Technology Innovation and Climate Change Mitigation: Effects and Transmission Channels

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Abs t r a c t

The main objective of our study is to examine the relationship between innovation technology and environmental sustainability in the case of MENA countries during the period from 1990 to 2019 period. In order to integrate explicitly the possible cross-sectional dependencies problem, we use the panel cointegration methods.

The outcome indicates the rejection of the EKC hypothesis because these countries have not yet reached the threshold of GDP. Yet, financial development and technological innovation not having direct effects on CO2 emissions. Also, foreign direct investment and energy consumption have negative impacts on environmental quality. However, the interaction between innovation technology on the one hand and energy consumption, financial development, trade and foreign direct investment on the other hand can reduce CO2 emissions. Consequently, policy makers should not only develop financial and technological systems but also develop more technological goods traded and enhance renewable energy use.

JEL Classification: Q4, Q5, O5, C5

Keywords: “CO_2 emissions”, “Economic growth”, “Environmental Kuznets Curve”; “technological innovation”.

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1. Introduction:

Climate change has become a global problem that affects all nations, prompting a significant increase in national and international efforts in the area of climate change adaptation and mitigation. Therefore, climate change mitigation and adaptation policies have become an absolute necessity (Lomborg, 2020; Coumou and Rahmstorf, 2012). Mitigation is used to avoid future climate change, but adaptation is represented as a phenomenon that we can plan for now, but that will occur in the future (Youssef et al., 2018). Seven years ago, at the 2015 Paris Conference on Climate Change, 193 nations came to an agreement on combating climate change and speeding the shift to a sustainable development model. This agreement establishes challenging mitigation and adaptation targets. These goals include keeping the rise in global temperature below 2 degrees Celsius relative to pre-industrial levels and, if at all possible, limiting it to 1.5 degrees Celsius by 2030. Achievements have fallen short of expectations seven years later. Thus, the pace of the global economy's transition makes the fight against climate change impossible. Along the same lines, climate change is becoming more pronounced and evident. Reduced rainfall, rising temperatures, rising sea levels, floods, droughts, and an increased risk of desertification in fertile areas are all effects of these changes. Numerous studies demonstrate the profound damage that climate change will cause to future well-being (Breyer et al., 2017).

According to current literature, the adoption of advanced technologies is considered the main factor in mitigating climate change not only by reducing emissions, but also by preserving energy and encouraging more ecological modes of production (Ahmed et al., 2016; Lin and Zhu, 2019; Amri et al., 2019). Despite the literature on the determinants of climate change mitigation, the studies related to the effect of technological innovation remain narrow (Amri et al., 2019).

Furthermore, the channels through which technology can help in climate change mitigation efforts have been ignored. Moreover, there are few studies that consider a regional group of countries, but there is no study that is particularly interested in the case of MENA countries. For this, we reexamine e between technological innovation-CO2 emissions nexus in the case of MENA countries.

Contrary to the previous writing, the present work is the first to explicitly integrate some transmission channels as mitigating factors in the relationship between innovation technology and environmental sustainability. Moreover, our paper is the first to investigate the linkage between technological advancement and CO2 emissions in the case of MENA countries. The selection of MENA nations in the study is justified for a variety of reasons. In terms of CO2 emissions per person, this region is second in the world. Second, this region is changing toward economies in the energy transition. Thirdly, this area has experienced significant socioeconomic vulnerability. In addition, our paper is the first to integrate the non-linear impact of innovation fluctuations on the mentioned relationship, i.e., initially climate change rises with technology adoption, but after a threshold level of technology, it begins to decrease. Moreover, we examine the role of some transmission channels in accelerating the role of technology in climate change mitigation.

In order to reach our objectives, we use the panel cointegration approach in the case of MENA countries, using annual data covering the most recent available period 1971-2018.

The remainder of the present paper is fixed in the following way. Section 2 is allowed to present the literature review. Section 3 is enabled to expose materials and methods. Section 4 synthesizes the empirical results. The last section finishes with some conclusions and policy implications.

2. Literature Review

In the studies that focused on the determinants of environmental quality, some of them examined the role of technology in achieving environmental sustainability (Cheng et al., 2019). In this case, the literature can be divided into two categories.

