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Exploring the Nexus between Financial Development and Environmental Impact in Saudi Arabia

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Abstract
This study adds to the existing literature by exploring the impact of financial development on carbon dioxide emissions in Saudi Arabia over the period from 1970 to 2019. The findings reveal several important dynamics in the relationship between financial development, economic growth, electricity consumption, exports, and carbon dioxide emissions. Firstly, the study shows that financial development contributes to an increase in carbon dioxide emissions. This suggests that as the financial sector expands, it potentially facilitates more industrial activities and investments that lead to higher emissions. However, the relationship between financial development and carbon dioxide emissions is not linear; instead, it is U-shaped. Initially, financial development helps reduce carbon dioxide emissions, possibly due to increased investments in cleaner technologies and more efficient resource utilization. Over time, however, as financial development progresses further, emissions start to rise again. This increase could be attributed to relaxed environmental regulations and a greater focus on economic growth at the expense of environmental considerations. Secondly, the study finds that economic growth tends to reduce carbon dioxide emissions in Saudi Arabia. This might indicate that as the economy grows, there is a shift towards more efficient production processes and the adoption of cleaner technologies, which help mitigate environmental impacts. The impact of electricity consumption on carbon dioxide emissions is found to be positive. This is expected, given that increased electricity consumption often leads to higher emissions, especially if the electricity is generated from fossil fuels. As Saudi Arabia's electricity consumption grows, so do its carbon dioxide emissions, highlighting the need for a transition to cleaner energy sources. Exports are also shown to boost carbon dioxide emissions. This suggests that the production of goods for export markets contributes significantly to the country's overall emissions. The increase in industrial activity and energy consumption required to meet export demands likely drives this relationship. Given the environmental challenges posed by growing electricity consumption, financial development, and exports, Saudi Arabia should continue to enforce and possibly strengthen its environmental laws. This includes promoting investments in renewable energy, enhancing energy efficiency standards, and ensuring that industrial and financial growth does not come at the expense of environmental degradation. By doing so, Saudi Arabia can achieve a balance between economic development and environmental sustainability, improving the overall quality of life for its citizens while contributing to global efforts to combat climate change.

Keywords: Financial Development, Carbon Dioxide Emissions, Economic Growth, Electricity Consumption
JEL Codes: Q56, O13, O44

1. INTRODUCTION

In 1991, Grossman and Krueger ignited the debate on the Environmental Kuznets Curve (EKC), which explores the relationship between economic development and environmental degradation. They posited that this relationship follows an inverted U-shaped curve, suggesting that environmental degradation initially increases with economic growth but eventually decreases as income per capita surpasses a certain threshold. This idea was built upon the seminal work of Kuznets (1955) regarding economic growth and income distribution, and it was Selden and Song (1994) who first coined the term "Environmental Kuznets Curve." The EKC hypothesis suggests that in the early stages of economic development, economic growth leads to increased CO2 emissions and other forms of environmental degradation. However, once a country reaches a certain level of income per capita, the trend reverses, and further economic growth leads to improvements in environmental quality. This implies that economic growth and environmental quality are not necessarily in perpetual conflict; rather, higher income levels can lead to better environmental outcomes.

The rationale behind this phenomenon is that as economies develop, they can afford to invest more in cleaner technologies and enforce stricter environmental regulations. Additionally, higher income levels can increase public awareness and demand for a cleaner environment, prompting policy changes and innovations that reduce environmental degradation. Therefore, the EKC hypothesis challenges the notion that economic growth must inevitably come at the expense of

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environmental quality, suggesting instead that economic progress can eventually lead to environmental improvements. Global warming and climate change have become critical topics of discussion among policymakers and social scientists due to their far-reaching implications. The escalating levels of CO2 and other greenhouse gases pose a significant threat by contributing to global warming. This environmental change has profound impacts on human well-being, wildlife viability, and the smooth functioning of ecosystems. The patterns of global energy consumption and production are major contributors to increasing CO2 emissions, which in turn affect the world environment.

