 countries. Global warming and climate change are causing natural disasters and increasing the  
66 vulnerability of this region, making greater environmental sustainability an urgent priority for  
67 the financial sector. The “greening” of the financial sector and the development of new

68 financial instruments and markets to achieve sustainable development could be part of the  
69 solution to the global environmental problem. Sustainable development should become a  
70 management priority. Investment and management decisions should consider sustainability  
71 (UNEP Finance Initiative, 2007) and the modern financial industry should take into account  
72 the constraints on economic sustainability. Environmental awareness among consumers and  
73 investors in the developed economies has triggered many and rapid changes in the financial  
74 sectors of these countries. In contrast, regulation is driving the greening of the financial sector  
75 in the MENA countries. Therefore, understanding the contribution of the financial sector to  
76 achieving sustainability in the MENA region has become an urgent issue at the economic and  
77 political levels.

78 Finally, our study is driven by the need for the MENA countries to accelerate their  
79 energy transition and acknowledge the important role of the financial sector for advancing  
80 economic growth and enhancing sustainability. All the MENA countries have set renewable  
81 energy and energy efficiency targets. For instance, Morocco aims to reach 30% of renewables  
82 in electricity production by 2020 while Algeria has set a target of 27% (22 GW) by 2030  
83 (Belaïd and Youssef, 2017). Financial sector growth is correlated to this economic  
84 transformation and energy transition. Thus, it is assumed that financial development –based  
85 on an efficient banking system and availability of capital through the financial markets– will  
86 have a major impact on the speed of energy transition and the sustainability of the MENA  
87 economies. The financial sector is expected to play a key role in shaping energy transition and  
88 enhancing sustainability in the MENA countries.

89 This study extends the literature in several ways. First, it proposes a modified EKC  
90 model which incorporates financial development and genuine savings as a measure of  
91 sustainable development. The model examines the contribution of the financial sector to the  
92 achievement of sustainable development by the MENA countries. To the best of our  
93 knowledge, there are no empirical studies of the relationship between financial development  
94 and sustainable development. Second, the study shows that the relationship between financial  
95 development and unsustainability is non-linear i.e. initially unsustainability increases with  
96 financial development but after a given level of financial development it begins to decline.  
97 Third, among the various indicators of financial development, we use principal component  
98 analysis (PCA) to select among three indicators of financial development: M2 (broad money  
99 as a percentage of GDP), M3 (liquid liabilities as a percentage of GDP), and total credit to the  
100 private sector as a percentage of GDP. Our choice of PCA is that (i) it addresses the  
101 multicollinearity problem and the high correlation among various financial development

102 indicators, and (ii) it overcomes the problem of lack of consensus on the appropriate measures  
103 of financial sector development.

104 The paper is organized as follows. Section 2 describes how sustainability and green  
105 growth affect financial market and investor decisions and reviews the macroeconomic  
106 literature linking financial development to sustainability. Section 3 presents the empirical  
107 methodology and section 4 summarizes and analyzes the results. Section 5 concludes with  
108 some policy implications.

## 109 **2. Finance and sustainability**

### 110 *2.1. What is green finance and sustainable finance?*

111  
112 Green finance includes future-oriented financial processes, products, and services  
113 which combine environmental improvement, economic growth, and financial industry  
114 developments. Sustainable finance refers to more comprehensive and inclusive investments  
115 which take account of environmental, social, and governance aspects (Noh, 2018).  
116 Sustainable financial tools include among others, green bonds, green lending, and green  
117 equity investment. Green bonds are used to finance green projects. There are many types of  
118 green bonds including climate bonds which are related to climate change adaptation or  
119 mitigation projects (Croce, et al., 2011). In 2017, global green bonds accounted for \$121.9  
120 billion, representing 87.1% of the world's sustainable finance market (HSBC, 2018). In  
121 addition to green bonds, banks offer green loans mostly used to finance projects aimed at  
122 protecting the environment. At the same time, investors are adopting various sustainable  
123 investment strategies such as green equity investments involving mainly equity funds and  
124 index investing (Kahlenborn et al., 2017).

125 Obtaining funding and raising capital in the context of the green economy requires  
126 developed financial markets. Many green economy projects are associated to high returns but  
127 should not be seen as mere commercial opportunities; they allows the financial industry to  
128 behave in a socially responsible way by contributing to the shift to a low-carbon economy and  
129 a more sustainable world. Mitigation of climate change and adaptations to reduce the effects  
130 of climate change require the participation of various organizations and sectors including  
131 financial services. In the period to 2035 some \$90 trillion of investment in sustainable  
132 infrastructure will be needed to reduce world carbon emissions (Bhattacharya et al., 2015).  
133 The United Nations Environment Program (UNEP) estimates that the transition to a low  
134 carbon world will cost \$60 trillion by 2050 with \$35 trillion going to support decarbonization  
135 of energy and the remaining \$25 trillion to supporting climate change adaptation. Additional

136 investment in green sectors will be needed to advance the move towards a low carbon and  
137 climate resilient economy (Campiglio, 2016). For instance, the integration of green and  
138 sustainable finance requires financial professionals to have green finance knowledge and  
139 skills and availability of a wide range of innovative products and services especially in the  
140 insurance sector. Thus, green finance must shift from the provision of financial services to  
141 becoming a primary banking and finance provider. Environmental sustainability remains a  
142 long way off since significant funding continues to be allocated to destructive environmental  
143 activities including use of fossil fuel which has long-term catastrophic effects on climate  
144 change. Green financing and sustainability can be tackled only through the provision of  
145 significant investment in low-carbon technologies to reduce the impact of climate change.