The first category focuses in the situation in a particular country. For example, Wang et al. (2012) explore the linkage between innovation technology and CO_2 emissions in different regions of China from 1997 to 2008. Their empirical results demonstrate a positive effect of the domestic patent on environmental improvement and an insignificant impact of no domestic patent. Furthermore, Yii and Geetha (2107) consider the Malaysian economy to study the link between technological innovation and CO_2 emissions from 1971 to 2013. The empirical conclusions prove a short-term environmental improvement created by technological innovation. Besides, Samargandi (2017) examines the relationship between technology innovation and environmental improvement in Saudi Arabia over the period from 1970 to 2014. The empirical finding obtained by exploiting the autoregressive distributed lags (ARDL) method demonstrates that technological innovation has no effect on environmental quality. Elsewhere, Amri et al (2019) focus on the impact of technology innovation on CO_2 emissions in the case of the Tunisian economy. They prove that technology innovation is directly without effect but indirectly help to reduce emissions by reducing the energy consumption level over the period between 1971 and 2014 period.

The case of a group of countries is the focus of the second category. For example, Irandoust (2016) concentrated on the role of technological innovation on environmental improvement in Sweden, Norway, Finland, and Denmark during the period compressing from 1975 to 2012 period. The empirical outcome demonstrates the positive effect of innovation in reducing CO2 emissions. Furthermore, Alvarez-Herranz et al. (2017) focus on the relationship between energy innovation as a proxy of technology and CO_2 emissions in the sample of OECD Nations between 1990 and 2012. They prove the positive role of technology in environmental improvement. Moreover, Fernández et al. (2018) examined the impact of technology innovation on air quality in European countries, the USA, and China. They demonstrate a negative impact in China and a positive one in the other countries. Also, Cheng et al. (2019) are interested in the linkage between the development of patents as a proxy of technological innovation and CO_2 emissions in the case of OECD countries between 1996 and 2015. The empirical results obtained by using panel quantile regression indicate an insignificant impact of technological innovation on CO_2 emissions. Elsewhere, Chen and Lei (2018) are interested in the same relationship in the case of 30 countries from 1980 to 2014. Their panel data empirical results show that the impact of technological innovations on climate change mitigation is more important in the case of countries with higher carbon emissions. Likewise, by using a sample of 90 countries, over the period from 1996 to 2018, Chen and Lei (2020) examined the association between technology innovation and CO2 emissions. The use of spatial econometric models demonstrates that the group of countries with high CO2 emissions, advanced technology, and high income are the only ones that are impacted by technological advancements. Extra, Khattak et al (2020) examined the role of technology innovation on environmental improvement in the case of BRICS countries covering the period from 1980 to 2016. They demonstrate a positive impact of technological advancement only in the case of the Brazilian economy. Further, Fei et al. (2014) look at the environmental sustainability related to innovative activities in New Zealand and Norway during the period compressed from 1971 to 2010. They proved a positive association between technology innovation and CO2 emissions only in Norway. Else, by using a comparative analysis between India and China, Fan and Hossain (2018) proved a positive role of technology on co2 emissions on the both countries during the period from of 1974 to 2016.

From the above, this literature on the impact of technological innovation is only interested in the case of rich and developed countries that are likely to benefit from new technologies. There are a few studies that consider the developing countries, but there is no study that is interested in the case of the MENA countries.

For this, we formulate the following objective: demonstrate the role technological advancement on environmental quality in some MENA countries

3. Methodology and Analysis:

3.1 Data

In this paper, the data we will use is taken from the World Bank Indicators during the 1990-2019 period. This data covers the MENA countries: Lebanon, Turkey, the United Arab Emirates, Tunisia, Saudi Arabia, Qatar, Oman, Morocco, Kuwait, Jordan, Iran, Egypt, Bahrain, and Algeria. Table 1 presents the list of countries.

Table 1: List of countries

Lebanan	Qatar	Iran
Turkey	Oman	Egypt
United Arab Emirates	Morocco	Bahrin
Tunisia	Kuwait	Algeria
Saudi Arabia	Jordan	

We use CO2 emissions expressed as metric tons per capita to evaluate the mitigation of climate change. Moreover, the trade variable is defined by the sum of exports and imports in percentage of gross domestic product, the financial development variable is defined by the domestic credit to the private sector in percentage of gross domestic product, the energy consumption variable defined by the energy use in kg of oil equivalent per capita, the gross domestic product is defined as the gross domestic income in constant 2005 US dollars, and technology innovation is defined as the sum of patent applications for residents and non-residents expressed in thousands. Table 2 displays an explanation of the variables.