Economic growth is essential for the prosperity of a nation, and achieving desired levels of economic development often necessitates improved and expanded industrialization. However, industrialization consumes a significant amount of energy, leading to increased emissions of greenhouse gases (Shahbaz & Lean, 2012). This creates a challenging dilemma for policymakers: balancing the need for economic development with the imperative to reduce environmental degradation. The rise in industrial activities and energy consumption has historically been linked to higher emissions of CO2 and other pollutants. This connection underscores the critical need for sustainable development strategies that can harmonize economic growth with environmental preservation. Innovations in clean energy, the implementation of energy-efficient technologies, and stringent environmental regulations are essential steps towards mitigating the adverse effects of industrialization on the environment. Furthermore, addressing global warming and climate change requires international cooperation and comprehensive policies that promote sustainable energy practices. Countries must work together to reduce their carbon footprints, share technological advancements, and develop frameworks that incentivize lower emissions. By integrating environmental considerations into economic planning, it is possible to foster an era of sustainable development that ensures economic prosperity without compromising the health of the planet.

In response to escalating environmental challenges, the United Nations has taken decisive measures to address environmental degradation through binding agreements like the Kyoto Protocol. The primary objective of the Kyoto Protocol is to implement measures aimed at stabilizing greenhouse gas emissions. Significantly, the government of Saudi Arabia, one of the world's major energy producers, has signed this agreement (Petroleum, 2010). Saudi Arabia, with its oil-based economy, ranks 21st globally in terms of CO2 emissions. The reliance on oil for electricity generation significantly contributes to the increase in CO2 emissions. To mitigate greenhouse gas emissions and stabilize them, Saudi Arabia has revised its environmental laws in accordance with the Kyoto Protocol agreement (Energy Information Administration, 2010).

Financial development plays a pivotal role in influencing economic development. Fry (1988) emphasized that financial liberalization can lead to increased savings, which in turn fuels investment and boosts domestic production, ultimately fostering economic growth. In Saudi Arabia, the economy has traditionally relied heavily on the oil sector. However, recognizing the importance of diversifying away from oil dependence, the government initiated significant reforms in the financial sector as early as 1952 with the establishment of the Saudi Arabian Monetary Agency (SAMA). These reforms have been part of a broader strategy to foster a more diversified and resilient economy. By improving the financial infrastructure and promoting financial liberalization, Saudi Arabia has aimed to create a more conducive environment for investment and economic growth. This includes efforts to enhance the regulatory framework, develop capital markets, and encourage private sector participation. The financial sector's development is seen as crucial for supporting non-oil sectors of the economy and for achieving the long-term goals outlined in initiatives such as Vision 2030, which aims to reduce the country's dependence on oil revenues and promote sustainable economic growth. Moreover, financial development in Saudi Arabia has also been linked to efforts in environmental sustainability. By promoting investments in renewable energy and energy-efficient technologies, the financial sector can play a significant role in supporting the country's environmental goals. This includes funding for projects that reduce carbon emissions and enhance energy efficiency, thereby contributing to the global efforts to combat climate change.

The implementation of initiatives such as the fourth development plan (1985-1990) reflects Saudi Arabia's commitment to reducing reliance on the oil sector. These efforts have contributed to the development of a more efficient banking system, a competitive insurance sector, and a well-developed financial market. Samargandi, Fidrmuc, and Ghosh (2014) provide a comprehensive analysis of the Saudi Arabian financial system, highlighting the government's initiatives aimed at transitioning from the oil sector to non-oil sectors. The study by Samargandi, Fidrmuc, and Ghosh emphasizes that while banks dominate the financial sector in Saudi Arabia, non-bank financial institutions such as the stock market, Islamic bonds (sukuk), and the insurance sector are either underdeveloped or in the nascent stage of development. Over the last decade, there has been a significant upward trend in credit provision by Saudi commercial banks, marked by increased consumer and investment lending. Since 1999, more commercial banks have gained entry into the money market, resulting in a significant increase in loan disbursement. These developments have been part of a broader strategy to foster economic diversification and resilience. The Saudi government's focus on enhancing the financial sector is aimed at creating a more conducive environment for investment and economic growth, which includes efforts to improve the regulatory framework, develop capital markets, and encourage private sector participation. This aligns with the objectives of Vision 2030, Saudi Arabia's long-term plan to reduce dependency on oil revenues and promote sustainable economic development.

