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Article

Do green technology innovations promote green growth? Empirical evidence from MENA countries

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Abstract: The MENA region, known for its significant oil and gas production, has been widely acknowledged for its reliance on fossil fuels. The dependence on fossil fuels has led to significant environmental pollution. Therefore, the shift towards a more environmentally friendly and enduring future is crucial. Thus, the current study tries to investigate the effect of green technology innovations on green growth in MENA region. Specifically, we examine whether the effect of green technology innovations on green growth depend on the threshold level of income. To this end, a panel threshold model is estimated for a sample of 10 MENA countries over the period 1998–2022. Our main findings show that only countries with income level beyond the threshold can benefit significantly from green technology innovations in term of green growth. Nevertheless, our findings indicate a substantial and adverse impact of green technology innovation on countries where income levels fall below the specified threshold.

Keywords: green growth; green technology innovations; income; panel threshold model; MENA countries

1. Introduction

Since the advent of the Industrial revolution, the global economy has undergone rapid evolution, leading to substantial improvements in people's living standards. However, this development has also brought about severe environmental pollution, rendering it unsustainable. Consequently, it is imperative for humans to promptly implement the requisite actions to safeguard the planet from climate calamities (Du et al., 2019). The global conversation on achieving long-term economic stability has commenced, leading to the introduction of a new model of growth called 'green growth' by the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) in 2005. Green growth refers to a conceptual framework and practice that combines economic progress with ecological sustainability. The objective is to attain economic success while minimizing the negative impact on the environment and the depletion of resources. Green growth acknowledges the interconnectedness of economic, social, and environmental aspects, highlighting the necessity for sustainable and equitable progress. Therefore, it is imperative to adopt green economic growth policies in order to address environmental conflicts and attain Sustainable Development Goals (Ahmed et al., 2022). This is can be achieved by promoting the adoption of more efficient and environmentally friendly technology. According to Dutz and Sharma (2012), certain technologies have the ability to directly enhance resilience in the face of environmental shocks. According to the literature, innovations can play a crucial role in fostering green growth. They do this by facilitating the development and spread of green technology, improving the efficiency

of resource usage, and minimizing environmental harm. Guo et al. (2017) state that technical innovation is one of the key factors that contribute in promoting green growth. That is, the identification of technology solutions is considered crucial in addressing environmental issues. In the same line, Mensah et al. (2019) emphasized the significant impact of technology innovation on promoting sustainable economic growth. Renewable energy sources and environmentally-friendly technologies have a crucial role in promoting sustainable economic growth (Ahmed et al., 2022; Sohag et al., 2015).

Ghisetti and Quatraro (2017) argue that green technology plays a crucial role in promoting green growth by effectively minimizing industrial waste and pollution emissions. In fact, technological innovation serves as a tool to abate the acute environmental crisis and continuously promote sustainable development by converting traditional economies into green economies (Abid et al., 2022). Furthermore, green innovation has the potential to successfully accomplish the goal of decreasing greenhouse gas (GHG) emissions, enhancing energy efficiency, and safeguarding the environment (Ahmed et al., 2022). For instance, Zakari et al. (2023) have shown that investments in innovations can lead to innovations that reduce greenhouse gas emissions, improve energy efficiency, and support the transition to renewable energy sources.

This study seeks to examine the impact of green technology on green growth in the Middle East and North Africa (MENA) countries, drawing on the previous discussion. The MENA region, known for its significant production of oil and gas, has been widely acknowledged for its reliance on fossil fuels. In fact, current crude oil production stands at approximately 29.865 million bpd, amounting to about 30% of the total oil produced in the world. Natural gas production is about 925 billion m^3, roughly 23% of the total gas produced globally (International—US Energy Information Administration (EIA), 2023). Owing to this reliance, there has been a notable surge in CO_2 emissions, intensifying climate change and causing detrimental effects on the environment and human well-being (Albaker et al., 2023). Reducing air pollution in the MENA region would improve public health by tackling the issue of carbon emissions. Significant measures are necessary to address this issue and uphold the region's long-term viability. Therefore, the implementation of environmentally-friendly technological advancements has become a possible driving force for attaining both the preservation of the environment and economic expansion in the area.