146         The emergence of the green economy is providing investors with new opportunities  
147 and the possibility to identify optimal green portfolios. According to Noh (2018), green  
148 investors benefit compared to traditional investors. Firms that create green value offer better  
149 financing opportunities and the value of green investments has increased more than traditional  
150 investments. Policy efforts and opportunities for green investors should be encouraged. Green  
151 financing is important for several reasons (Noh, 2018) including the increasing risk linked to  
152 environmental degradation and reduced availability of natural resources. Firms need to deal  
153 with these risks to avoid potential economic losses. Stakeholders are requiring firms and  
154 financial agencies to be socially responsible and there is greater social awareness about  
155 climate change, exhaustion of natural resources, and environmental degradation which is  
156 promoting stricter international agreements and environmental regulation. Finally, firms'  
157 management strategies are emphasizing sustainability. Green finance has two effects (Noh,  
158 2018), namely, (i) mitigation of environmental damage, in particular the effects of climate  
159 change on human capital and economic systems, and (ii) support for green growth. The green  
160 growth paradigm combines economic growth and environmental protection which require  
161 capital financing.

162         The financing of green industries will involve several problems. First, there is a high  
163 level of uncertainty related to investment in green industries whose assets tend to be more  
164 intangible. Second, green industry enterprises feature high information asymmetry (Noh,  
165 2018). From the investor's point of view, the risks linked to sustainability and climate change  
166 incidents in recent years are a concern, and stakeholders in equity markets and credit rating  
167 agencies consider such investments and financing decision risks as non-trivial(Weber, 2014;  
168 Weber, Scholz, & Michalik, 2010). Also, Lopez and Toman (2006) point out that failure to

169 achieve sustainability is often the result of weak legal systems and financial markets,  
170 underinvestment in human and social capital, corruption, and rent seeking behavior.

171

## 172 2.2. *The role of financial development in decarbonization and sustainability*

173

174 The EKC literature includes analyses of the link between financial development and  
175 carbon emissions. This body of work is reviewed in detail since it is connected to the topic of  
176 our study. The EKC hypothesis is based on the link between environmental degradation and  
177 income. It assumes that up to a certain level carbon emissions increase with per capita income  
178 beyond which the relationship reverses and environmental pollution starts decreasing<sup>1</sup>.  
179 Grossman and Krueger's (1991) pioneering study tests Kuznets's (1955) assumptions and  
180 their findings have become the basis of much EKC research. However, the results of these  
181 empirical studies are inconclusive (Omri et al., 2015). Some find a linear link between income  
182 growth and CO<sub>2</sub> emissions (Shafik, 1994; Omri, 2013) while others report an N-shaped  
183 (Friedl and Getzner, 2003; Onafowora and Owoye, 2014), a U-shaped (Omri, 2018), or no  
184 relationship (Richmond and Kaufmann, 2006; Tiba and Omri, 2017). Tamazian et al. (2009)  
185 show that there are other variables that might affect environmental quality and should be  
186 included in the EKC model. They consider financial sector development to be a major  
187 contributor to sustainable development. Frankel and Romer (1999) also include financial  
188 development in the EKC function and find that improved environmental quality is sensitive to  
189 the level of financial development which attracts more foreign investment and in turn  
190 enhances economic growth and reduces environmental quality through the consumption of  
191 more energy (Islam et al., 2013). In contrast, financial development leads to use of  
192 environmentally friendly technology which decreases pollution and promotes economic  
193 growth (Omri et al., 2019).

194 Moreover, Steffen et al. (2015) update the great acceleration graphs and consider the joint  
195 presence of foreign direct investment, international tourism, and telecommunications as  
196 leading to increased globalization and connectivity. Primary energy use is a key indicator  
197 related directly to the carbon footprint and its effect on the functioning of the earth system; it

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<sup>1</sup> Most of the EKC literature assumes weak sustainability and does not take account of irreversibility and other issues linked to "strong sustainability". The studies in this strand of work use "CO<sub>2</sub> emissions, SO<sub>2</sub> emissions or GHG emissions in general" to proxy for environmental quality. Few papers extend the EKC framework to consider more complex indexes. In our work, despite these limitations we use Genuine savings (GS) as proxy for environmental quality (sustainability). This construct considers more environmental assets in its composition and tries to examine different facets of environmental degradation. However, the construct is still considered as a construct of a weak sustainability. These shortcomings should be considered when interpreting our results.

198 is considered a key feature of contemporary society. Lagoarde-Segot and Martinez (2020, p.  
199 14) consider ecological finance theory which states that “the world has entered the  
200 Anthropocene and posits that the fairness and efficacy of a financial system cannot be  
201 evaluated based on the monetary signals that it generates internally, but by examining  
202 feedbacks with the biophysical and socioeconomic spheres” . According to Nystrom (2019), it  
203 is necessary to redirect finance, increase transparency and traceability in supply chains, and  
204 involve a multitude of players in order to steer the global production ecosystem towards a  
205 sustainable trajectory.

206 Several works examine the financial development-environmental quality nexus but the  
207 findings are mixed . For example, Jalil and Feridn (2011) use Chinese data to investigate the  
208 effects of financial development, energy use, and income on environmental quality and find  
209 that financial sector development has no impact on reducing CO<sub>2</sub> emissions in China. Ozturk  
210 and Acaravci (2013) employ the ARDL approach and find no significant effect of financial  
211 sector development on CO<sub>2</sub> emissions although in the case of Pakistan, Javid and Sharif  
212 (2016) find a quadratic link between financial development and environmental degradation  
213 i.e. that financial development initially increases CO<sub>2</sub> emissions but beyond a certain level of  
214 financial development, the effect becomes negative. Dar and Asif (2018) find similar results  
215 for Turkey. and Haseeb et al. (2018) analyze the effect of financial sector development on  
216 environmental quality for the BRICS economies using a standard EKC model. They show that  
217 financial development increases carbon emissions in these economies.

218

### 219 *2.3. The case of the MENA region countries*

220 Only a few studies assess the link between financial development and environmental  
221 degradation in the MENA countries. However, the effect of financial development on the  
222 environment in the countries is of concern. Arouri et al. (2012) examine the relationship  
223 between CO<sub>2</sub> emissions, energy consumption, and real GDP in the MENA countries and find  
224 no confirmation of an EKC except in the case of Jordan. In almost all countries the estimated  
225 long-run coefficient of income and its square support the EKC hypothesis. However, in some  
226 cases the turning points of the EKC are very low in some cases they are very high which  
227 provides only weak support for the EKC hypothesis. Omri et al. (2015) examine 12 MENA  
228 countries using a simultaneous equation modeling approach which includes financial  
229 development in the standard EKC function. They show that financial development decreases  
230 carbon emissions only in Jordan. Omri et al. (2019) examine the non-linear link between  
231 financial development, human development, FDI, trade, and environmental sustainability in



232 the case of Saudi Arabia and find that financial sector development initially increases carbon  
233 emissions but after a certain level they decline. They suggest that the level of financial  
234 development in Saudi Arabia should be boosted to a certain level to achieve a positive effect  
235 on environmental sustainability.