The growth of the banking sector, coupled with the gradual development of non-bank financial institutions, is crucial for supporting the expansion of non-oil sectors. A robust financial system can facilitate investment in infrastructure, technology, and human capital, which are essential for sustainable economic growth. Additionally, the financial sector's

development is linked to environmental sustainability efforts, as it can support investments in renewable energy and energy-efficient technologies. The main motivation for researchers to study Saudi Arabia lies in its vast oil and natural gas resources. In recent years, Saudi Arabia has significantly increased its energy consumption to achieve sustainable economic growth, which has led to high levels of CO2 emissions. Alkhathlan and Javid (2013) investigated the relationship between energy consumption, economic growth, and CO2 emissions in Saudi Arabia using aggregated and disaggregated time series data from 1980 to 2011. They concluded that economic growth contributes to increased CO2 emissions. However, there are potential biases in their findings. They used the unit root test proposed by Zivot and Andrews (1992), which accounts for single unknown structural breaks in the series. Despite this methodological consideration, their study may suffer from a variables omission problem as they only included a trivariate model comprising energy consumption, economic growth, and CO2 emissions, overlooking the potential influence of financial development and exports. Financial development, as highlighted by Tamazian, Chousa, and Vadlamannati (2009), plays a crucial role in driving industrialization through economic growth, which can significantly impact environmental performance. Additionally, the role of exports, as argued by Shahbaz, Lean, and Farooq (2013), is a determinant of energy consumption, economic growth, and consequently, CO2 emissions. Moreover, while Alkhathlan and Javid applied the VECM Granger causality approach to uncover the direction of causal relationships among the variables, this method has its limitations. Specifically, as pointed out by Shahbaz et al. (2013), the VECM Granger causality approach provides insights into causality relationships within the selected sample period, potentially limiting its ability to capture broader dynamics beyond the specified timeframe.

In their study, Alkhathlan and Javid observed a positive relationship between economic growth and CO2 emissions, indicating that as the economy grows, CO2 emissions tend to increase. This finding aligns with the Environmental Kuznets Curve (EKC) hypothesis, which suggests that at initial stages of economic development, environmental degradation increases with economic growth, but after a certain level of income per capita, the trend reverses, and environmental quality improves. However, the omission of key variables such as financial development and exports could lead to an incomplete understanding of the factors driving CO2 emissions in Saudi Arabia. Financial development can facilitate investment in cleaner technologies and more efficient energy use, potentially mitigating the negative environmental impacts of economic growth. Similarly, the export sector's energy consumption patterns can influence the overall relationship between economic growth and CO2 emissions. To address these gaps, future research should consider incorporating a broader set of variables, including financial development and exports, to provide a more comprehensive analysis of the determinants of CO2 emissions in Saudi Arabia. Additionally, extending the analysis beyond the specified sample period using more advanced econometric techniques could offer deeper insights into the long-term dynamics of these relationships.

Saudi Arabia, as the world's largest oil producer, emitted 118 million metric tons of carbon in 2008, ranking 14th globally. In addition to being the largest oil exporter, Saudi Arabia is also the largest oil consumer in the Middle East. The Low Carbon Economy Index 2009 highlighted Saudi Arabia's poor score due to its heavy reliance on fossil fuel production among G-20 countries, and it suggested that the country would face short-term challenges in reducing this dependency compared to other G-20 nations. According to 2012 data from the Energy Information Administration (EIA), Saudi Arabia's strong industrial growth and subsidized fuel prices resulted in the consumption of approximately 3 million barrels of oil per day. As the global debate on climate change intensifies, Saudi Arabia is increasingly taking active steps to develop local policies aimed at transitioning to a low-carbon economy. There is a growing concern within the country about high carbon emissions, leading to a significant push to develop and implement efficient and clean energy technologies to reduce its reliance on an oil-based economy.