Table 2: Description of the variables

Variable	**Description**	**Label**
Technology innovation	Sum of patent applications for residents and non-residents expressed in thousand	Tech
GDP per capita	Gross domestic income (constant 2005 US$)	Y
CO_2 emissions per capita	CO2 emissions expressed as metric tons per capita	CC
Energy consumption	Energy use in kg of oil equivalent per capita	EC
Financial development	Domestic credit to private sector in percentage of gross domestic product	FD
Trade openness	sum of exports and imports in percentage of gross domestic product	TR
Foreign direct investment	Foreign direct investment net inflows in percentage of gross domestic product	FI

Notes: all variables are collected from the World Development Indicators source.

3.2 Model specification

In order to examine the impact of technology innovation on CO2 emissions, we perform the Stochastic Impact by Regression on Population, Affluence and Technology model, as presented by Dietz and Rosa (1994). An extended version of the mentioned model is presented as follows:

$$I_{it} = aP_{it}^{b} A_{it}^{c} T_{it}^{d} TC_{it}^{e} \varepsilon_{it} \quad (1)$$

According to Eq. (1), THE environment (I) can be influenced by technology (T), affluence (A), population size (P), and some transmission canals (TC).

The linear and logarithmic formS of Eq. (1) are given as follows:

$$\log I_{it} = a + b\log P_{it} + c\log A_{it} + d\log T_{it} + e\log TC_{it} + \varepsilon_{it} \quad (2)$$

In order to check the validity of the impact of technological innovation on climate change mitigation in MENA countries, equation 2 is given as follows:

$$\log CC_{it} = \alpha_0 + \alpha_1 \log Tech_{it} + \beta_1 \log Y_{it} + \beta_2 \log Y^2{}_{it} + \phi_1 EC_{it} + \phi_2 FD_{it} + \phi_3 TR_{it} + \phi_4 FI_{it} + \nu_i + \gamma_t + \varepsilon_{it}$$

(3)

Where CC denotes climate change mitigation indicators at time t in country i. According to Eq. (3), the climate change mitigation indicator (CC) can be influenced by technology innovation (Tech), GDP per capita (Y), the squared GDP per capita (Y^2), and some other variables. Are considered as transmission canals and reflect respective per capita energy consumption (EC), financial development (FD), trade openness (TR), and foreign direct investment (FI).

Furthermore, in order to check the non-linear validity of the impact of technological innovation on climate change mitigation in MENA countries, equation 3 is transformed as follows:

$$\log CC_{it} = \alpha_0 + \alpha_1 \log Tech_{it} + \alpha_2 Tech^2{}_{it} + \beta_1 \log Y_{it} + \beta_2 \log Y^2{}_{it} + \phi_1 EC_{it} + \phi_2 FD_{it} + \phi_3 TR_{it} + \phi_4 FI_{it} + \nu_i + \gamma_t + \varepsilon_{it}$$

(4)

According to Eq. (4), the climate change mitigation (CC) can be influenced by the linear term of technology innovation (Tech), and the non- linear one ($Tech^2$).

Moreover, in order to check the role played by some transmission channels i.e., trade, energy consumption, financial development, and foreign direct investment, in mediating the impact of technology innovation on climate change mitigation in MENA countries, we integrate some interactive terms. Thus, we use the same approach as Amri et al. (2019), and Omri and Bel Haj (2020). To the best of our knowledge, our paper is the first to focus on the transmission channels from technological innovation to environmental improvement.

To address this goal, we consider a modified model as follows:

$$CC_{it} = \alpha_1 + \alpha_2 Y_{it} + \alpha_3 Y^2{}_{it} + \alpha_4 Tech_{it} + \alpha_5 FI_{it} + \alpha_6 FI * Tech_{\ it} + \alpha_7 EC_{it} + \alpha_8 EC_{it} * Tech_{\ it} + \alpha_9 FD_{it} + \alpha_{10} FD_{it} * Tech_{\ it} + \alpha_{11} TR_{it} + \alpha_{12} TR_{it} * Tech_{\ it} + \varepsilon_{it}$$

(5)

According to Eq. (5), the climate change mitigation (CC) can be influenced by the interaction between innovation technology on the one side, and energy, trade, financial development, and foreign direct investment on the other side. The moderate impact of each variable on the relationship between technology innovation and environmental improvement can be captured by the coefficient associated with each interactive term. For example, α_{12} coefficient is used to capture the role played by trade openness in moderating the impact of technology innovation on CO2 emissions. Furthermore, α_6, α_8, and α_{10} parameters are used to capture the role played respectively by foreign direct investment, energy consumption, and financial development openness.

