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Stock Market Development and Environmental Sustainability in Saudi Arabia: Asymmetry Analysis

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ABSTRACT

Stock Market Development (SMD) can have positive or negative environmental effects by providing the capital to clean or dirty production processes, respectively. The present study investigates the effect of SMD on CO_2 emissions in Saudi Arabia from 1985 to 2022 by conducting symmetrical and asymmetrical analyses. The results validate the environmental Kuznets curve in both symmetrical and asymmetrical analyses. The turning point of the curve is found at 61500 SR and 49944 of income per capita in symmetrical and asymmetrical analyses, respectively, in the long run. The turning points are found at 65895 SR and 54979 SR in the symmetrical and asymmetrical models, respectively, in the short run. All points are within the range of sample period's income. Thus, Saudi economic growth has no environmental problems. Moreover, SMD and increasing SMD help reduce CO_2 emissions in the long run with elasticity parameters 0.8548 and 0.9854 in symmetrical and asymmetrical models, respectively. Thus, SMD should further be focused to have pleasant environmental effects in Saudi Arabia.

Keywords: Stock Market Development; CO_2 Emissions; The Environmental Kuznets Curve; Economic Growth
JEL Classifications: Q57, G24, O47

1. INTRODUCTION

Saudi Arabia has 17% of a prominent oil reserve in the global share and is the chief exporter of petroleum in the globe. Saudi Aramco is among the largest energy and chemical companies in the world and produces hydrocarbon by 11.5 mmbpd of crude oil. However, this company claims the production of the lowest carbon per oil barrel and is targeted to achieve net-zero emissions in the year 2050. For this purpose, the government has started to invest in cleaner and renewable technologies. Aramco is among the largest company in the Saudi stock market, which has declared 604.0 billion net income in the year 2022 and distributed a dividend of 73.0 billion in the 4th quarter of 2022 (International Trade Administration, 2024).

Aramco is working from upstream to downstream sectors of oil and natural gas and continuously investing in the upstream sector from exploration to production of oil and natural gas. Side by side, Aramco is also investing in downstream activities from petrochemical manufacturing to power generation with a partner of SABIC. To care about the environmental problem, Aramco devoted $1.5 billion to sustainability projects in the year 2022 to find innovative solutions to the environmental problem in the oil sector. Moreover, Saudi Arabia is heavily investing in blue and green hydrogen to reduce greenhouse gas emissions and has also established a carbon capture and storage hub (International Trade Administration, 2024).

The Stock Market Development (SMD) can play an effective role in environmental sustainability in Saudi Arabia as Aramco is a significant part of the SMD in Saudi Arabia. For instance, Saudi Arabia is initiating a green project for environmental sustainability and SMD can channel the flow of capital towards green investment to support green and sustainable projects such as renewable energy projects, waste management projects, and other environmentally friendly technologies. Moreover, SMD can promote green bonds to finance green projects with positive environmental outcomes. Moreover, investors and shareholders may also put pressure on the companies to disclose the environmental impacts and sustainability practices in their business activities, which would encourage them to adopt sustainable practices (Paramati et al., 2017; Saqib et al., 2024; Christodoulou-Volos and Tserkezos; 2024).

Investors would prefer to invest in projects carrying top sustainability index in the stock market. By achieving a top sustainability index, listed companies can win the trust of both investors and customers and may perform financially better than other companies in the stock market with a low sustainability index. In addition, SMD may provide funds for R&D activities and would result in environmentally friendly technologies (Alam et al., 2020). Moreover, the stock market may help the government to measure environmental performance by monitoring compliance with the government's environmental regulations and standards for listed companies (Bolton and Kacperczyk, 2021). The Saudi economy is dependent on the oil and gas sector and is targeting to diversify in its Vision 2030. The SMD in Saudi Arabia may help to boost the objective of economic diversification from the oil sector by providing investment funds to the non-oil sector.

