

-RESEARCH ARTICLE-

EFFECTS OF EMERGING TECHNOLOGICAL INNOVATION ON CARBON DIOXIDE EMISSIONS: EXAMINING THE MODERATING ROLE OF FOREIGN DIRECT INVESTMENT

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—Abstract—

The objective of this research is to examine the role of foreign direct investment (FDI) in influencing the association between emerging technological innovations (TEI) and carbon dioxide emissions in the energy sectors of Saudi Arabia and Malaysia. Our analysis is based on panel data obtained from the World Development Indicators, covering the period from 2000 to 2022. The study utilised a longitudinal research design and adopted a quantitative research approach. The analysis was conducted using STATA-14 software, incorporating techniques such as cross-sectional dependence, co-integration, and regression analysis. These methods were employed to evaluate the impact of exogenous and moderating variables on carbon dioxide emissions. The results indicate that the implementation of technology-enabled innovation (TEI) has a substantial adverse impact on the levels of carbon dioxide emissions. This is supported by the outcomes obtained from the application of both the Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Least Squares (DLOS) models. On the contrary, it can be argued that foreign direct investment has a discernible and noteworthy impact on the levels of carbon dioxide emissions. Furthermore, our analysis reveals that foreign direct investment (FDI) serves as a vital moderating factor, substantially amplifying the association between technological innovation and carbon dioxide emissions. This study makes a valuable contribution to the current body of literature by introducing an

Citation (APA): Al Doghan, M. A., Sadiq, A. (2023). Effects of Emerging Technological Innovation on Carbon Dioxide Emissions: Examining the Moderating Role of Foreign Direct Investment. *International Journal of Economics and Finance Studies*, 15(03), 1-21. doi:10.34111/ijefs.202315301

expanded model that examines the moderating influence of foreign direct investment, with a specific focus on the countries of Saudi Arabia and Malaysia. The implications of these findings are of practical significance for policymakers and investment institutions, as they provide valuable insights into the significance of investing in technological innovation as a means to reduce carbon dioxide emissions. Furthermore, this study sheds light on the significance of foreign direct investment in promoting technological advancements, which may result in a rise in carbon dioxide emissions, particularly in developing countries. This groundbreaking research contributes to our comprehension of the complex relationships among technological advancements, foreign direct investment, and carbon dioxide emissions. It provides valuable insights into how these factors interact within the specific contexts of Saudi Arabia and Malaysia.

Keywords: foreign direct investment, technological innovation, Saudi Arabia, energy companies.

INTRODUCTION

In contemporary times, scholars have expressed significant interest in the investigation of climate change and environmental economics. The potential impact of environmental sustainability on a nation's financial monopolies may be influenced by environmental economic factors such as global warming (Destek & Sarkodie, 2019). In the past few decades, there has been a notable increase in the process of urbanisation and industrialization, which have been associated with adverse environmental consequences (Mehmood, 2021). Information sharing service centres were established to facilitate the structural growth of economies in both advanced and developing countries. Significant advancements have been observed in various domains related to technology, the field of economics, and environmentally sustainable approaches (Destek & Sarkodie, 2019). The weather is inevitably impacted by the various advancements in society. Rapid economic growth is accompanied by notable environmental concerns, including heightened carbon emissions (Mehmood, Mansoor, Tariq, & Ul-Haq, 2021). Several scholars have posited that recent advancements in technology, foreign direct investment, and gross domestic product (GDP) have significantly influenced the mitigation of carbon dioxide (CO₂) emissions (Fan & Hao, 2020; Khattak, Ahmad, Khan, & Li, 2021; Pao & Tsai, 2011). Reducing these factors may potentially give rise to challenges in the context of CO₂ emissions (Chowdhury & Chowdhury, 2022).

Foreign direct investment (FDI) is a significant factor that enables developing countries to enhance their domestic production. The availability of contemporary financial and production methods is positively associated with an increase in the investment rate (Xu et al., 2018). There is a clear positive relationship between foreign direct investment (FDI) and carbon dioxide (CO₂) emissions (Ziaei, 2015). Within the context of the environment, the halo theory of foreign direct investment (FDI) posits that there is an overall beneficial effect on carbon

dioxide emissions. This is due to the fact that FDI often leads to the dissemination of advanced technologies from developed countries to developing nations (Balsalobre-Lorente, Gokmenoglu, Taspinar, & Cantos-Cantos, 2019). The economies of developing nations derive significant advantages from the guidance provided by international monetary organisations, as they effectively attract foreign direct investment. Furthermore, the cessation of domestic technological advancements has a consequential impact on the disruption of CO₂ emissions (Abid, Mehmood, Tariq, & Haq, 2022). This issue may be attributed to foreign direct investment (FDI), which has the potential to impact carbon dioxide emissions. Foreign direct investment (FDI) produces dual and long-lasting economic benefits in terms of technological advancements, which in turn have a long-lasting effect on reducing carbon dioxide emissions (Rafique, Li, Larik, & Monaheng, 2020). This supports the argument even further. The reason behind the favourable climate for foreign direct investment (FDI) lies in states that possess strong financial sectors. This is attributed to the potential reduction of financial risk, which subsequently promotes technological innovation. Ultimately, this leads to a positive impact on carbon dioxide emissions. The imperative of fostering secure economic development is crucial in order to attract and retain talented individuals while also promoting the entrepreneurial spirit and capital investment that are instrumental in driving innovation and enhancing productivity within the domestic economy. Consequently, the escalation of carbon dioxide (CO₂) emissions can be attributed to the expansion of the financial sector (Sadorsky, 2011), which has the potential to be further amplified by foreign direct investment and advancements in technology.