236 Charfeddine and Kahia (2019) employ a panel vector autoregressive (PVAR) model to  
237 investigate the impact of renewable energy and financial development on CO<sub>2</sub> emissions and  
238 economic growth in 24 MENA countries. They show that renewable energy consumption and  
239 financial development have a minor influence and only explain a small part of CO<sub>2</sub> emissions  
240 and economic growth. Their findings suggest that the financial and renewable energy sectors  
241 in MENA countries need to be strengthened to improve the contribution to economic growth  
242 and environmental quality. Gaies et al. (2019) examine the relationship between financial  
243 development and energy consumption in the MENA countries and find that financial  
244 development has positive impact on energy demand in these countries. They suggest that  
245 when modeling energy demand, financial development variables need to be included to  
246 address energy reduction and greenhouse gas emissions issues. Muhammad (2019) also finds  
247 a positive relationship between financial development and energy consumption in the MENA  
248 countries.

249 Ekwueme and Zoaka (2020) use FMOLS (fully modified ordinary least squares) and  
250 DOLS (dynamic ordinary least squares), to examine the influence of financial development,  
251 willingness to trade, and utilization of energy on CO<sub>2</sub> emissions in the case of 10 MENA  
252 countries. Their main finding is of a negative relationship between financial development and  
253 CO<sub>2</sub> emissions, meaning that higher levels of financial development result in reduced CO<sub>2</sub>  
254 emissions. Nathaniel et al. (2020) employ an augmented mean group algorithm, to examine  
255 the impact on the environment of renewable and non-renewable energy consumption in the  
256 MENA countries, accounting for financial development. They suggest that urbanization,  
257 economic growth, and financial development contribute to environmental degradation in the  
258 region, pointing to the need for environmentally-friendly energy sources. Similarly, Saidi  
259 (2020) found that CO<sub>2</sub> emissions are driven by growth, urbanization, openness to trade, and  
260 financial development.

261 Awan et al. (2020) investigated the impact of globalization and financial development  
262 on CO<sub>2</sub> emissions in six MENA countries. Using panel data, they show that globalization and  
263 financial development have an adverse and significant impact on the environment. Their  
264 results also support the EKC hypothesis for the MENA countries included in their study.  
265 Yilanci and Gorus (2020) examine the impact of economic globalization on the ecological

266 footprint of 14 MENA countries. Their findings indicate that financial globalization can  
267 predict the environmental degradation in MENA countries.

268  
269

### 270 3. Empirical methodology

#### 271 3.1. Model specifications

272 Critique of the standard EKC formulation has promoted intense discussion over  
273 alternatives ways to illustrate the causality between income growth and per capita CO<sub>2</sub>  
274 emissions. For example, Tamazian et al. (2009) indicate that to avoid omitted variables bias in  
275 the econometric estimations, other variables than income, energy use, and CO<sub>2</sub> emissions  
276 need to be included in the EKC function. Several studies include other major determinants of  
277 carbon emissions such as trade liberalization to test the “pollution haven hypothesis”<sup>2</sup> (Ang,  
278 2009; Omri et al., 2015). Other works argue that the inclusion of control variables such as the  
279 manufacturing sector, human development indicators (Ben Youssef et al., 2016), and the  
280 financial sector (Pata, 2018; Omri e al., 2019) would increase the representativeness of the  
281 EKC model.

282 Based on the above, we propose the following EKC function

$$283 E_{it} = \alpha_0 + \alpha_1 Y_{it} + \alpha_2 Y_{it}^2 + \alpha_3 EC_{it} + \alpha_4 T_{it} + \alpha_5 MAN_{it} + \alpha_6 MHDI_{it} + \alpha_7 F_{it} + \mu_{it} \quad (1)$$

284 In equation (1), we include MHDI (a modified HDI) to substitute for HDI which does  
285 not include per capita GDP. Also in excluding income, the MHDI avoids multicollinearity  
286 between the human development index (HDI) and economic growth (Y). Instead of  
287 controlling for omitted variables by including additional explanatory variables in the standard  
288 EKC model, we build a more sustainably oriented EKC model which includes financial  
289 development as an explanatory variable and as a sustainability instrument. Financial  
290 development allows investors to use advanced environmentally friendly technologies for  
291 production which improves both environmental quality and economic development (Shahbaz  
292 et al. 2013a). Financial development also has an impact on environmental degradation (Omri  
293 et al., 2015). Using data for Indonesia, Shahbaz et al. (2013b) investigate the determinants of  
294 environmental degradation and find that the link between financial development and

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<sup>2</sup> Indicates that globalization (foreign direct investment and trade liberalization) increases pollution levels in host countries (Omri and Belhadj, 2020).

295 environmental degradation takes a quadratic form. This implies that a less developed financial  
 296 sector reduces environmental quality, and *vice versa*.

297 Following Shahbaz et al. (2013b), a first modification to the EKC model is given by:

$$E_{it} = \alpha_0 + \alpha_1 F_{it} + \alpha_2 F_{it}^2 + \alpha_3 Y_{it} + \alpha_4 E_{it} + \alpha_5 T_{it} + \alpha_6 MAN_{it} + \alpha_7 MHDI_{it} + \alpha_8 \theta_{it} \quad (2)$$

299 The linear and non-linear terms for financial development ( $F$  and  $F^2$ ) are introduced  
 300 into the model to assess the existence of an EKC between financial development and  
 301 pollution. To provide a more general framework for sustainability, we (i) include a more  
 302 comprehensive measure of development in the EKC model i.e. human development to replace  
 303 GDP ( $Y$ ) with, (ii) replace the dependent variable ( $E$ ) by an economic sustainable variable  
 304 (i.e. genuine saving -GS), and (iii) incorporate rule of law (RL) as a main determinant of  
 305 sustainability (Ben Youssef et al., 2018).