Along with the expected positive environmental outcomes of SMD, the SMD may also be responsible for environmental degradation in Saudi Arabia. For instance, SMD may attract the investment in oil and gas sector or other pollution-oriented industries, which may damage the environmental quality (Chang et al., 2020). Moreover, powerful listed companies may be involved in lobbying to relax environmental regulations to reduce their cost to improve their financial performance. Moreover, the cost involved in listing the companies may discourage small and younger businesses with green projects and environmentally focused companies from entering the stock market. Lastly, the listed companies may focus on short-term quick profits by saving environment-related costs instead of adopting long-run sustainable practices. Thus, SMD could have an environmentally damaging effect along with expected positive environmental outcomes (Zhao et al., 2023). Thus, the exact association between SMD and environment-sustainability is an empirical question, which is targeted in the present research by taking a sample of the oil-abundant Saudi economy.

Focusing on the above discussions, Saudi literature has investigated the stock market sustainability through environmental social governance (Vinodkumar and Alarifi, 2020), determinants of emissions (Omri et al., 2019), the influence of environment on stock performance (Alsahlawi et al., 2021), the effect of financial expansion on pollution (Abro et al., 2022), and the effect of institutions and markets on pollution (Raggad et al., 2023, Emmanuel et al., 2024). Still, the environmental effects of SMD are not tested in Saudi Arabia. Thus, the present fills this gap by using a maximum time sample in Saudi Arabia.

2. LITERATURE REVIEW

There is scant literature on the SMD and environment nexus and we try to cover all important studies on this nexus. Zhao et al. (2023) investigated the impacts of Renewable Energy Consumption (REC), innovation, SMD, and natural resources on Carbon Footprint (CF) in BRICS-T nations from 1990 to 2018 and found that natural resources negatively impacted the environment by reducing CF by 0.1814%. Additionally, SMD affected environmental quality by decreasing CF by 0.1409%. Conversely, REC positively contributed to environmental quality. The causality tests revealed a uni-directional causality from income to CF and from both REC and SMD to CF. Zafar et al. (2019) reconnoitered the impact of SMD and REC on carbon emissions from 1990 to 2016 and found that REC reduced carbon emissions in both groups. Banking development decreased emissions and SMD decreased emissions. Moreover, income increased carbon emissions. Wen et al. (2020) analyzed the asymmetrical nexus between emissions and SMD in China and found a negative association. Xu et al. (2022) analyzed the nexus between carbon emissions and SMD in China and found SMD raised emissions.

Chang et al. (2020) scrutinized causality among stock returns and emissions in 18 countries from 1971 to 2017 and found unidirectional causality from SMD to emissions. Specifically, a 1% rise in SMD leads to a 9% decline in coal emissions, a 2% increase in oil combustion, and no significant effect from gas combustion. Alam et al. (2020) examined 30 OECD nations from 1996 to 2013 and documented that SMD positively impacted REC and negatively impacted CO_2 emissions. Bolton and Kacperczyk (2021) reported that stocks of firms with emissions got better returns. Habiba et al. (2021) analyzed the influences of SMD and Financial Market Development (FMD) in G20 nations from 1981 to 2017 and found that SMD reduced carbon emissions and FMD increased carbon emissions. REC reduced environmental degradation and FDI improved environmental quality. Paramati et al. (2017) scrutinized the effects of SMD, FDI, and REC in G20 countries and found that FDI and SMD reduced CO_2 emissions. Additionally, REC substantially decreased CO_2 emissions and boosted economic output.

Most literature has focused on FMD and environment nexus. For instance, Chiu and Zhang (2023) explored the controlling effect of FMD in OECD countries and indicated that FMD and the banking sector reduced emissions. However, SMD raised emissions. Moreover, REC reduced CO_2 emissions, which is moderated by FMD as well. Thus, FMD could affect the REC to have a pleasant effect on emissions. Arzova and Sahin (2023) analyzed the impact of FMD on REC and CO_2 emissions in 19 emerging countries from 1997 to 2016 and found that FMD through credit raised CO_2 emissions and could not affect REC. The stock market reduced REC and could not affect emissions. FDI reduced REC and CO_2 emissions. Thus, different proxies of FMD had a different effect on emissions and REC. Thus, it is suggested to consider all separate effects while tracing environmental and financial policies.

Yu et al. (2022) scrutinized Nigeria from 1981 to 2019 and documented that FMD raised emissions and the shadow economy improved environmental quality. Moreover, the authors also found the causality from FMD, income, and trade to carbon emissions. Liu and Gong (2022) examined China's 30 provinces from 2003 to 2017 and found that FMD through credit reduced emissions. However, FMD proxied by the stock market had nonlinear effects on CO_2 emissions with different shapes of effects. Khan et al. (2020) explored the impact of Pakistani FMD from 1982 to 2018 and discovered that SMD, FDI, income, and oil usage accelerated CO_2 emissions. However, FMD by credit reduced CO_2 emissions.