In recent decades, foreign direct investment and emerging technologies have emerged as key drivers of carbon dioxide emissions. However, it is worth noting that investments in technological innovations remain relatively nascent in developing economies. Nations such as France, Italy, Russia, the United States, the United Kingdom, and Canada have collectively undergone substantial industrialization, leading to noteworthy economic advancements in recent years. As a result, these countries find themselves in a comparable situation. The aforementioned factors contributed to the gross domestic product (GDP) of \$56,766,000 in 2010 (Dong et al., 2018). The emerging economies are currently in the initial phases of attaining economic growth (Chang, 2015).

Ensuring the ongoing sustainability of Earth's natural ecosystems stands as a formidable task for humanity (Tariq, Nawaz, Ul-Haq, & Mehmood, 2021). Numerous policies have been embraced in developed economies as a response to this apprehension, aiming to mitigate the ecological impact and carbon dioxide emissions associated with increasing economic activity (Akadiri, Lasisi, Uzuner, & Akadiri, 2019). Hence, it is imperative to formulate effective policies aimed at mitigating carbon emissions and ozone depletion in developing economies as well. However, previous research has primarily focused on developed economies (Hasanbeigi, Arens, & Price, 2014; Maqsood et al., 2014), with less attention given to developing economies. In these developing economies, technological innovation is still in its early stages (Abid, Mehmood, Tariq, & Haq, 2022).

Hence, it is imperative to acknowledge the significance of conducting research in emerging economies such as Saudi Arabia and Malaysia. In essence, prior research has primarily focused on the direct impact of technological innovation on CO₂ emissions, while giving less attention to the indirect moderating effect of foreign direct investment (FDI) in the relationship between technological innovation and CO₂ emissions. This study primarily examined the indirect moderating effect of foreign direct investment (FDI) on the relationship between technological innovations and carbon dioxide (CO₂) emissions among companies in Saudi Arabia and Malaysia. The analysis was conducted by reviewing relevant studies in the field. Environmental scientists have proposed various energy methods as potential strategies for regulating specific temperatures (Pachauri et al., 2014). The nations of Saudi Arabia and Malaysia bear significant responsibility for the escalation of global temperatures, resulting in adverse consequences such as coastal droughts and floods (Rafique, Li, Larik, & Monaheng, 2020). The increase in carbon dioxide emissions is primarily driven by rapid economic growth, prompting these nations to progressively augment their foreign direct investment in technology, thereby influencing the levels of CO₂ emissions. The primary objectives revolve around the United States of America, Canada, France, Germany, Italy, Japan, and France, which collectively constitute the largest importers and exporters globally. The organisation allocates a significant proportion of its financial resources towards research and development of TEI in order to cater to the requirements of its constituents. However, it exhibits limited focus on the advancement of TEI in developing economies.

The United Nations Climate Change Conference held in November 2021 prompted the announcement of climate goals and commitments by nearly two hundred countries, including Saudi Arabia. The government of Thailand has made a firm commitment to attaining carbon neutrality by the year 2050 and achieving a state of net-zero greenhouse gas emissions by the year 2065. The prevalence of air pollution as the primary concern among Saudi Arabian residents in 2020 is not unexpected, given its conspicuous nature and adverse environmental impact. The main contributors to air pollution in Saudi Arabia are heavy vehicle traffic and emissions from industrial activities. Furthermore, it should be noted that Malaysia experienced a marginal reduction in emissions intensity from 573 gCO₂e/kWh to 570 gCO₂e/kWh during the period spanning from 2013 to 2018. However, it is anticipated that this trend will be reversed by the year 2023 due to the ongoing construction of additional coal and gas facilities in the country. Consequently, this development is projected to result in an increase in emissions intensity to 622 gCO₂e/kWh. Malaysia has demonstrated noteworthy advancements in mitigating carbon dioxide emissions, specifically in the domain of energy utilisation, as substantiated by the implemented measures thus far (Liu et al., 2023).

Consequently, the existing body of research predominantly concentrates on Malaysia and Saudi Arabia, as evidenced by the identified gaps in the literature.

Upon the conclusion of the study, several recommendations are put forth for the two major nations. This research provides insights into the interrelated nature of variables that contribute to foreign direct investment (FDI), economic growth, and technological advancements in reducing CO₂ emissions between two nations. This study contributed to the existing body of literature by examining the relationship between foreign direct investment (FDI), technological and energy intensity (TEI), gross domestic product (GDP), and carbon dioxide (CO₂) emissions using an extended model. Hence, this research is regarded as a pioneering study, characterised by noteworthy research findings. Furthermore, the improvement of environmental health in Malaysia and Saudi Arabia can be achieved through the implementation of more judicious energy consumption practices and the advancement of state-of-the-art technologies. Investing substantial financial resources in eco-friendly technologies holds the potential to significantly improve meteorological conditions.