306 Based on the works of Ben Youssef et al. (2018), the macroeconomic sustainable  
 307 variable (GS) is described as follows

308

$$309 \quad GS = K - (F_R - f_r)(R - g) - b(e - d) \quad (3)$$

310 where  $K$ ,  $F_R$ ,  $f_r$ ,  $R$ ,  $g$ ,  $b$ ,  $e$ ,  $d$  denote respectively economic capital formation, resource rental  
 311 rates net of the marginal costs of extraction, resources extracted, natural growth rate for  
 312 renewables, the marginal cost of abatement, pollution, and natural dissipation.

313 Genuine saving (GS) is based on the hypothesis of a limit and a perfect value of  
 314 sustainability where

315

- 316 • *Non-sustainability(-GS)*  $\rightarrow GS < 0$
- 317 • *Minimum level of sustainability*  $\rightarrow GS = 0$
- 318 • *Sustainability(+GS)*  $\rightarrow GS > 0$

319

320 The quadratic link between per capita income and carbon emissions in equation 1 can  
 321 be reformulated using a modified EKC to introduce the non-linear terms of financial sector  
 322 development, substituting the environmental degradation-related dependent variable ( $E$ ) with  
 323 a negative GS ( $-GS$ ) as a measure of non-sustainability, and replacing GDP by HDI.  
 324 Therefore, the modified HDI is the sum of the education and life expectancy indices. Also,

325 excluding GDP from the modified HDI mitigates the multicollinearity problem between  
 326 GS saving and HDI.

327 The incorporation of additional variables in the standard EKC function allows the  
 328 effect of financial development on sustainable development to be analyzed. Thus, the standard  
 329 and modified EKC models are given respectively by equations 4 and 5

$$330 \quad E_{it} = \alpha_0 + \alpha_1 Y_{it} + \alpha_2 Y_{it}^2 + \alpha_3 EC_{it} + \alpha_4 T_{it} + \alpha_5 MAN_{it} + \alpha_6 MHDI_{it} + \alpha_7 F_{it} + \mu_{it} \quad (4)$$

$$331 \quad -GS_{it} = \lambda_0 + \lambda_1 F_{it} + \lambda_2 F_{it}^2 + \lambda_3 EC_{it} + \lambda_4 T_{it} + \lambda_5 MAN_{it} + \lambda_6 MHDI_{it} + \lambda_7 RL_{it} + \varepsilon_{it} \quad (5)$$

332

333 where  $i$  ( $i = 1 \dots N$ ) is country and  $t$  ( $t = 1 \dots T$ ) is the time period.  $\alpha_1 \dots, \alpha_7$  are the elasticities of  
 334 environmental degradation with respect to GDP, squared GDP, energy use, trade,  
 335 manufacturing, MHDI, and financial development respectively. In the first model, we use  
 336 CO<sub>2</sub> emissions and ecological footprints as measures of environmental degradation (E)<sup>4</sup>.  
 337

338 In equations 4 and 5, the expected signs of  $dY/dE > 0$ ;  $dF/dGS > 0$  and  $dY^2/dE < 0$ ;  
 339  $dF^2/dE < 0$  suggest a quadratic relationship between income and CO<sub>2</sub> emissions, and financial  
 340 development and sustainability. The signs of  $\alpha_3$  and  $\lambda_3$  are expected to be positive because  
 341 more energy use results in greater economic activity and leads to more environmental  
 342 pollution. The signs of  $\alpha_4$  and  $\lambda_4$  are expected to change depending on the stage of  
 343 development. The signs of  $\alpha_5$  and  $\lambda_5$  are expected to be positive indicating that a higher  
 344 manufacturing value added is associated to higher levels of environmental degradation and  
 345 GS per capita. The sign of  $\alpha_7$  depends *a priori* on the stage of development. In the early  
 346 stages, the financial sector is less concerned with environmental degradation. However, once  
 347 the economy matures, financial sector development benefits the environment through lending  
 348 for environmentally-friendly technologies to support domestic production. This implies that a  
 349 less developed (efficient) financial sector reduces (improves) environmental quality. The sign  
 350 on rule of law is expected to be negative, implying that greater control over corruption  
 351 reduces negative genuine saving. Finally, the presence of financial development and genuine  
 352 saving in the MEKC allows assessment of the link between financial development and  
 353 sustainable development.

### 354 3.2. Data description and financial development measures

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<sup>4</sup> Most studies use CO<sub>2</sub> emissions to measure environmental degradation but these represent a small proportion of total environmental degradation (Al-Mulali et al., 2015).

355 *3.2.1. Data description*

356 To study the contribution of financial development to sustainable development using a  
 357 MEKC, we analyze 14 MENA countries over 1990-2017. These countries are Algeria,  
 358 Bahrain, Egypt, Iran, Jordan, Kuwait, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia,  
 359 Turkey, and United Arab Emirates. We include CO<sub>2</sub> emissions (C) and ecological footprint  
 360 (ECL) as dependent variables to allow comparison between the standard and modified EKC.