Fang et al. (2020) examined the effects of FMD and the stock market on carbon emissions in China and documented that financial scale and income accelerated carbon emissions. Thus, FMD harmed the environment at the cost of economic progress. However, SMD had a minute effect on emissions. It was suggested to develop financial strategies promoting low-carbon growth. Wei and Kong (2017) investigated 30 Chinese provinces from 1997 to 2013 and documented that FMD in Eastern regions reduced emissions. FMD in Central and Western regions raised emissions. The stock market also showed different effects and the financial structure played a crucial role in different provinces. Shahbaz et al. (2016) explored the asymmetric effect of Pakistani FMD from 1985Q1 to 2014Q4 and found that FMD based on bank and stock market mitigated emissions and bank-based FMD hampered the environment.

Ziaei (2015) investigated the nexus among income, FMD, and CO_2 emissions in 25 countries from 1989 to 2011 and found shocks in emissions could not affect FMD. However, the stock market raised energy usage. Zhang (2011) scrutinized the influence of FMD and found that FMD raised carbon emissions through financial intermediation in China. The efficiency of financial markets shows a weaker influence and China's stock market and FDI could improve carbon-intensive sectors. Ridzuan et al. (2022) analyzed Indonesia from 1971 to 2020 and found that FMD improved environmental quality in Indonesia. Thus, financial institutions provide the necessary capital to adopt environmentally friendly practices and technologies. However, trade liberalization raised emissions. Rosa et al. (2020) examined Malaysia from 2014 to 2018 and documented that ecosystem vitality and carbon emission intensity negatively impacted banking sector profitability and performance indicators. The banking sector contributed to emissions.

Teklie and Yağmur (2024) investigated Africa from 1997 to 2021 and found that emissions increased with energy usage and the EKC was validated. FMD and financial institutions accelerated carbon emissions. Moreover, financial markets showed a negligible effect. Political globalization had a U-shaped effect. Van and Phuong (2023) examined the nexus between REC, FMD, FDI, population, urbanization, and CO_2 emissions in Southeast Asia from 2000 to 2020 and documented that urbanization raised CO_2 emissions due to higher labor mobility in cities. Moreover, population, FMD, and FDI could not affect CO_2 emissions in Southeast Asian economies.

Alola et al. (2024) explored BRICS nations from 1995 to 2017 and demonstrated that economic complexity, technological innovation, and FMD reduced carbon emissions. However, economic growth raised emissions. FMD and economic complexity could not significantly affect carbon emissions and technological innovation helped FMD to have positive environmental effects, which corroborated the potential of technology transfer in improving environmental sustainability in BRICS. Ullah et al. (2024) examined the environmental effects of financial innovations in the OECD and found that financial-innovations reduced emissions. The N-shaped EKC hypothesis was also validated and initially, economic growth raised carbon emissions. Later, it reduced emissions but again raised emissions with further growth. These results corroborated the complexity of income's impact on the environment.

Shahbaz et al. (2024) investigated Russia from 1990 to 2021 and suggested that strong financial regulations mitigated emissions. However, energy price and climate policy uncertainties raised emissions. Thus, stable financial and climate policies helped to reduce CO_2 emissions. Le and Ozturk (2020) reconnoitered the impacts of FMD and institutions on emissions in 47 emerging economies from 1990 to 2014 and validated the EKC in analysis. Globalization, FMD, and energy usage increased CO_2 emissions. Additionally, government expenditures also accelerated carbon emissions. Moreover, feedback was found between most of the investigated variables. Mahmood (2020) reconnoitered GCC from 1980 to 2018 and documented that income positively affected emissions and FMD had an insignificant impact.