Consequently, it is imperative to allocate additional financial resources towards the development and implementation of environmentally sustainable technologies. We maintain a strong conviction that the reduction of environmental degradation can be achieved through the implementation of financial transparency in government policies and research and development (R&D) activities related to foreign direct investment (FDI). When soliciting foreign investment groups, it is imperative to establish a discernible framework of regulations pertaining to environmentally sustainable technology. Given the imperative to mitigate energy consumption, it is conceivable to devise systems wherein all applications can transition from conventional energy sources to renewable alternatives. The implementation of energy policies that promote the increased utilisation of renewable sources of power holds the potential to enhance output, thereby fostering long-term economic growth. The study was structured into five distinct chapters, namely: an introductory section, a comprehensive review of relevant literature and a detailed explanation of the research methodology, a thorough analysis of the collected data, and finally, a concluding section that includes recommendations for future research.

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Technological Innovation and CO₂ Emissions

Uzunidis, Boutillier, and Laperche (2020) present an exposition on the notion of technological change. They argue that contemporary advancements in technology are not currently being fostered in the marketplace. Consequently, Schumpeter's theory of dissemination encompasses three key dimensions: innovation, diffusion, and invention. During the diffusion phase, the process of invention and innovation is propelled by research and development (R&D) efforts and is governed by the implementation of technological innovation by organisations or individuals who will ultimately utilise it.

The aforementioned three stages exhibit interdependence in facilitating the process of technological advancement. The adverse effects on the environment can be partially attributed to the swift progression of technological advancements. The topics of time and environmental change are addressed in the work by [Weitzman \(1997\)](#). Numerous discussions are conducted in order to ascertain the extent of technological advancement. The outcome yielded a reduction in environmental pollution. This investigation encompasses modifications to the fuel composition, the adoption of enhanced technologies, and adjustments to the tailpipe configuration within the system.

In order to gain a comprehensive understanding of the impact of climate change on the environment and energy consumption, it is imperative for pivotal theories to incorporate an analysis of the nature and scale of technological advancements ([Haas, Sayer, Ajanovic, & Auer, 2023](#)). There is a correlation between the growth of research and development (R&D) activities and technological advancements and a subsequent reduction in levels of carbon dioxide (CO₂) emissions ([Bloom, Jones, Van Reenen, & Webb, 2020](#)). Currently, there is ongoing discussion regarding the potential reduction of carbon dioxide (CO₂) emissions, which could potentially contribute to addressing environmental issues, assuming their existence ([Wang & Tang, 2018](#)). The increasing need for energy can be attributed to the growth of global trade and the expansion of the economy. [Islam \(2021\)](#) provides empirical evidence supporting the use of technological innovation (TI) as a means to achieve a gradual reduction in carbon dioxide (CO₂) emissions. On the contrary, alternative studies have yielded contrasting findings regarding the relationship between the environment and technological innovation. Our investigation focused on the potential utilisation of technological innovation within an ideal framework to mitigate pollution and carbon dioxide emissions. The individual posited that technological advancements are the most efficient means of reducing pollution when compared to alternative benefit programmes. This study aims to further investigate the significant impact of technological innovation on CO₂ emissions ([Abid, Mehmood, Tariq, & Haq, 2022](#)). Thus, based on these evidences, the following research hypothesis formulated below;

H1: *technology innovation negatively and significantly effects to the carbon dioxide emissions.*

Foreign Direct Investment and Carbon Dioxide Emissions

The primary objective of this study is to examine the influence of environmental factors on foreign direct investment (FDI). The theory of foreign direct investment (FDI) categorises the impacts of FDI on the environment as either neutral, positive, or negative. Various theories have been proposed to explain this phenomenon. One such perspective is the scale impacts theory, which suggests that the size of a company or industry can influence its environmental impact. Conversely, the pollution halo theory

posits that certain industries may enjoy a positive reputation despite their negative environmental practices. Additionally, the pollution haven theory proposes that companies may relocate to countries with less stringent environmental regulations in order to minimise costs and maximise profits (Pao, Li, & Fu, 2014). The impact of foreign direct investment (FDI) on the environment exhibits variability across different states and regions, leading to divergent outcomes, as reported in various research studies. One illustrative instance can be found in the research conducted by Pao, Li, and Fu (2014) and Paziienza (2015), which examines the impact of foreign direct investment (FDI) on environmental quality in BRICS and OECD states.