361 The models include: CO<sub>2</sub> emissions (C) and ecological footprint (ECL) to measure  
 362 environmental degradation (E), per capita income (GDP, Y) to measure economic growth, per  
 363 capita energy use (EC), per capita trade defined as total exports plus imports, manufacturing  
 364 value added as a proportion of GDP (MAN), financial development (F) measured by total  
 365 credit to the private sector as a proportion of GDP, per capita –GS as a measure of sustainable  
 366 development, institutional quality measured by the rule of law, and MHDI measured as  
 367 secondary education plus life expectancy but excluding the GDP index (Y) to avoid  
 368 multicollinearity between GDP and HDI and between GDP and negative real saving (–GS).  
 369 Each country’s human development index is calculated as the simple arithmetic average of the  
 370 ???, ??? and ??? (Sagar and Najam, 1998; UNDP, 2008). The HDI formula depends on  
 371 these three indexes:

$$HDI = \frac{1}{3} GDP + \frac{1}{3} Education + \frac{1}{3} Life\ expectancy$$

372 Several studies modify the conventional HDI by subtracting the share of GDP. In this  
 373 case, the MHDI does not include an income factor and multicollinearity remains a potential  
 374 problem in the regression analysis. Costantini and Monni (2008) used a similar approach to  
 375 examine the linkage between sustainable development and economic growth for 179 countries  
 376 and Dhahri and Omri (2018) use it to explore the relationship between entrepreneurship and  
 377 sustainable development for the case of 20 developing countries.

378 MHDI is presented as follows:  $MHDI = \frac{1}{2} Education + \frac{1}{2} Life\ expectancy$

379 Table 1 reports the source and definition of the used variables.

381 **Table 1**  
 382 Variables definition and data sources

Variable	Definition	Data Source
Ecological footprint (ECL)	Natural logarithm of ecological footprint (gha per capita).	Global Footprint Network
CO <sub>2</sub> emissions (C)	Natural logarithm of CO <sub>2</sub> emissions (tons per capita).	World Development Indicators
Genuine Saving (–GS)	Natural logarithm of per capita GS (constant 2005 \$).	World Development Indicators
GDP (Y)	Natural logarithm of GDP per capita (constant 2005 \$).	World Development Indicators

Financial development (F)	Natural logarithm of Board money (M2) as share of GDP. Natural logarithm of liquid liabilities (M3) as share of GDP. Natural logarithm of total credit to the private sector as a share of GDP.	World Development Indicators
Foreign trade (T)	Natural logarithm of trade (imports and exports) as a share of GDP	World Development Indicators
Energy consumption (E)	Natural logarithm of energy use (oil equivalent per capita).	World Development Indicators
Human development (MHDI)	Measured by the Modified Human Development Index. The MHDI measures the average achievements in a country in two basic dimensions of human development (Education index and Life expectancy index).	Calculated using data from World Development Indicators
Manufacture (MAN)	Natural logarithm of manufacture value added as share of GDP.	World Development Indicators
Institutional quality	Rule of law	World Development Indicators

383

### 384 3.2.2. Financial development measure: Principal component analysis

385

386 PCA is used to select the best indicators of financial development among M2 (broad  
387 money as a share of GDP), M3 (liquid liabilities as a share of GDP), and total credit to private  
388 sector as a proportion of GDP (see e.g. Ang and McKibbin, 2007). We chose PCA because  
389 (i) it addresses the multicollinearity problem and the high correlation among the various  
390 indicators of financial development, and (ii) there is no consensus on the most appropriate  
391 measure of financial development.

392 The PCA results are reported in table 2. The eigenvalue related to the first component  
393 is greater than 1 (2.533). It accounts for around 84.4% of the standardized variance. The  
394 second (third) principal component explains another 13.4% (0.022%) of the standardized  
395 variation but with eigenvalues less than 1. In this case, the first principal component is related  
396 to total credit to the private sector and is the best indicator of financial development.

397 **Table 2**

398 Results of the principal component analysis (PCA).

Component	Eigenvalue	Difference	Proportion	Cumulative
1	2.533	2.132	0.844	0.844
2	0.401	0.335	0.134	0.978
3	0.066	–	0.022	1.000

399

### 400 3.3. Estimation procedures

401 We use a five-step empirical methodology to estimate equations 4 and 5: (i) checking  
 402 cross-section dependence (CD) for residuals using various statistic tests, (ii) examining the  
 403 stationary properties of our variables, (iii) testing for the presence of cointegration among the  
 404 variables, (iv) estimating the long run parameters of the two models considered, and (v)  
 405 examining short- and long-term causality among the variables.

406

407 **4. Empirical results and discussion**

408 Three CD statistical tests data (Friedman (1937); Frees (1995); Pesaran (2004, 2006,  
 409 2015) are used to check the presence of cross-section dependence in our. The results of these  
 410 tests are reported in table 3 and show that the null hypothesis of cross-section independence is  
 411 rejected. In this case, the first-generation panel unit root tests could produce biased results  
 412 (due to size distortions) (Apergis and Payne, 2014). Thus, it is desirable to implement second-  
 413 generation panel unit root tests (Chudik et al., 2011). Accordingly, we use a second-  
 414 generation panel unit root test, a cross-section augmented IPS (CIPS) which accounts for the  
 415 presence of cross-section dependence. Table 4 shows that at level, all the variables are non-  
 416 stationary but in first differences they are all integrated, indicating that our variables are  
 417 integrated at the order 1 (I(1)). Given the above results of the panel unit root tests, it is  
 418 possible to investigate the existence of long-run relationships among the variables using the  
 419 Westerlund (2007) panel cointegration test. Pedroni's (1999, 2004) and Kao's (1999) tests are  
 420 used as robustness checks for long-run relationships among the variables. The results in table  
 421 5 confirm the existence of long-run associations among the variables in both the EKC and  
 422 MEKC models. Thus, these statistical tests suggest that the variables included are  
 423 cointegrated.

424

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**Table 3**  
 Results of cross-sectional dependence (CD) tests.

	Friedman (1937)	Frees (1995)	Pesaran (2004)	Pesaran (2006)	Pesaran (2015)		
					LM	LM adj*	LM CD*
EKC model							
Statistics	121.493	11.622	8.770	10.006	309.226	103.329	6.061
Prob.	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
MEKC model							
Statistics	78.042	18.803	5.296	7.178	511.739	94.084	4.920
Prob.	0.000*	0.000*	0.004*	0.000*	0.000*	0.000*	0.000*

428

Note: The superscript \* denotes statistical significance at the 1% level. Null hypothesis: Cross-sectional independence.