3.3 Methodology

We employ an empirical methodology that follows three steps. Firstly, we examine the order of the integration of our variables. For this, we use the test developed by Pesaran (2007), which fits into the second-generation of panel data unit root tests. The main contribution of this generation compared to the tests of the first one is the explicit modeling of the dependence between the individuals (countries) of the panel. Our variables can be considered cointegrated only if the series are I (1) at the level and become I (0) after their first variation. It should be noted that the mentioned unit root test is applied after testing the absence or presence of cross-section dependence (Pesaran, 2007). Secondly, we examine the panel cointegration analysis. For this purpose, we perform the panel cointegration test proposed by Pedroni (1999, 2004). This latter can permit to test the no cointegration relationships between variables hypothesis against cointegration one. Four tests are based on within-dimension (panel cointegration statistics) and the three are based on between- dimension (mean panel cointegration statistics). The advantages of these statistics are both the integration of heterogeneities in the case of panel data and the correction for the bias related to endogenous variables. The long-run cointegration coefficients are estimated only if our variables are cointegrated. Thirdly, we use the modified ordinary least square (FMOLS) techniques proposed by Pedroni (1999) in order to evaluate the panel long-run coefficients. This method can help to correct the endogeneity of regressors and theautocorrelation and heteroskedasticity of the residuals.

4. Results and discussions

Table 3: Unit root test and Cross-sectional dependence

Indicators	**Pesaran (2007) Cross-sectional dependence test**	**Pesaran (2007) Unit root test**	
		Level	First difference
CC	8.123***	-1.642	-4.133***
	(0.000)	(0.563)	(0.000)
Y	7.064***	-1.234	-4.231***
	(0.000)	(0.576)	(0.000)
Y^2	8.445***	-2.723	-4.268***
	(0.000)	(0.869)	(0.000)
Tech	8.273***	-2.526	-3.442***
	(0.000)	(0.776)	(0.000)
$Tech^2$	7.663***	-1.546	-4.569***
	(0.000)	(0.234)	(0.000)
EC	7.123***	-2.246	-3.236***
	(0.000)	(0.669)	(0.000)
FD	8.623***	-1.236	-3.189***
	(0.000)	(0.779)	(0.000)
FI	8.123***	-1.236	-4.569***
	(0.000)	(0.596)	(0.000)
TR	6.227***	-2.635	-4.126***

(0.000)	(0.896)	(0.000)

We begin by examining the cross-sectional dependence and the stationarity of the variables figured in our models by using the cross-sectional dependence test and panel unit root test developed by Pesaran (2007) respectively.

Table 4: Cointegration test

Statistics	T-statistics	P-Values
PP-stat within	--5.123***	0.000
ADF-stat within	-5.623***	0.000
Rho-stat within	-5.123***	0.000
V-stat within	-4.323***	0.000
PP-stat between	-0.446	0.231
ADF-stat between	-4.123***	0.000
Rho-stat between	-5.556***	0.000

*Notes*** indicates significance at 1%.*

The Pesaran cross-sectional dependence test result, which is presented in Table 3, reveals that our variables do not support cross-sectional independence. For our variables stated in levels and in first differences, we can therefore execute panel unit root tests using the test created by Pesaran (2007).

The aforementioned variables become stationary following the initial difference transformation, as seen in Table 3. The Pedroni (1999, 2004) cointegration test is used to examine the cointegration relationship between the variables in light of the last conclusion.

The findings shown in Table 4 show that all variables are cointegrated and that there may be a long-term relationship between them. Both within- and between-dimension testing are used to validate this finding.

Table 5: FMOLS results

Variables	Model 1	Model 2	Model 3
Y	**0.136***** **(0.000)**	**0.156***** **(0.000)**	**0.096***** **(0.000)**
Y^2	**-0.069** **(0.523)**	**-0.098** **(0.364)**	**-0.096** **(0.321)**
Tech	**0.063** **(0.536)**	**0.023** **(0.236)**	**0.089** **(0.236)**
$Tech^2$		**0.023** **(0.156)**	
EC	**0.232***** **(0.000)**	**0.256***** **(0.000)**	**0.278***** **(0.000)**
EC*Tech			**-0.033***** **(0.000)**
TR	**0.253***** **(0.000)**	**0.213***** **(0.000)**	**0.206***** **(0.000)**
TR*Tech			**0.231***** **(0.231)**
FD	**0.012** **(0.245)**	**0.023** **(0.568)**	**0.231** **(0.623)**
FD*Tech			**-0.003***** **(0.000)**
FI	**0.023*****	**0.015*****	**0.067*****

	(0.000)	**(0.000)**	**(0.000)**
FI*Tech			**-0.003***** **(0.000)**
constant	**0.236***** **(0.000)**	**0.433***** **(0.000)**	**0.123***** **(0.000)**

Notes*** indicates significanceat 1%.