The findings of this study indicate that FDI has played a significant role in enhancing the environmental conditions of these nations. Numerous studies have been undertaken to ascertain the environmental ramifications of foreign direct investment (FDI) and to discern the diverse categories of impacts that have been observed. Ahmad, Jiang, Majeed, and Raza (2020) conducted a study that suggests that foreign direct investment (FDI) is the primary factor contributing to the environmental degradation in France. In contrast, the research conducted by Kiviyiro and Arminen (2014) in sub-Saharan regions presents divergent outcomes, indicating that the effect of foreign direct investment (FDI) is not definitively positive or negative but rather exerts a significant influence. The aforementioned studies did not consider the potential positive impact of foreign direct investment (FDI) on economic development and growth. The current study aimed to examine the impact of foreign direct investment (FDI) on carbon dioxide (CO₂) emissions in the countries of Saudi Arabia and Malaysia. Therefore, the following research hypothesis is formulated below;

H2: *Foreign direct investment has positive and significant effect on carbon dioxide emissions.*

Technological Innovation, Foreign Direct investment and Carbon Dioxide Emissions

Previous research has examined the relationship between technological innovation, foreign direct investment (FDI), and CO₂ emissions. However, the findings regarding these associations remain inconclusive. Hence, the present study focuses on the field of environmental economics, which examines the connection between technological innovation and carbon dioxide emissions, taking into account the moderating effect of foreign direct investment (FDI). The rationale behind this investigation is that a well-developed financial sector plays a pivotal role in achieving the desired reduction in carbon dioxide emissions, as it stimulates economic growth by attracting FDI. This is accomplished through substantiation. Within academic circles (Hsiao & Hsiao, 2006), there exists a prevailing perspective that posits a strong correlation between a thriving economy and the facilitation of advancements in environmentally sustainable

technology. With the objective of promoting a cleaner environment, the company provides environmentally friendly products and endeavours to steer regional, national, and international progress towards the goal of sustainability (Khan, Hossain, & Chen, 2021). The public sector stands to gain greater advantages from economic growth than previously acknowledged, particularly through the execution of information technology initiatives (Abid, Mehmood, Tariq, & Haq, 2022).

This phenomenon holds considerable implications for the reduction of CO₂ emissions by enhancing the efficiency of currently accessible energy resources (Tang, 2015). The Granger causality test revealed a unidirectional pattern of change originating from foreign direct investment (FDI), agriculture, population, and energy consumption. Adebayo, Udemba, Ahmed, and Kirikkaleli (2021) employ CO₂ emissions resulting from consumer consumption as a surrogate measure for environmental degradation in the context of Chile. The limited efficacy of technological innovation in mitigating CO₂ emissions resulting from consumption patterns indicates that the focus of technological innovation in Chile does not prioritise the development of environmentally sustainable products. This can be attributed to the relatively low priority placed on environmental concerns by companies seeking foreign direct investment. According to the research conducted by Udemba, Güngör, Bekun, and Kirikkaleli (2021), Chile has been recognised for its commendable performance in mitigating carbon emissions. The nation has made progress in improving its carbon emissions reduction efforts and technological innovations, but it is still striving to achieve self-sufficiency in these areas after previously facing significant deficiencies. In another study, it was proposed that companies possess greater financial resources to facilitate the adoption of novel technological innovations. This, in turn, has the potential to contribute to the mitigation of carbon dioxide emissions, a matter of increasing significance within the context of foreign direct investment. Previous empirical studies have suggested that a moderating effect mediates the impact of technology on CO₂ emissions (Abid, Mehmood, Tariq, & Haq, 2022). Thus, in the present study, foreign direct investment has been employed as a moderating variable between total energy intensity and carbon dioxide emissions, giving rise to the following research hypotheses:

H3: *Foreign direct investment has significant moderating effect between technology innovation and carbon dioxide.*

Research Design

The present study has employed a quantitative research methodology. The quantitative research technique is considered superior to the qualitative method due to its reliance on secondary data. The study employed a longitudinal research design, wherein data was gathered from world development indicators spanning the years 2000 to 2022. The data was gathered from the perspectives of two countries, namely Saudi Arabia and Malaysia. In

summary, following the UN Climate Change Conference in Glasgow (COP26) held in November 2021, a significant number of countries, approximately two hundred, including Saudi Arabia, have declared their climate objectives and pledged to address the issue of climate change. The Thai government has made a firm commitment to attaining carbon neutrality by the year 2050 and achieving a state of net-zero greenhouse gas emissions by the year 2065. The prevalence of air pollution as the primary concern among Saudi Arabian residents in 2020 is unsurprising, given its conspicuous nature and impact on the environment.

The main contributors to air pollution in Saudi Arabia are heavy vehicle traffic and industrial emissions. Furthermore, it is noteworthy that Malaysia experienced a marginal decrease in emissions intensity from 573 gCO₂e/kWh to 570 gCO₂e/kWh during the period spanning from 2013 to 2018. However, it is anticipated that this trend will be reversed by the year 2023 due to the ongoing construction of fresh coal and gas facilities in the country. Consequently, this development is projected to result in an emissions intensity of 622 gCO₂e/kWh. According to the current implemented measures, Malaysia has made significant progress in reducing carbon dioxide emissions, particularly in the area of energy consumption (Liu et al., 2023). Consequently, data was collected from the energy sectors of Thailand and Malaysia. The present investigation examines the relationship between per capita carbon dioxide emissions (CO₂E) and two independent variables: technology innovation (TEI), measured by the number of patents, and gross domestic product (GDP), measured by net inflows of GDP. Moreover, the utilisation of foreign direct investment (FDI) was employed as a moderating variable in examining the association between technological energy intensity (TEI) and carbon dioxide (CO₂) emissions.