The main contribution of this paper is to examine whether the effect of green technology on green growth depend on the income level in MENA countries. To the best of our knowledge this paper is the first one that has tackled this topic in MENA region. To this end a panel threshold model is estimated for a sample of 10 MENA countries over the period of 1998–2022

The primary results of our study offer compelling evidence that green technology has a positive and significant impact on green growth in MENA countries. This phenomenon is observed with greater accuracy in countries characterized by a high degree of development. Nevertheless, in less developed countries, the impact of green technology on green growth is adverse.

The remainder of this paper is organized as follows: a literature review is provided in section 2. Section 3 presents details about data, model and methods of

estimations. Results and discussions are presented in section 4. Conclusion and implications are summarized in section 5.

2. Literature review

Economists have widely debated the concept that green innovation plays a crucial role in improving environmental quality, which is a fundamental component of green growth (Huang, 2024). Green growth is an economic theory that focuses on sustainable development that promotes economic growth while also taking into consideration environmental protection and resource efficiency. It emphasizes the importance of investing in renewable energy, reducing carbon emissions, and promoting eco-friendly practices to ensure long-term prosperity without compromising the health of our planet. The concept of Green Growth acknowledges that economic growth and environmental sustainability are not incompatible. They have the ability to complement each other. Nations can simultaneously foster economic growth and decrease their carbon emissions by allocating resources towards renewable energy, energy efficiency, and other eco-friendly technology.

2.1. Technical innovation and environmental quality

Multiple studies have demonstrated that technical innovation is crucial for enhancing environmental quality. Specifically, technical innovation has been found to decrease carbon emissions by improving the efficiency of production factors (Liu and Liang, 2013; Sohag et al., 2015). According to Popp (2010) technological advances in the way that energy is generated and delivered will play an important role in efforts to stabilize greenhouse gas emissions. In this particular scenario, a study conducted by Du et al. (2019) involved an empirical research to examine the influence of advancements in green technology on carbon dioxide (CO_2) emissions. The study utilized a data panel including 71 economies spanning the years 1996 to 2012. The findings of Du et al. (2019) indicate that green innovation has a positive impact on CO_2 emissions, however this effect is observed primarily in nations with a high-income level. Klewitz and Hansen (2014) demonstrate that technological advancements are the most effective means of achieving efficient, optimal, and environmentally-friendly utilization of resources, leading to improved environmental quality and eventually enhancing individuals' living standards and promoting social sustainability. In their study, Wang et al. (2012) examined the correlation between patents related to energy technology and carbon dioxide (CO_2) emissions in 30 provinces of mainland China from 1997 to 2008. Research indicates that domestic patents for carbon-free energy technology have a significant impact on the reduction of CO_2 emissions. Murad et al. (2019) examined the correlation between technical innovation, energy price, economic growth, and energy use in Denmark from 1970 to 2002. Results of study provide empirical evidence that there is a positive association between economic growth and energy innovation. Besides, their findings show that technological innovation and energy price place significant role in bringing energy efficiency and carbon free society.

Ghisetti and Quatraro (2017) conducted a cross-sectoral analysis on a panel of Italian regions monitored from 2002 to 2005 to investigate the impact of green

technology on environmental productivity. Their research demonstrates that regions and sectors with more adoption of green technology (GTs) have superior environmental performance.

2.2. Green technology and green growth

The existing body of literature regarding the correlation between green innovation and green economic growth is currently somewhat restricted. The majority of researchers concentrated on the significance of technical advancement.

Considering a sample of data covering 30 provincial administrative regions in China during 2011–2012, Guo et al. (2017) investigate the relationships among, technological innovation and regional green growth performance. The empirical results provide evidence that technological innovation affect positively green growth. Zhang et al. (2018) examine the effect of technological innovation on urban green development. Their findings show that technological innovations enhanced urban eco-efficiency in China. The latest results are supported by Li et al. (2022). Utilizing the system generalized method of moments (SYS-GMM) estimator for exploring the impacts of green energy and green technological innovation on green growth in China, Li et al. (2022) provide empirical evidence that green technological innovation affect positively green growth.

Danish and Ulucak (2020) examine the influence of environmental technologies on sustainable economic growth by regulating the usage of renewable and non-renewable energy in BRICS nations from 1992 to 2016. Their research demonstrates that environmental technologies play a pivotal role in fostering sustainable economic growth in BRICS countries. The study conducted by Ahmed et al. (2022) examines the impact of cleaner energy production, green innovation, and green trade on the green economic growth of South Asian countries. Data from 2000–2018 was collected from various sources, and the study used Pesaran's second-generation unit root test and Wasteland's cointegration test to test data stationarity and long-run associations. They showed that clean energy production, green innovation, and green trade positively contribute to South Asian economies' green economic growth.