429

430

**Table 4**  
 CIPS unit root tests.

Variables	CIPS test	
	Level	$\Delta$
ECL	-0.986 [1.000]	-6.302* [0.000]
C	-1.299 [0.822]	-8.091* [0.000]
Y	-1.834 [0.211]	-4.071* [0.000]
EC	-0.998 [1.000]	-3.990* [0.000]
T	-1.189 [0.902]	-7.760* [0.000]
MAN	-1.660 [0.452]	-5.077* [0.000]
MHDI	-1.697 [0.431]	-5.903* [0.000]
F	-1.420 [0.580]	-4.229* [0.000]
GS	-1.499 [0.489]	-6.039* [0.000]
RL	-1.541 [0.476]	-6.224* [0.000]

Note: The superscript \* and \*\* denote statistical significance at the 1% and 5% levels, respectively.

**Table 5**

Results of panel cointegration tests.

I–Westerlund (2007) panel cointegration test

	EKC model				MEKC model			
	Value	Z-value	P-value	Robust P-value	Value	Z-value	P-value	Robust P-value
Gt	-2.113	1.102	0.922	0.544	-2.691**	-4.006	0.036	0.018
Ga	-8.426*	2.447	0.004	0.000	-5.280*	-3.995	0.000	0.000
Pt	-10.622*	-4.148	0.000	0.000	-18.047*	-8.201	0.000	0.000
Pa	-13.079*	-3.368	0.000	0.000	-12.814*	-9.577	0.000	0.000

II– Pedroni (1999, 2004) panel cointegration test

	EKC model		MEKC model		
	<i>t</i> -statistics	Prob.	<i>t</i> -statistics	Prob.	
<i>Within-dimension</i>					
Panel v-stat	-3.812*	0.000	Panel v-stat	-2.890*	0.000
Panel rho-stat	-5.009*	0.000	Panel rho-stat	-5.188*	0.000
Panel ADF-stat	-6.798*	0.000	Panel ADF-stat	-5.872*	0.000
Panel PP-stat	-2.840*	0.000	Panel PP-stat	-4.773*	0.000
<i>Between-dimension</i>					
Group rho-stat	-5.219*	0.000	Group rho-stat	-0.938	0.329
Group ADF-stat	-4.2194*	0.000	Group ADF-stat	-6.495*	0.000
Group PP-stat	-2.446*	0.000	Group PP-stat	-3.048*	0.000

III– Kao's (1999) panel cointegration test

	EKC model		MEKC model		
	<i>T</i> -statistics	Prob.	<i>T</i> -statistics	Prob.	
ADF	-7.587*	[0.000]	ADF	-6.011*	[0.000]

Note: The superscripts \* and \*\* denote statistical significance at the 1% and 5% levels, respectively. Null hypothesis: No cointegration.

Table 6 presents the results of the long-run estimates of equations (4) and (5). The results of the EKC model show that economic growth has a positive effect on both CO<sub>2</sub> emissions and ecological footprint. The respective values 0.209 and 0.417 indicate that a 1% rise in economic growth raises carbon emissions and ecological footprint by 0.21% and 0.42%; thus, an increase in economic growth is expected to lead to an increase in carbon emissions. However, the coefficient of income squared is negative and significant for both environmental variables. The positive (negative) effects of per capita income (and its square) support the EKC hypothesis that environmental degradation initially increases but then begins to decrease as per capita income goes above a certain level which confirms Omri et al.'s (2015) findings for the MENA countries and Paramati et al.'s (2018) results for Vietnam.



448 Table 6 shows also that financial development contributes positively to per capita  
449 carbon emissions and per capita ecological footprint. A 1% rise in total credit to the private  
450 sector raises per capita CO<sub>2</sub> emissions and ecological footprint by around 0.22% and 0.18%,  
451 respectively. This finding contrasts with the results in Tamazian et al. (2009) that higher  
452 levels of financial development in the BRICS economies reduces environmental degradation.  
453 However, it supports the results in Zhang et al. (2011) that bank loans help Chinese  
454 companies to access external finance and enhances their investment levels, hence improving  
455 economic growth and environmental quality. The negative effect of financial sector  
456 development on carbon emissions in the MENA region suggests that a well-developed  
457 financial sector leads to lower CO<sub>2</sub> emissions and a reduced ecological footprint. Therefore,  
458 financial development could reduce carbon emissions by providing incentives for firms to  
459 use advanced-environmentally-friendly technologies in their production processes (Ben  
460 Youssef et al., 2018). A stable financial system which allows adoption of new technologies  
461 should improve environmental quality although this might not apply in periods of economic  
462 and financial instability. Governments in the MENA region need to balance improving  
463 environmental quality with development of their financial sectors.

464 We show also that energy use has the expected positive and significant impact on the  
465 two indicators of environmental degradation. A 1% increase in the use of energy increases  
466 carbon emissions and ecological footprint by around 0.32% and 0.28% respectively. The  
467 findings for the other control variables show that international trade and manufacturing value-  
468 added contribute positively to carbon emissions and ecological footprint, confirming the  
469 findings in Tiba and Omri (2015) for less developed countries which show that trade  
470 liberalization is accompanied by higher levels of environmental degradation due to  
471 delocalization of polluting industries and the pollution haven effect (Costantini and Monni,  
472 2008).

473 One of the objectives of this study was to examine the effectiveness of financial  
474 development for achieving sustainable development. The MEKC estimates show that  
475 financial development increases unsustainability (-GS). The coefficient of financial  
476 development shows that a 1% increase in financial sector development increases -GS by  
477 0.34%. However, the square of financial development reduces unsustainability (-GS). These  
478 positive and negative impacts of financial development show a quadratic relationship between  
479 financial development and -GS, meaning that initially non-sustainability increases with  
480 financial development up to a certain level after which it starts to reduce -GS and increase  
481 sustainability. Despite the non-linear link between non-sustainability and development of the

482 financial sector, since the financial sector coefficient (F) is superior to its squared value (F<sup>2</sup>),  
 483 an increase in financial development is likely to have only a small long-term impact on  
 484 sustainable development. Hence, given the scale of the problem there is no expectation that  
 485 current sustainable development efforts will be very effective. Many of the MENA economies  
 486 have large reserves of natural resources whose deployment does not contribute to  
 487 sustainability. We found also that foreign trade and rule of law decrease -GS by around 0.19%  
 488 and 0.04%, respectively similar to the findings in Costantini and Monni (2008).