Econometrics Model

The research model of the study are formulated below,

$$\text{CO}_2\text{emissions} = \alpha_0 + \alpha_1 \text{FDI}_{it} + \alpha_2 \text{TEI}_{it} + \alpha_3 \text{GDP}_{it} + \varepsilon_{it} \quad (\text{M-1})$$

$$\text{CO}_2\text{emissions} = \alpha_0 + \alpha_1 \text{FDI}_{it} + \alpha_2 \text{TEI}_{it} + \alpha_3 \text{FDI} * \text{TEI}_{it} + \varepsilon_{it} \quad (\text{M-2})$$

The equation presented above represents the mathematical model utilised in this study. In the aforementioned equation, FDI denotes foreign direct investment, TEI denotes technological innovations, and GDP denotes gross domestic product. The utilisation of panel data studies allows for the integration of both time series and cross-sectional data collection and analysis, thereby capitalising on the respective strengths of these two approaches. The management of endogeneity, heteroscedasticity, serial correlation, and multicollinearity is deemed feasible in panel data analysis (Islam, Shahbaz, Ahmed, & Alam, 2013). Consequently, the panel data technique is employed for the purpose of analysis. Before conducting the panel unit root test, it is necessary to first engage in the empirical analysis of panel data as an initial step in investigating the presence of cross-sectional dependence (CD) (Dong, Sun, Li, & Liao, 2018). The utilisation of CD

obviates the necessity for computational methods of correlation. The null hypothesis for the cross-sectional panel assumes the presence of the variable in question; however, this assumption was refuted in the study conducted by [Rauf et al. \(2018\)](#). The identification of the integrational pattern for all variables is crucial in order to perform the co-integrated test and determine the order of integration. The panel unit root test can be employed for this purpose ([Ozturk & Al-Mulali, 2015](#)).

A diverse range of panel root tests can be found in the academic literature. Each of these outcomes arises from a distinct amalgamation of cross-sectional attributes and the unit root methodology. The Fisher ADF, IPS ([Zeng, Liu, Liu, & Nan, 2017](#)), and Fisher PP are classified as second-generation unit root tests. These analyses effectively address concerns related to homogeneity. The countries comprising the G8 panel possess a considerable level of economic development while also experiencing fluctuations in carbon dioxide emissions. Despite these circumstances, they continue to face challenges related to climate change and environmental sustainability. The study utilised the Pesaran cross-sectional test and the unit root-second generation test in its analysis. The study also employed the Full-Motion Ordinary Least Square (FMOLS) and Dynamic Ordinary Least Square (DOLS) methods. The Fully Modified Ordinary Least Squares (FMOLS) estimator is employed in order to address the issue of autocorrelation in the error term, U_{it} , by applying the Newey-West correction. In the process of incorporating the error term U_{it} into the model, it is imperative to carefully choose both preceding and subsequent variables to effectively address the issue of autocorrelation (DOLS).

DATA ANALYSIS AND RESULTS

Previous research has predominantly concentrated on either panel data or time series analysis, with limited consideration given to cross-sectional dependence. Hence, the preceding studies have yielded unreliable findings as a result of disregarding cross-sectional analysis. Hence, this study opted for the use of the LM test to assess cross-sectional dependence. The Stata package known as "Unit Root" is designed to facilitate the execution of various tests aimed at ascertaining the presence of unit roots or stationarity in panel datasets. The null hypothesis for tests in panel data analysis is that each panel exhibits a unit root ([Im, Pesaran, & Shin, 2003](#)). The initial premise of the Lagrange multiplier (LM) test, as formulated by [Hadri \(2000\)](#), is the inherent immobility of all panels. Subsequently, scholars have utilised this knowledge to develop factor-based 'second-generation' testing methodologies that exhibit resilience against cross-section dependence ([Baltagi, 2008](#)). The cross-section augmented ADF (CADF) and IPS (CIPS) tests developed by Pesaran are highly prevalent second-generation tests in the field. [Frydman and Saks \(2010\)](#), [Eberhardt, Helmers, and Strauss \(2013\)](#) and [Omri, Daly, Rault, and Chaibi \(2015\)](#) are prominent studies that have conducted tests widely recognised in the field ([Eberhardt, Helmers, & Strauss, 2013](#)). Consequently, the CADF and CIPS unit root tests were employed to verify the stationarity of the data at either the initial level or the initial difference.

The decision regarding the choice between first- and second-generation panel unit root tests was facilitated by the utilisation of a cross-sectional dependence test. The predicted results in Table 1 demonstrate that cross-sectional dependence was statistically assessed using the LM test. This exemplifies how enhancements made in one location can have an immediate impact on another. The additional results indicate that the unit root, which serves two main purposes, namely (a) in level form and (b) in first difference form, was assessed using the CADF and CIPS methods. All variables in the results exhibit stationarity after being compared once. Furthermore, the Westerlund test was employed to assess the presence of co-integration among the variables. The results presented in Table 1 indicate that the variables under consideration continue to exhibit co-integration. This observation indicates that there exists a prolonged period of co-integration among variables. The robustness of the findings could be further demonstrated by conducting additional co-integration testing. The Westerlund test has gained prominence as a significant method for verifying the absence of co-integration across all panels, thereby promoting responsibility in statistical analysis. Based on the obtained findings, it can be concluded that the absence of co-integration is effectively eliminated. Table 1 presents the anticipated findings in their current state.