In more recent study, Chen et al. (2023) investigate the impact of green innovation and financial globalization on green growth in the BRICS (Brazil, Russia, India, China and South Africa) economies. Their findings provide empirical evidence that environment-related technologies are helpful in attaining green growth in the BRICS economies. The latest findings are supported by Huang (2024) findings. Using a dynamic system panel data estimations and robust random effect GLS regression for long-run estimates for BRICS countries over the period of (1990–2021), Huang (2024) provide strong evidence that technological innovation is essential to addressing environmental challenges and promoting sustainable development.

Applying a system generalized method of moment (S-GMM) on a dataset of 11 years (from 2008 to 2019) for Australia and 23 top green scheme economies, Zakari et al. (2023) findings show that environmental technology innovation promotes environmental quality.

3. Data and econometric methodology

3.1. Econometric methodology

3.1.1. Benchmark model

This In order to empirically investigate the effect of green technology innovations on green growth, we consider the following-reduced econometric model:

$$GG_{it} = \alpha_i + \beta_1 GI_{it} + \rho Z_{it} + \mu_{it} \quad (1)$$

where (*GG*) stands for green growth which is the dependent. (*GI*) refers to green technology innovation which is the key explanatory variable that we are interested. Z_{it} represents a matrix of control variables including international trade, research and development expenditure, human capital development. (α_i) is an unobserved country specific effect and (μ_{it}) is the error term of each observation term.

3.1.2. The conditional green innovation- green growth relationship

The aim of this sub-section is to examine the conditional green innovation – green growth relationship. More specifically we want to investigate whether the effect of green innovation on green growth depend on the level of income. Thus, we consider (Hansen, 1999) panel threshold model (PTR) which is developed for non-dynamic panels with individual fixed effect. The panel threshold model is defined as follow:

$$GG_{it} = \alpha_i + \beta_1[GI_{it}\mathrm{I}_{(PCGNI_{it}\leq\gamma)}] + \beta_2[GI_{it}\mathrm{I}_{(PCGNI_{it}\geq\gamma)}] + \rho Z_{it} + \mu_{it} \quad (2)$$

where *I*(.) is the indicator function and γ is a threshold parameter, gross national income per capita is considered as threshold variable in this model is scalar. The observations are divided into 'two regimes' depending on whether the income level ($PCGNI_{it}$) it is smaller or larger than the threshold γ. The regimes are distinguished by differing regression slopes β_1 and β_2.

3.2. Data description

In this study we compile a balanced data panel covering 10 MENA countries over 1998–2022 period. **Table 1** presents detailed information related to symbols, descriptive statistics, and data sources.

Table 1. Definitions and data descriptions.

Variable	Definitions	Mean	Max	Min	Sources
GG	Green growth	28.20	39.18	22.40	World Bank
GI	Green technology innovations	2.37	6.29	−13.57	OECD
RD	Research and Development	−1.43	0.406	−7.637	World Bank
HC	Human capital index	4.38	4.95	3.45	World Bank
TO	Trade openness	4.31	5.15	3.37	World Bank
PCGNI	Per capita gross national income	9.80	11.71	7.76	World Bank

Green growth: Following Ahmed et al. (2022), and Wang et al. (2023) and given the availability of data, we have calculated a green growth indicator (GG) as follow:

$$GG = GDP + EE - NRP - NFD - CO_2$$

where GDP is gross domestic product (Annual %); EE is education expenditure (% of GDP); NRP is fossil fuel consumption (% of total); NFD is net forest depletion, CO_2

is carbon emissions (% of fuel). The data on green growth are collected from the World Bank.

Green technology innovation: Organizations can boost green growth by implementing eco-friendly green technologies, which reduce energy usage and pollutant emissions (Chen et al., 2023a). In this paper we follow Ahmed et al. (2022), and Du et al. (2019) to utilize environmental-related technologies as indicator of green technology innovation. The data are collected from OECD statistics database.