Ali et al. (2015) investigated relationships among FMD, income, energy prices, and fossil fuel usage in Nigeria from 1972Q1 to 2011Q4 and found cointegration among the variables. Moreover, FMD and income reduced fossil fuel usage. However, energy prices raised fossil fuel usage. Dogan and Turkekul (2015) investigated and documented that energy and urbanization contributed to emissions in the US. FMD could not affect emissions. Trade reduced emissions and the EKC could not be substantiated. Acheampong (2019) reconnoitered 46 SSA nations from 2000 to 2015 and documented that FMD by money and loans raised emissions. FDI and other financial indicators did not significantly affect emissions. The study did not support the EKC. Population, energy usage, trade, and urbanization raised carbon emissions.

Huang and Guo (2023) analyzed the effects of resource rents, infrastructure, innovation, FMD, green investments, and energy investments on carbon emissions and documented that resource rents and infrastructure raised emissions. Green investments increased short-term carbon emissions. Thus, the authors recommended enhancing innovation levels, green investments, and energy investments. Moreover, FMD should be environmentally friendly. Yu and Latif (2023) moderated the role of FMD in 26 developing countries from 1990 to 2014 and documented that innovation reduced CO_2 emissions with the stock market to FMD ratio lower than 1.71. However, innovation raised CO_2 emissions with the stock market to FMD ratio higher than 1.71. Thus, it is suggested that developing nations emphasize FMD and poverty reduction programs instead of focusing on CO_2 emissions.

We signify that testing the nexus between SMD and the environment is scarce. Moreover, this nexus has not been tested in Saudi's oil-abundant economy, which is an effort of present research.

3. METHODOLOGY

The major plan of the research is to estimate the effect of SMD on carbon emissions but we cannot ignore a very important determinant of pollution, which is economic growth. The relationship between both can be assumed non-linear to test the EKC hypothesis (Grossman and Krueger, 1991). Because, income growth would reduce environmental quality at first and could improve later for a better living standard (Grossman and Krueger, 1995). In the relationship between SMD and emissions, recent literature has been analyzed in symmetrical settings (Yu et al., 2022; Zhao et al., 2023; Alam et al., 2020). However, Wen et al. (2020) realized the possibility of an asymmetrical effect of SMD on emissions. In our perception, SMD could play an asymmetrical role in determining emissions. For instance, if positive shocks of SMD increase emissions, then it is not certain that negative shocks of SMD would also decrease emissions due to the Ratchet Effect. Thus, we assume the following model assuming the quadratic effect of income and asymmetrical effect of SMD on CO_2 emissions:

$$\text{CO2}_t = f(\text{Y}_t, Y_t^2, \text{SMD}_t) \quad (1)$$

Y_t is per capita GDP and Y_t^2 is a square of Y_t. Data is taken from the World Bank (2024). $CO2_t$ is per capita tCO_2 emissions and is taken from the Global Carbon Atlas (2024). SMD is measured as a percentage of total stock traded in Gross Domestic Product (GDP) and its data is sourced from Saudi Central Bank (2024). All data is taken in a natural log from 1985 to 2022. Then, SMD is converted into two series SMDP and SMDN by using the methodology of Shin et al. (2014):

$$\text{SMDP}_t = \sum_{j=1}^{t} SMD_j^+ = \sum_{j=1}^{t} \max(\Delta SMD_j, 0) \quad (2)$$

$$\text{SMDN}_t = \sum_{j=1}^{t} SMD_j^- = \sum_{j=1}^{t} \min(\Delta SMD_j, 0) \quad (3)$$

Thus, model 1 can be written in the following way by replacing SMD with SMDP and SMDN:

$$\text{CO2}_t = f(\text{Y}_t, Y_t^2, \text{SMDP}_t, \text{SMDN}_t) \quad (4)$$

We will regress both models 1 and 4. Before regression analysis, we will check the unit root in series by using Ng and Perron's (2001) statistics:

$$MZ_a^d = \left[\frac{Y_T^d}{T}\right]^2 * 2K^{-1} - f_0 * 2K^{-1} \quad (5)$$

$$MSB^d = \left[\frac{k}{f_0}\right]^{1/2} \quad (6)$$

$$MZ_t^d = MZ_a^d . MSB^d \quad (7)$$

$$MPT_T^d = [c^2 * K * \frac{Y_T^d}{f_0} + \frac{1-c}{T} * \frac{Y_T^d}{f_0}] \quad (8)$$