Table 1: Cross Dependence, CADF, CIPS, Co-integration Test Results

	LM		CD	
CO2E	40.44		13.00	
FDI	12.71		11.27	
GDP	62.30		23.03	
TEI	27.11		0.179	
FDI*TEI	15.47		10.00	
	CADF		CIPS	
	Level	first difference	Level	First difference
CO2	-1.714	-9.321	-1.361	-7.353
FDI	-1.837	-6.401	-2.161	-8.234
GDP	-3.105	-7.322	0.0796	-7.052
TEI	-1.438	-5.124	0.234	-5.760
FDI*TEI	-1.358	-6.526	-1.631	-8.305
Co-integration test				
Stats	Values	Z-value	Prob	Robust prob
G_t	-1.22	4.12	1.00	0.70
G_a	-2.60***	4.23	1.00	0.00
P_t	-1.70	4.26	1.00	0.45
P_a	-2.76***	3.20	1.00	0.01

Note: CO2E-carbon dioxide emissions, FDI-foreign direct investment, GDP-gross domestic product, TEI-technology innovation.

Diagnostics Test

In this section, a series of diagnostic tests were conducted to assess the normality and assumptions of the data analysis. These tests included assessments for data normality, autocorrelation, heteroscedasticity, and multicollinearity.

Data Normality

The assumption of normality of residuals is a fundamental requirement in ordinary least squares (OLS) estimation (Ziemnowicz, 2020). The assumption in statistical analysis is that residuals or error terms should follow an independent and identically distributed (IID) pattern (Chatterjee & Hadi, 2015; Osborne & Waters, 2019). In the context of this study, a range of methodologies have been established in prior scholarly works within the fields of financial econometrics and business statistics. The kernel-density estimate is a prominent method used to emphasise the normal distribution of residuals and the normal density (Silverman, 2018). Figure 4:12 displays the normal distribution of residuals (FS-ROA) generated using the k-density command in STATA-14. The study revealed that both the kernel density estimates and the normal density exhibited similarity, albeit with a minor peak observed in the kdensity.

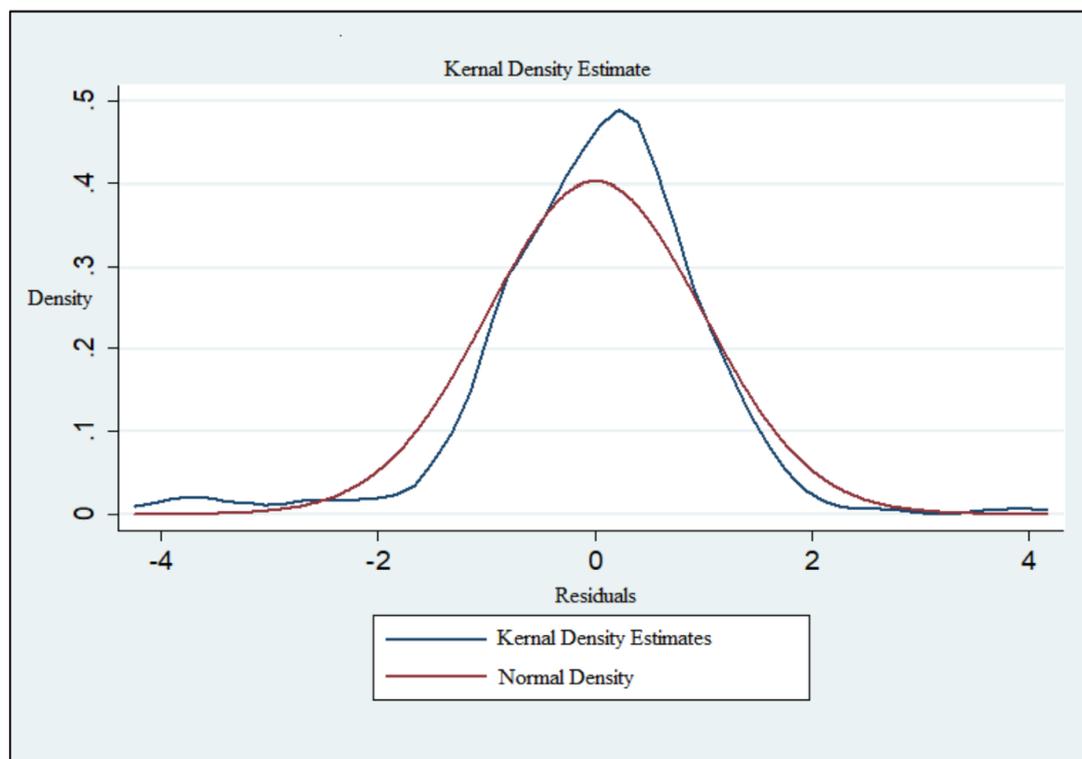


Figure 1: Normal of Residuals (co2 Emissions)