International trade: Wang et al. (2021) assert that international trade plays a crucial role in influencing green growth. Therefore, we regard foreign trade as an independent variable. The impact of trade openness on green growth is mediated by three distinct channels: the scale effect, the structural effect, and the technology effect (Danish and Ulucak, 2020). First and foremost, international commerce promotes economic activities, resulting in a higher demand for fossil fuels, which in turn has an impact on sustainable environmental growth. Furthermore, trade openness has the potential to impact the composition of industries, therefore influencing the progress of sustainable and environmentally-friendly economic growth. Furthermore, the technological impact hypothesis suggests that with the implementation of more efficient and environmentally friendly green innovations, international trade has the potential to decrease pollution emissions, thereby promoting the rise of sustainable and environmentally conscious practices. The data on trade openness are extracted from World Bank database.

Human development index: The favourable impact of the human development on green growth is anticipated since human capital fosters awareness through education, hence facilitating the promotion of green growth. To measure the level of human capital development we consider the Human Capital Index from the Penn World Table (PWT 10.01) database and which calculated as the mean number of years of secondary education.

Research and development expenditure: According to Wang et al. (2021), research and development have a significant impact on encouraging economic green growth. By allocating resources to research and development, companies can embrace environmentally sustainable technologies with the aim of enhancing the overall state of the environment. In this study, R&D expenditure variable refers to the private and public R&D. Based on the research conducted by Lan et al. (2012) and Wang et al. (2021), we anticipate that RD will have a beneficial effect on the promotion of green growth.

Per capita gross national income: To examine whether the effect of the level of income matters for the effect of green technology on green growth we consider the PCGNI variable as the threshold variable. It is considered by the World Bank in the classification of the countries in different income groups. The data are collected from World Bank.

4. Results and discussions

4.1. Benchmark regression

Fixed effects (FE) as well as random (RE) effects models are considered in this study. The Hausman test is employed to determine the suitable estimator. If the

Hausman test indicates a rejection of the null hypothesis that the individual effects are uncorrelated with the explanatory variables, the most appropriate estimate method would be the fixed-effects. According to Hausman test value (0.007) (**Table 2**), fixed effects estimator is the more appropriate to estimate equation (1). The results in **Table 2** illustrate that the coefficient of green technology is estimated is significant at 1%. A 1% green technology level will bring about 0.068% green growth. Our results are in line with Wang et al. (2021), Chen et al. (2023) and Danish and Ulucak (2020) findings. The advancement of green technologies in the energy industry contributes to the rise in the market for sustainable energy sources. The beneficial impacts may manifest gradually in MENA nations. Energy technology development enhances production equipment efficiency, while the advancement of environment-related energy technologies can enhance environmental sustainability. As green technologies advance, the substitution of fossil fuels with clean energy sources may become feasible, thereby aiding in the reduction of carbon emissions. Another potential factor is the pivotal role of innovation in advancing and enhancing technological processes that mitigate energy consumption through the promotion of energy conservation, hence fostering the progress of green economic growth.

Table 2. Estimation results of benchmark model.

Variables	**Coefficients**
GI	0.0676* (0.001) “3.04”
RD	0.257* (0.00) “5.60”
HC	2.212*(0.00) “9.46”
TO	−0.38 (0.415) “−1.71”
Constant	4.17 (0.152) “0.33”
H-Statistic (Hausman specification)	0.013
No observations	250

Note: *P*-value in parentheses. ***, ** and * is for 10%, 5% and 1% level of significance respectively.

The findings additionally demonstrate that green growth is contingent upon research and development (RD). The positive and significant coefficients of RD indicate an augmentation in research and development (RD) plays a crucial role in fostering sustainable and environmentally-friendly economic growth. Through investment in research and development (RD), companies have the opportunity to embrace and implement environmentally friendly technology, thereby enhancing the overall state of the environment. The findings additionally demonstrate that the development of human capital (HC) has a favourable impact on green growth. The findings corroborate the results of Wang et al. (2021) who contend that human capital fosters green growth by cultivating awareness through education. Nations possessing well-developed human capital are better equipped to utilize sophisticated environmentally friendly technologies. The findings additionally indicate that international commerce does not seem to be a substantial factor influencing green growth in MENA countries.