Later, we will proceed to apply Autoregressive Distributive Lag (ARDL) suggested by Pesaran et al. (2001) on equations 1 and 4 in the following way:

$$\Delta \text{CO2}_t = a_0 + a_1 CO2_{t-1} + a_2 Y_{t-1} + a_3 Y_{t-1}^2 + a_4 SMD_{t-1} + \sum_{i=1}^{l-1} b_{1i} \Delta CO2_{t-i} + \sum_{i=0}^{m-1} b_{2i} \Delta Y_{t-i} + \sum_{i=0}^{m-1} b_{3i} \Delta Y_{t-1}^2 + \sum_{i=0}^{n-1} b_{4i} \Delta SMDP_{t-i} + U_{1t} \quad (9)$$

$$\Delta \text{CO2}_t = a_0 + a_1 CO2_{t-1} + a_2 Y_{t-1} + a_3 Y_{t-1}^2 + a_4 SMDP_{t-1} + a_5 SMDN_{t-1} + \sum_{i=1}^{l-1} b_{1i} \Delta CO2_{t-i} + \sum_{i=0}^{m-1} b_{2i} \Delta Y_{t-i} + \sum_{i=0}^{m-1} b_{3i} \Delta Y_{t-1}^2 + \sum_{i=0}^{n-1} (b_{4i} \Delta SMDP_{t-i} + b_{5i} \Delta SMDN_{t-i}) + U_{2t} \quad (10)$$

Equation 9 will estimate symmetrical model 1 and equation 10 will estimate asymmetrical model 4. We use Kripfganz and Schneider's (2019) bound critical statistics and Pesaran et al. (2001) for cointegration. The Wald test will be applied to the parameters of SMDP and SMDN to verify asymmetry. Later, the short-run effects will be estimated using the following models:

$$\Delta \text{CO2}_t = a_1 ECT_{t-1} + \sum_{i=1}^{l-1} b_{1i} \Delta CO2_{t-i} + \sum_{i=0}^{m-1} b_{2i} \Delta \text{Y}_{t-i} + \sum_{i=0}^{m-1} b_{3i} \Delta Y_{t-1}^2 + \sum_{i=0}^{n-1} b_{4i} \Delta SMDP_{t-i} + U_{3t} \quad (11)$$

$$\Delta \text{CO2}_t = a_1 ECT_{t-1} + \sum_{i=1}^{l-1} b_{1i} \Delta CO2_{t-i} + \sum_{i=0}^{m-1} b_{2i} \Delta \text{Y}_{t-i} + \sum_{i=0}^{m-1} b_{3i} \Delta Y_{t-1}^2 + \sum_{i=0}^{n-1} (b_{4i} \Delta SMDP_{t-i} + b_{5i} \Delta SMDN_{t-i}) + U_{4t} \quad (12)$$

Equation 11 will estimate the symmetrical short-run model of Equation 9 and Equation 12 will estimate the asymmetrical short-run model of Equation 10. Later, the Wald test will be applied to the parameters of ΔSMDP and ΔSMDN to verify the short-run asymmetry.

4. DATA ANALYSES

We start with unit root analyses and Table 1 shows the results. The leveled Y_t, Y_t^2, and $CO2_t$ show unit roots but are stationary at a 1% significance level. $SMDP_t$, $SMDN_t$, and SMD_t show unit roots but are stationary at a 5% significance level. Thus, results corroborate the first difference stationary series.

Table 2 discloses the cointegration results of equations 9 and 10. F-values are 6.8575 and 5.9874 for equations 9 and 10, respectively, which are bigger than upper critical values at 1% and corroborate cointegration in equations 9 and 10. Thus, the hypothesized symmetrical and asymmetrical models have long-run valid relationships. In addition, the P-values of diagnostic tests are more than 0.10, which corroborates that models have good health out of econometric issues.