Autocorrelation and Heteroscedasticity

The Wooldridge test is used to detect the presence of autocorrelation in various econometric models. Based on the findings from all four models, it can be observed that the probability values for each model exceed the threshold of 5%. Hence, it can be asserted that none of the three models exhibit any autocorrelation concerns. The purpose of employing the Breusch-Pagan test is to assess the presence of heteroscedasticity in each of the three models employed in the study. The results presented in the table indicate that for each model, the probability value exceeds the threshold of 5%. Consequently, it does not demonstrate any heteroscedasticity concerns. The anticipated outcomes are presented in [Table 2](#) below.

Table 2: Breuch-Pagan Lagrange multiplier

Model	Auto-Correlation	Auto-Correlation	Heteroscedasticity	Heteroscedasticity
	X ² - Value	Probability Value	f – Value	Probability Value
Model-1	0.81	0.7	0.29	0.31
Model-2	0.23	0.22	1.28	0.42

Multicollinearity

The variance inflation factor (VIF) is a valuable metric in the operationalization of the regression model, as it is one of the assumptions that must be acknowledged and accepted. This statistical measure is used to find out if the independent variables (IVs) in the three regression models being looked at have a lot in common. The results displayed in [Table 3](#) demonstrate that the variance inflation factor (VIF) for each variable is below the threshold of 5. Both regression models used in this investigation indicate the absence of multicollinearity among the independent variables. [Hair \(2009\)](#) suggests that a variance inflation factor (VIF) value below 5 should be employed as a criterion for assessing the presence of multicollinearity among the independent variables in ordinary least squares (OLS) regression.

Table 3: Multicollinearity Statistics -VIF

Variable	
GDP	2.93
FDI	2.20
TEI	2.16
Mean VIF	1.68

Note: CO2E-carbon dioxide emissions, FDI-foreign direct investment, GDP-gross domestic product, TEI-technology innovation.

Hypothesis testing

Moreover, “fully modified ordinary least Square (FMOLS)” is being presenting the extensive parameters in the [Table.4](#). The results are being presented using two comparable methods. In the context of the Fully Modified Ordinary Least Squares (FMOLS) model, the coefficient estimate for GDP is observed to be relatively small, despite the fact that the corresponding GDP value is relatively large. Hence, the findings suggest that a 1 percent rise in foreign direct investment leads to a reduction in CO₂ emissions. These findings are consistent with research by [Al-Mulali and Tang \(2013\)](#) and [Pazienza \(2015\)](#). The findings suggest that an increase in foreign direct investment (FDI) is associated with a decrease in carbon dioxide (CO₂) emissions in Malaysia and Saudi Arabia. On the contrary, the advancement of technology has a noteworthy and adverse impact on carbon dioxide (CO₂) levels. This suggests that as technological innovations increase, so does the emission of CO₂. This finding aligns with prior research that posits a positive relationship between technological advancements and enhanced pollution control regulations, leading to improved environmental sustainability. This is due to the fact that production activities, which are essential to economic development, are the main cause of environmental degradation. The reduction of pollution due to technological advancements is widely recognised as a positive development for the ecosystem ([Abid, Mehmood, Tariq, & Haq, 2022](#)).

Additionally, additional findings suggest that gross domestic product (GDP) exerts a positive and statistically significant influence on carbon dioxide (CO₂) emissions. This implies that an increase in GDP, or economic growth, in Saudi Arabia and Malaysia is associated with a corresponding increase in CO₂ emissions. The findings align with previous studies conducted by [Shahbaz, Ozturk, Afza, and Ali \(2013\)](#), as well as [Usman, Balsalobre-Lorente, Jahanger, and Ahmad \(2022\)](#). Furthermore, researchers have examined the moderating effect of foreign direct investment (FDI) on the relationship between technological innovation and CO₂ emissions. The findings suggest that when FDI is present as a moderator, technological innovation has a positive and statistically significant impact on CO₂ emissions. This suggests that the impact of foreign direct investment (FDI) and technological innovation on reducing CO₂ emissions is distinct. However, when FDI is present, it moderates the effect of technological innovations on CO₂ emissions, causing a shift from a negative to a positive relationship. On the contrary, estimations using the Difference in Ordinary Least Squares (DOLS) method also demonstrate similar outcomes to those obtained through Fully Modified Ordinary Least Squares (FMOLS), albeit with distinct coefficient values. The impact of technological innovation on CO₂ emissions in the dynamic ordinary least squares (DOLS) model was found to be negative, although not as pronounced as the findings from the fully modified ordinary least squares (FMOLS) estimations. The impact of foreign direct investment (FDI) on carbon dioxide (CO₂) emissions was found to have a positive effect in the dynamic ordinary least squares (DOLS) estimations, and this effect was statistically significant.