4.2. Estimation results for the panel threshold model (PTM)

In order to examine the relationship between green technology advancements and income in green growth, we employ a panel threshold model. The findings are displayed in **Table 3**. The likelihood test results indicate that linearity is rejected at a significance level of 5%. Regime transitions occur when there are changes in the effect of green technological developments on green growth, which is influenced by the income level. When the per capita gross national income exceeds a specific threshold, the impact of green technology advancements on green economic expansion would undergo a transformation. The projected threshold parameter is 9.53, which is equivalent to 13,787 US Dollars per capita. This implies that only countries with greater wealth levels can benefit from green technology innovation in terms of green growth. According to the World Bank classification, countries are considered upper income if their per capita gross national income (GNI) reaches 12,376 US Dollars or more. Among the countries of our MENA sample, only Oman, Saudi Arabia, United Arab Emirates and Kuwait have the potential to reap the benefits of green technological innovation in terms of promoting green growth. The results of the sample grouping, which were determined using the threshold parameter, are presented in **Table 4**. For countries with a level of development below the threshold parameter like Algeria, Iraq, Iran, Egypt, Tunisia and Morocco, the introduction of green technological advances has a notable and adverse impact on green growth, suggesting that these innovations hinder the progress of green growth. The recent findings align with the research conducted by Mensah et al. (2019), which posits that the unwillingness of patent holders to transfer inventions contributes to environmental deterioration despite advancements in technology. Another probable factor is the lack of diffusion of certain green technologies, which can be attributed to inventors failing to patent or protect them with intellectual properties (IPs). Consequently, the diffusion of these technologies results in the loss of authority over these discoveries for the inventors. Disseminating such technology results in innovators forfeiting their profits from their inventions. One effective approach to promoting sustainable economic growth is to disseminate exclusive patented technologies to heavily polluting industries that do not currently have access to them.

Table 3. Estimation results of panel threshold model (PTM).

Variables	**Coefficients**
Threshold estimates *c* (PCGNI)	9.5315** (0.02)
RD	0.304* (0.00) "7.25"
HC	1.782* (0.00) "7.93"
TO	−0.230 (0.268) "−1.11"
*c**GI	
Under the threshold level (*c*)	−0.273* (0.00) "−4.94"
Above the threshold level (*c*)	0.110* (0.00) "5.16"
Constant	5.372*** (0.098) "1.66"
No observations	250

Note: *P*-value in parentheses. ***, ** and * is for 10%, 5% and 1% level of significance respectively.

Table 4. The group classification based on the estimated threshold parameter.

Classification	Countries
Upper regime: Above the threshold level c = 9.5315 (13.787 US)	Oman, Saudi Arabia, United Arab Emirates, Kuwait
Lower regime: Under the threshold level c = 9.5315 (13.787 US)	Algeria, Egypt, Iran, Iraq, Morocco, Tunisia

5. Conclusion and implications

Nations worldwide have increasingly prioritized the goal of sustainable development in recent years. The MENA area, renowned for its abundant natural resources, has acknowledged the necessity of shifting towards a more environmentally friendly and sustainable future. While past researches have mostly concentrated on the factors influencing environmental quality in various regions worldwide, there has been limited attention given to the MENA region. Furthermore, no study has specifically investigated the elements of green growth in this particular region. This study aims to address the existing research vacuum by investigating the impact of green technology on green growth in MENA nations. The analysis takes into account factors such as R&D, human capital, and trade openness. The study covers the period from 1998 to 2022

The outcomes of our analysis demonstrate that the econometric estimation yields reliable and consistent findings. i) The findings of the benchmark model indicate that the use of green technology contributes to the promotion of green growth in MENA countries. ii) The outcomes of the panel threshold model reveal that only countries that have surpassed a certain level of income development, may derive benefits from green technology in terms of green growth. Nevertheless, countries with upper-level of development do not seem to benefit from green technology.

Our findings have key policy implications. The study's findings suggest that green technology plays a significant role in fostering green growth. Consequently, policymakers in MENA nations should prioritize research and development efforts that might stimulate the advancement of green innovations. For example, policymakers could redirect financial resources towards investing in environmentally friendly technologies and promote businesses to develop innovative green solutions. Furthermore, it is imperative for low-income economies to actively encourage the implementation of green management practices, as this can significantly enhance the efficiency of resource consumption, taking into account the existing production technology (Raharjo, 2018). Furthermore, it is crucial for MENA nations to prioritize the enhancement of human capital development in order to effectively harness the potential of green technology and achieve green growth. Indeed, nations that possess a higher level of advanced human resources, achieved via superior education and training, demonstrate more proficiency in the development and utilization of environmentally sustainable technologies, as stated by Wang et al. (2021).

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