489 Table 6 presents the short- and long-run Granger causality results for the EKC and  
 490 MEKC models. The coefficients of the error correction term (ECT) are significant which is  
 491 evidence of a stable long-run relationship among the variables. For the lagged ECT, we find a  
 492 long-run relationship among the variables considered in both models. The results show that all  
 493 the coefficients are statistically significant, and that there is bidirectional causality among  
 494 most of our considered variables.

495 **Table 5**  
 496 Long-run estimates for EKC and MEKC models.

Independent variables	EKC model				MEKC model	
	'C' as dependent variable		'ECL' as dependent variable		'-GS' as dependent variable	
	<i>Coef.</i>	<i>Prob.</i>	<i>Coef.</i>	<i>Prob.</i>	<i>Coef.</i>	<i>Prob.</i>
Y	0.209*	[0.000]	0.417*	[0.000]	–	–
Y <sup>2</sup>	-0.109**	[0.024]	-0.188*	[0.000]	–	–
F	0.223*	[0.000]	0.180*	[0.000]	0.196*	[0.000]
F <sup>2</sup>	–	–	–	–	-0.098**	[0.033]
EC	0.322*	[0.000]	0.282*	[0.002]	0.210*	[0.009]
T	0.097	[0.321]	-0.109	[0.231]	-0.185*	[0.000]
MAN	0.219*	[0.006]	0.199*	[0.000]	0.099	[0.217]
MHDI	0.107**	[0.000]	0.098*	[0.008]	0.129**	[0.043]
RL	–	–	–	–	-0.077**	[0.022]
Constant	-11.602*	[0.000]	-8.281*	[0.000]	-7.109*	[0.000]

497 Notes: P-values are reported in brackets. C and ECL denote per capita CO<sub>2</sub> emissions and per capita ecological footprint, respectively. The  
 498 superscripts \* and \*\* denote statistical significance at the 1% and 5% levels, respectively.  
 499

500  
 501 The results of the standard and the modified EKC show that per capita GDP, financial  
 502 development, energy use, manufacturing, trade, and human development have significant  
 503 causal impacts on CO<sub>2</sub> emissions and ecological footprint. In addition, in both models the  
 504 ECT is statistically significant, indicating that the speed of adjustment of all the variables to  
 505 the long-run equilibrium is relatively slow.

506 We found short and long-term causality among most of the variables considered in the  
 507 models, and a significant ECT for the remaining variables. These relationships suggest some  
 508 general implications related to the sustainability process. First, in line with work on the  
 509 standard EKC, achieving a sufficient level of sustainability with a positive effect of financial

510 development is difficult in the initial stages of economic development. Financial system  
511 development is a crucial condition for achieving this goal. However, the modified EKC shows  
512 that it is possible to invert and reduce non-sustainable growth in the mid term phases of  
513 economic development. Second, financial development facilitates achievement and  
514 maintenance of higher levels of future sustainable development . The positive impact of  
515 financial development is much higher than the negative impact of natural resources  
516 endowments. The resources curse can be nullified by appropriate financial system  
517 development with positive effects on sustainability and environmental quality. Third, higher  
518 quality institutions promote higher sustainable development. An economy with higher  
519 resources exploitation combined with poor institutions is expected to experience rent-seeking  
520 or Dutch disease effects resulting in reduced economic growth, and therefore, low levels of  
521 financial and human development (Ben Youssef et al., 2018). Excessive resources  
522 exploitation in the initial stages of development, associated to lower development of the  
523 financial system and poor institutional quality is expected to lead to non-sustainable  
524 development.

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**Table 6**  
Results of causality test.

Dependent variables		Short-run sources of causation (independent variables)								Long-run
EKC model		$\Delta E$		$\Delta Y (\Delta Y^2)$	$\Delta EC$	$\Delta T$	$\Delta MAN$	$\Delta MHD I$	$\Delta F$	ECT
		$\Delta C$	$\Delta ECL$							
$\Delta E$	$\Delta C$	–	–	0.994* [0.000]	0.272*** [0.080]	0.481* [0.000]	0.352* [0.000]	0.287* [0.000]	0.330* [0.001]	–0.119* [0.007]
	$\Delta ECL$	–	–	0.691* [0.000]	0.278* [0.000]	0.197** [0.030]	0.591* [0.000]	0.206* [0.000]	0.196** [0.014]	–0.213** [0.010]
$\Delta Y (\Delta Y^2)$		0.198* [0.000]	0.189** [0.013]	–	0.521** [0.021]	1.902* [0.000]	0.428* [0.000]	0.321** [0.026]	0.778* [0.000]	–0.052** [0.030]
$\Delta EC$		0.160 [0.211]	0.098 [0.302]	0.237** [0.040]	–	0.093 [0.271]	1.046* [0.000]	0.079 [0.111]	0.527* [0.000]	–0.229* [0.000]
$\Delta T$		0.092 [0.244]	0.209* [0.000]	0.176 [0.285]	0.388 [0.109]	–	0.389** [0.048]	0.106 [0.128]	0.293* [0.000]	–0.401* [0.000]
$\Delta MAN$		0.288** [0.000]	0.179** [0.020]	0.665* [0.000]	0.429* [0.000]	0.991* [0.000]	–	0.309* [0.000]	0.129* [0.006]	–0.179** [0.011]
$\Delta MHD I$		0.430* [0.000]	0.222* [0.000]	0.771* [0.000]	0.155*** [0.082]	0.370*** [0.052]	0.176 [0.120]	–	0.289* [0.000]	–0.290* [0.000]
$\Delta F$		0.920* [0.000]	1.955* [0.000]	1.089* [0.000]	0.118 [0.227]	0.280* [0.000]	0.440* [0.000]	0.339* [0.000]	–	–0.196* [0.000]
MEKC model		$\Delta(-GS)$	$\Delta F (\Delta F^2)$	$\Delta EC$	$\Delta T$	$\Delta MAN$	$\Delta MHD I$	$\Delta RL$	ECT	
$\Delta(-GS)$		–	2.981* [0.000]	0.542* [0.000]	0.922* [0.000]	1.019* [0.000]	1.156* [0.000]	0.472* [0.000]	–1.508** [0.018]	
$\Delta F (\Delta F^2)$		0.319* [0.000]	–	0.339* [0.000]	0.356* [0.000]	0.218** [0.017]	0.312* [0.001]	0.801* [0.000]	–3.978* [0.000]	
$\Delta EC$		0.549* [0.000]	0.892* [0.000]	–	1.091** [0.035]	0.880* [0.000]	0.198** [0.020]	0.501* [0.000]	–2.020* [0.000]	
$\Delta T$		0.228* [0.009]	0.517* [0.000]	0.189 [0.156]	–	0.318* [0.000]	0.075 [0.219]	0.400* [0.008]	–0.925* [0.000]	
$\Delta MAN$		0.362* [0.000]	3.210* [0.000]	0.227** [0.027]	0.289* [0.000]	–	0.861* [0.000]	1.008* [0.000]	–2.144* [0.000]	
$\Delta MHD I$		0.224** [0.017]	0.331** [0.012]	0.176 [0.154]	0.587* [0.000]	0.544* [0.000]	–	0.609* [0.000]	–2.509* [0.000]	
$\Delta RL$		0.415* [0.000]	0.438* [0.000]	0.078 [0.364]	0.433* [0.000]	0.210 [0.135]	0.470* [0.000]	–	–3.008* [0.000]	