The long results of equations 9 and 10 are provided in Table 3 and Y_t and Y_t^2 showed positive and negative parameters for

Table 1: Unit root estimates

Series	MZa	MZt	MSB	MPT
$CO2_t$	−2.1542	−0.7785	0.4568	12.6852
Y_t	−4.8541	−1.3574	0.2865	16.6054
Y_t^2	−5.6342	−1.6541	0.2767	7.5214
SMD_t	−7.5241	−2.2451	0.2054	7.9821
$SMDP_t$	−7.2645	−2.2536	0.2189	7.3145
$SMDN_t$	−7.4596	−1.8965	0.2602	8.1541
$\Delta CO2_t$	−25.8524***	−4.6325***	0.1352***	2.9652***
ΔY_t	−24.6321***	−3.5241***	0.1396***	3.0654***
ΔY_t^2	−25.1548***	−3.6987***	0.1368***	2.8657***
ΔSMD_t	−18.8541**	−3.1563**	0.1532**	4.9652**
$\Delta SMDP_t$	−18.9624**	−3.2541**	0.1603**	4.8352**
$\Delta SMDN_t$	−18.6352**	−3.1964**	0.1586**	4.9257**

*, **, and *** are displaying the level of significance for stationarity at 10%, 5%, and 1%

Table 2: Cointegration estimates

Equation	F-statistic	Hetero	Serial corr.	Normality	Function
9	6.8575	1.2154 (0.2954)	0.1956 (0.8125)	0.1254 (0.9298)	1.9874 (0.2015)
10	5.9874	1.3954 (0.2561)	0.1752 (0.8463)	0.3056 (0.8254)	2.1563 (0.1467)
At	1%	5%	10%		
Bound-values	2.88-3.99	2.27-3.28	1.99-2.94		

Table 3: Long run estimates

Variables	Equation 9	Equation 10
Y_t	208.5984 (0.0012)	271.6524 (0.0000)
Y_t^2	−9.4587 (0.0254)	−12.5548 (0.0025)
SMD_t	−0.8548 (0.0393)	
$SMDP_t$		−0.9854 (0.0425)
$SMDN_t$		−0.7892 (0.1648)
Intercept	9.8547 (0.0002)	6.8547 (0.0000)
The Wald test		254.6544 (0.0000)

(P-value)

Table 4: Short run estimates

Variables	Equation 11	Equation 12
$\Delta CO2_{t-1}$	0.6524 (0.0894)	0.5874 (0.0367)
ΔY_t	163.9852 (0.0632)	196.6352 (0.0152)
ΔY_t^2	−7.3895 (0.0264)	−9.0078 (0.0005)
ΔSMD_t	−0.6589 (0.0635)	
ΔSMD_{t-1}	0.2987 (0.4528)	
$\Delta SMDP_t$		−0.6874 (0.0556)
$\Delta SMDP_{t-1}$		−0.2748 (0.1289)
$\Delta SMDN_t$		0.9541 (0.6541)
$\Delta SMDN_{t-1}$		−0.2574 (0.0896)
ECTt-1	−0.5345 (0.0000)	−0.7256 (0.0000)
The Wald test		185.6526 (0.0000)

(P-value)

equations 9 and 10, respectively. Thus, the EKC hypothesis stands true with turning points 61500 Saudi Riyals (SR) (exponent of 208.5984/2/9.4587) in equation 9 and 49944 SR (exponent of 271.6524/2/12.5548) in equation 10. The estimated turning points are within the GDP per capita of the sample period, which validates the correctness of the estimated parameters of Y_t and Y_t^2 and also corroborates that Saudi Arabian economic growth has no environmental issues. Moreover, the recent GDP per capita is helping in reducing CO_2 emissions and is environmentally friendly.

In equation 9, SMD mitigated emissions with an elasticity of (−0.8548). Thus, 1% increasing/decreasing SMD is helping to reduce/increase CO_2 emissions by 0.8548%. In equation 10 of the asymmetrical model, $SMDP_t$ mitigated emissions with an elasticity of (−0.9854). Thus, a 1% increasing SMD series would reduce CO_2 emissions by 0.9854%. However, the estimation of $SMDN_t$ is insignificant. Thus, decreasing the SMD series could not affect CO_2 emissions. So, the effect of SMD is asymmetrical in the asymmetrical analyses of equation 10, which is also tested and corroborated by the Wald test with the estimated P=0.0000. The result of the negative effect of SMD on emissions follows some previous empirical studies (Zhao et al., 2023; Zafar et al., 2019; Chang et al., 2020; Alam et al., 2020; Habiba et al., 2021).