Then, we present the FMOLS panel long-run results (Table 5).

Firstly, the coefficient related to GDP in the level form is positive, but the coefficient of GDP in the square form is negative and insignificant. This implies that the EKC hypothesis is rejected. This result is not surprising since the MENA countries have not yet reached the GDP threshold, allowing them to create a high quality atmosphere. Our outcome is in harmony with those of Amri et al. (2019), Fodha and Zaghdoud (2010), and Ben Jebli and Ben Youssef (2015).

Secondly, CO_2 emissions are not elastic to technological innovation since the parameters related to Tech and Tech squared are insignificant. This outcome is not surprising since the research and development realized in MENA countries are very limited. This result is in harmony with the outcome of Amri (2019). These results indicate that the MENA countries should, in order to reduce CO2 emissions, invest in research and development programs.

Thirdly, CO2 emissions are highly elastic to energy consumption variation. This conclusion is expected since in the case of MENA countries the energy consumption is dominated by the non-renewable energy component. This result is in harmony with those of Amri (2019), Farhani et al. (2014), Farhani and Otzurk (2015), and Ben Mbarek et al. (2018). Consequently, policy makers in these countries should encourage the transition to renewable energy. This result is in line with Amri (2016), and Amri (2017).

Fourth, given that the financial development variable has a negligible coefficient, it appears that in the case of MENA nations, financial development has no direct impact on environmental improvement. This can be caused by the underdeveloped financial and banking systems in the MENA region. However, it appears that financial development indirectly aids the technological transition when one looks at the coefficients associated with the interaction term between financial development and technological innovation. For this, policymakers should establish the financial market required to finance investments in technology and in R&D.

Fifth, commerce has a positive and notable effect on CO2 emissions. To keep domestic businesses competitive in both home and foreign markets, trade openness is a source of boosting production.

Sixthly, it appears that trade cannot indirectly contribute to environmental sustainability when one considers the coefficients associated with our interaction term between trade and technological innovation. The nature of commerce, which is based on trade in intermediary items with minimal technological content, can be used to explain this outcome. Therefore, by easing the switch to renewable energy, policymakers in these nations should promote the growth of trade and the energy supply. This outcome is consistent with Amri (2016) and Amri (2017).

Seventhly, FI has a negative effect on the environment. In actuality, rising FI will be followed by rising CO2 emissions. However, foreign direct investment can help to improve environmental quality by fostering the transfer of new technologies as well as managerial abilities, FI can also improve the efficiency of production processes. This minimal impact is a result of the high caliber of FI attracted to low-tech industries.

5. Conclusion and policy implications:

The main objective of the present paper is to examine the relationship between innovation technology and environmental sustainability by explicitly integrating some mitigating factors. For this, we used a sample of MENA countries in the period from 1990 to 2019.

There are different results and implications from this research. First, economic growth is a source of environmental degradation, and the MENA countries have not yet reached the threshold level of GDP needed to reverse the situation. Consequently, MENA countries should enhance their GDP in order to reach the wished level.

Second, there is an insignificant impact of technological innovation on environmental quality. This suggests that the low share of technology innovation in MENA countries doesn't permit a technical or efficiency improvement. Consequently, policy makers should invest in technological innovation. Third, the interaction between innovation technology, energy consumption, foreign direct investment, and financial development can help reduce CO2 emissions. Consequently, MENA countries should focus on the adoption of innovative technologies to moderate the negative effects of non-renewable energy consumption. Fourth, there is no linear impact of technological innovation on environmental improvement. Consequently, MENA countries should adopt a new environmental strategy permitting the improvement of technologies.

Fifth, the financial development system is not able to participate in the efforts employed to reduce pollution and ameliorate growth. Consequently, the policy makers should develop the financial system in order to stimulate international and locals investments, participate in the research and development programs, and to finance the renewable energy projects.

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