539 Notes: P-values are in brackets. The superscript \*, \*\* and \*\*\* denote statistical significance at the 1%, 5% and 10% levels, respectively.

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## 543 **5. Concluding remarks and policy implications**

544  
545 Although the relationship between financial sector development and environmental  
546 quality has been analyzed in the EKC literature little attention has been paid to its impact on  
547 sustainable development. The lack of empirical work on this issue was the motivation for our  
548 proposed modified EKC model which integrates both financial development and  
549 macroeconomic sustainability and allows examination of the impact of the financial sector on  
550 sustainable development in the case of 14 selected MENA countries during 1990-2017.

551 Our findings show (i) [the validity of the EKC hypothesis for both per capita CO<sub>2</sub>](#)  
552 [emissions and ecological footprint](#), (ii) the presence of a non-linear link between per capita  
553 financial development and the two indicators of environmental degradation i.e. the level of  
554 environmental degradation initially increases with financial sector development but after a  
555 certain level becomes positive as more energy-efficient technologies and more efficient  
556 infrastructures are implemented in the country's development process. Our findings show also  
557 that despite the non-linear link between unsustainability and financial sector development, the  
558 larger coefficient of financial sector development compared to its squared value indicates that  
559 financial development is likely to have only a small long-term impact on sustainable  
560 development. Therefore, current efforts aimed at protecting the environment and achieving  
561 sustainability are expected to be ineffective given the extent of the problem.

562 Our paper has several implications for policy in the MENA region in particular and in  
563 developing countries more general.

564 *First*, an efficient financial sector increases the amount of capital available to  
565 investors, provides economic agents with liquidity, and allocates capital more efficiently  
566 among economic sectors. Financial sector development would help MENA countries  
567 transform their economies and move to a post-oil era.

568 *Second*, the ethics and values of financial sectors worldwide are changing and the  
569 environment is being seen as an opportunity rather than a constraint. Green financing provides  
570 funding for investors who want to invest in green sectors and is encouraging traditional  
571 sectors to reduce their carbon emissions. By helping to diffuse these new values worldwide a  
572 developed financial sector could promote the move to less polluting economies. Since most  
573 MENA region financial organizations have branches in other parts of the world and belong to  
574 multinationals with social and environmental responsibility programs the diffusion of these  
575 values and good practices should be ensured. Social and environmental responsibility  
576 programs are encouraging new behaviors in the MENA region and helping local entrepreneurs

577 to see the environment as offering green opportunities in their sectors. Governments in the  
578 MENA region must encourage their financial sectors to improve economic and ecological  
579 conditions by including provisions related to government loans and warranties, and interest  
580 rates for responsible environmental and social investments.

581 *Third*, the financial sector could play a crucial role in persuading investors to consider  
582 environmental and ecological sectors, such as recycling, sanitation, water, water purification,  
583 and renewable energies. Many MENA region entrepreneurs are failing to recognize the  
584 opportunities offered by climate change and consumers' increased environmental awareness.  
585 For example, most MENA countries have important oil and gas resources and therefore, are  
586 neglecting the potential of green energies especially solar. It has been estimated that installing  
587 solar panels on just 20% of the surface of the Sahara desert in Algeria could satisfy world  
588 demand for electricity. Algeria's solar energy potential is 60 times that of current European  
589 Union electricity consumption (Bélaïd and Abderrahmani, 2013). Financial sectors working  
590 with governments could help firms to exploit these sectors and reduce the risks for newborn  
591 firms. Policy makers in the MENA countries should see their financial sectors as part of the  
592 solution and should involve them in the definition of environmental policies, targets, and  
593 strategies.

594 *Fourth*, the ongoing economic, social, and ecological crisis calls for a reconsideration  
595 of the relationship between economic growth, finance, and sustainability (Lagoarde-Segot,  
596 2015). Strengthening financial sectors and changing their focus from brown to green goals  
597 could have an important impact on environmental change in the MENA countries where most  
598 financial markets are under-developed.

599 This study has some limitations. The first is related to the sustainable development  
600 indicator. A transition from the Millennium Development Goals to the 17 SDGs will require  
601 different indicators related for example to food security, well-being, education quality, climate  
602 change, and pollution mitigation, among others. Future work should focus on defining these  
603 indicators. Second, this study analyzes only the direct effect of financial development on  
604 sustainability. Future research could extend this by examining policy thresholds and critical  
605 masses at which renewable energy could achieve the environmental, social, and economic  
606 objectives of sustainable development simultaneously.

607