Our results corroborate that Saudi SMD has promoted investment in green projects, which helped reduce CO_2 emissions in the economy. Thus, SMD provides funds to listed companies to invest in green projects, that prove to be environmentally friendly or generate environmentally friendly technologies. The Saudi government is initiating green projects and investors put pressure on the listed companies to invest in green projects and technologies. Moreover, the result also corroborates the economic diversification policies of the Saudi government. For instance, the government is diversifying the Saudi economy from oil-income share and focusing on tourism and other green sectors to reduce the environmental problems in the kingdom. In this domain, SMD is also helping to this diversification policy by providing investment in non-oil listed companies, which help reduce CO_2 emissions in the country. Moreover, Saudi listed companies are also focusing on reporting their environmental performance, which might help in raising investments in highly environmentally friendly listed companies compared to non-reporting or low-environmentally friendly performing companies.

The short results of equations 11 and 12 are provided in Table 4 and the short-run relationships are corroborated with parameters of ECT_{t-1}. Moreover, ΔY_t and ΔY_t^2 have positive and negative parameters in equations 11 and 12, respectively. Thus, the EKC hypothesis is also corroborated with turning points of 65895 SR (exponent of 163.9852/2/7.3895) in equation 11 and of 54979 SR (exponent of 196.6352/2/9.0078) in equation 12. The estimated turning points are within the GDP per capita of the sample period, which validates that economic growth is also environmentally friendly in the short run. In symmetrical equation 11, ΔSMD mitigated emissions with an elasticity of (−0.6589). Thus, a 1% increasing/decreasing SMD is helping to reduce/increase emissions by 0.6589%. In equation 12 of the asymmetrical model, $\Delta SMDP_t$ mitigated emissions with the elasticity of (−0.6874). Thus, a 1% increasing SMDP series would reduce CO_2 emissions by 0.6574%. However, the estimation of $\Delta SMDN_t$ is insignificant and is negative with a one-year lag $\Delta SMDN_{t-1}$. Thus, decreasing the SMDN series with a one-year lag reduces emissions. The effect of SMD is asymmetrical in equation 12 with an estimated P-value=0.0000 of the Wald test.

5. CONCLUSION

The SMD may determine the CO_2 emissions in Saudi Arabia due to a heavy reliance on the oil sector in the stock market. Moreover, the rising and falling SMD must not necessarily have the same effects on CO_2 emissions. Therefore, we estimated the SMD and CO_2 emissions nexus in both symmetrical and asymmetrical models by using a period from 1985 to 2022. The results corroborate the cointegration in both models and unit root analyses confirm the order integration as one. In symmetrical and asymmetrical models, the EKC is corroborated at 61500 SR and 49944 turning points, respectively, which has been achieved by the country in the sample period. In the short run, the EKC is corroborated at 65895 SR and 54979 SR turning points in the symmetrical and asymmetrical models, respectively. The estimated turning points have been achieved by the country in the sample period. Thus, Saudi Arabia has no environmental problems of economic growth. SMD helped reduce emissions with elasticity parameters of 0.8548 and 0.6589, respectively, in the long and short-term. Thus, a 100% increase in SMD helped reduce CO_2 emissions by 85.48% and 65.89%, respectively, in the long and short term.

In asymmetrical results, the EKC is corroborated with a turning point at 49944 SR, which is within income during the sample period. Increasing SMD helped CO_2 emissions with elasticity parameters of 0.9854 and 0.6874, respectively, in the long and short run. Thus, a 100% increase in SMD helped reduce CO_2 emissions by 98.54% and 68.74%, respectively, in the long and short term. Decreasing SMD does not affect CO_2 emissions in the long run but reduces CO_2 emissions in the short run with a one-year lag's elasticity parameter of 0.2574. On the whole, SMD helped improve the environment in Saudi Arabia, which reflects the Aramco and Saudi government's efforts toward environmental sustainability in the Kingdom. In addition, the results corroborate that SMD is motivating the listed companies to adhere to environmental regulations and also providing funds for R&D activities to promote environmentally friendly technologies. Moreover, the results also reflect the diversification efforts of the government from the oil sector, which would help reduce environmental problems from the oil sector.

As per findings, Saudi economy should focus more on SMD to support the clean environment in the Kingdom. Moreover, the government should give incentives to the listed companies disclosing environmental performance and also initiate environmentally friendly technologies or projects. Moreover, the government should also support the R&D activities of the listed companies related to the innovation of clean technologies and processes. In turn, the positive environmental effects of SMD might be increased by reducing emissions.

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