Conversely, it is noteworthy that technological advancements have also exhibited a significant reduction in CO₂ emissions, as indicated by the estimations conducted using the Difference in Ordinary Least Squares (DOLS) method. The indirect moderating effect of foreign direct investment (FDI) was found to be consistent with the estimations obtained through the Fully Modified Ordinary Least Squares (FMOLS) method. There was no significant alteration observed in the moderating effect when comparing the results obtained from both the FMOLS and Dynamic Ordinary Least Squares (DOLS) methods. All of the above results are predicted in the following [Table.4](#) below.

Table 4: Hypothesis Results

Hypothesis	FMOLS coefficients	P Values	DOLS coefficients	P Values
FDI>CO ₂ E	-1.261	0.00	-0.313	0.00
GDP>CO ₂ E	0.234	0.00	0.0231	0.00
TEI>CO ₂ E	-0.251	0.00	-0.134	0.02
FDI*TEI>CO ₂ E	0.328	0.00	0.328	0.00

Note: CO₂E-carbon dioxide emissions, FDI-foreign direct investment, GDP-gross domestic product, TEI-technology innovation.

CONCLUSION AND FUTURE DIRECTIONS

Carbon dioxide is of utmost importance as a greenhouse gas in the process of heat retention within the Earth's atmosphere. The presence of it is essential for the survival of any form of life on Earth. The increase in average global temperatures is attributed to the concurrent increase in atmospheric carbon dioxide (CO₂) concentrations, leading to subsequent repercussions on various components of Earth's climate system. There are multiple factors that contribute to the emissions of carbon dioxide (CO₂), and two of these factors that have been identified as significant are foreign direct investment (FDI) and technology innovation (TEI) (Xue et al., 2020; Yang et al., 2022). Hence, the objective of this study is to investigate the moderating effect of foreign direct investment (FDI) on the associations between technological efficiency innovation (TEI) and carbon dioxide (CO₂) emissions. The cross-dependence test was observed in the econometric models of various countries and series. Both Foreign Direct Investment (FDI) and Technological Energy Intensity (TEI) exhibit a statistically significant and negative impact on carbon dioxide (CO₂) emissions, as observed in both the Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) models. Furthermore, it was observed that there exists a positive and statistically significant relationship between gross domestic product (GDP) and carbon dioxide (CO₂) emissions. The findings align with the findings of prior research. Therefore, drawing from these findings, it can be inferred that TEI, FDI, and GDP have exerted a significant influence on the escalation of CO₂ emissions. The environmental

degradation observed in Malaysia and Saudi Arabia can largely be attributed to their prioritisation of economic growth. The study's empirical findings support the argument for the development of a more efficient system in the domains of environmentally friendly architecture, urban transportation, and the utilisation of renewable energy sources (Saint Akadiri, Alkawfi, Uğural, & Akadiri, 2019).

Upon the conclusion of the study, several recommendations are put forth for the two major nations. This study provides insights into the interconnected relationship between various variables that contribute to foreign direct investment (FDI), economic growth, and technological advancements aimed at reducing carbon dioxide (CO₂) emissions in two countries. This study contributes to the existing body of literature by examining the relationship between foreign direct investment (FDI), technological energy intensity (TEI), gross domestic product (GDP), and carbon dioxide (CO₂) emissions using an extended model. Hence, this research is regarded as a pioneering study, accompanied by noteworthy research discoveries. Furthermore, the environmental well-being of Malaysia and Saudi Arabia can be improved through the implementation of more judicious energy consumption practices and the advancement of state-of-the-art technologies. Investing significant financial resources in eco-friendly technologies holds the potential to significantly improve meteorological conditions. Consequently, there is a need for increased financial investment in environmentally sustainable technologies. We maintain a strong conviction that the mitigation of environmental degradation can be achieved through the implementation of financial transparency in government policies and research and development activities related to foreign direct investment (FDI). The invitation of foreign investment groups necessitates the establishment of a discernible framework of regulations pertaining to environmentally sustainable technology. Given the imperative to mitigate energy consumption, it is feasible to devise systems wherein all applications can transition from conventional power sources to renewable alternatives. The implementation of energy policies that promote the increased utilisation of renewable sources of power holds the potential to enhance output, thereby fostering long-term economic growth.

The research that has yielded significant findings still exhibits certain limitations that may contribute to the expansion of future research endeavours. The scope of the research was constrained to Saudi Arabia and Malaysia, both of which are developing nations characterised by distinct industrial environments in comparison to more advanced economies. As a result, the generalizability of the research findings was limited. Hence, it is recommended that future studies investigate additional developed economies in order to enhance the generalizability of the research findings. Furthermore, the scope of the study was restricted to examining moderating and direct effects, neglecting the potential influence of other mediating variables that could potentially mediate the relationship between exogenous and endogenous variables. Hence, it is recommended that future research endeavours consider expanding the

existing framework by incorporating additional mediating factors, thereby enhancing the generalizability of the research findings. Furthermore, the study was carried out in two developing countries. Subsequent investigations could be undertaken by incorporating additional developing nations to broaden the research's scope.

ACKNOWLEDGMENT

This work was supported by the Deanship of Scientific Research, Vice Presidency for Graduate Studies and Scientific Research, King Faisal University, Saudi Arabia [Grant 4230]'.

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