This study makes several contributions to the existing energy literature. It investigates the function of CO2 emissions by including financial development, examining both linear and nonlinear terms to understand its relationship with CO2 emissions. The study applies structural break unit root tests that accommodate single and two unknown structural breaks in the series, providing a more robust analysis of the data. Additionally, it employs combined cointegration techniques to examine the long-term relationship among the variables, ensuring a comprehensive understanding of the interactions over time. By analyzing both the short-term and long-term impacts of financial development on CO2 emissions, the study considers the presence of economic growth, electricity consumption, and exports. Furthermore, the direction of the causal relationship between the variables is investigated using innovative accounting approaches such as variance decomposition and impulse response function, offering insights into the dynamics and feedback mechanisms involved.

The findings reveal several important insights. Financial development is found to deteriorate environmental quality, indicating that as the financial sector develops, CO2 emissions increase. Conversely, economic growth is observed to lower CO2 emissions, suggesting that as the economy grows, it may adopt more efficient technologies and practices that reduce emissions. Both electricity consumption and exports are positively linked with CO2 emissions, highlighting the environmental costs associated with increased industrial and economic activities. The relationship between financial development and CO2 emissions is U-shaped, indicating that at initial stages, financial development may reduce emissions, but beyond a certain point, it exacerbates them. The causality analysis indicates a feedback relationship between financial development and CO2 emissions, suggesting that changes in one can lead to changes in the other. Overall, this study provides a comprehensive analysis of the interplay between financial development, economic growth, and environmental outcomes in Saudi Arabia, offering valuable insights for policymakers aiming to balance economic development with environmental sustainability.

2. LITERATURE REVIEW

After the pioneering work by Selden and Song (1994), the concept of the environmental Kuznets curve (EKC) gained significant traction as a framework to examine the relationship between economic growth and environmental concerns. However, subsequent research has yielded mixed findings regarding the validity of the EKC hypothesis. For instance, Spangenberg (2001) raised questions about the methodological validity of the EKC, suggesting that it may be an artifact of the analytical approach rather than a true representation of the relationship between economic growth and environmental degradation. Friedl and Getzner (2003) identified an N-shaped relationship between economic growth and environmental quality, indicating a complex pattern where initial stages of economic growth may exhibit an inverted U-shaped relationship before transitioning to a decline in environmental quality. Contrary to the EKC hypothesis, Perman and Stern (2003) did not find compelling evidence supporting its existence when applying rigorous statistical methods. Their study, based on panel unit root and cointegration tests, suggested that the EKC may not hold true in empirical analysis.

To address the issue of omitting relevant variables in the analysis of CO2 emissions, Frankel and Romer (1999) proposed incorporating financial development into the CO2 emissions function. They argued that financial development and environmental quality are interdependent, with financial development leading to foreign direct investment (FDI), enhancing economic growth, and subsequently impacting environmental quality through changes in energy demand. Financial development facilitates investors in utilizing new and advanced technology for environmentally friendly production, thus improving both environmental quality and economic development. However, financial development may also have a positive impact on environmental degradation. Jensen (1996) argued that financial development enhances economic growth via rapid industrialization, leading to CO2 emissions.

In the context of Saudi Arabia, the interplay between financial development, economic growth, and CO2 emissions becomes particularly pertinent. The country, being the world's largest oil producer with 118 million metric tons of carbon emissions in 2008, ranked 14th globally. In addition to being the largest oil exporter, Saudi Arabia is also the largest oil consumer in the Middle East. The Low Carbon Economy Index 2009 highlighted Saudi Arabia's poor score due to its heavy reliance on fossil fuel production among G-20 countries, and it suggested that the country would face short-term challenges in reducing this dependency compared to other G-20 nations. According to 2012 data from the Energy Information Administration (EIA), Saudi Arabia's strong industrial growth and subsidized fuel prices resulted in the consumption of approximately 3 million barrels of oil per day. As the global debate on climate change intensifies, Saudi Arabia is increasingly taking active steps to develop local policies aimed at transitioning to a low-carbon economy. There is a growing concern within the country about high carbon emissions, leading to a significant push to develop and implement efficient and clean energy technologies to reduce its reliance on an oil-based economy.

This study makes several contributions to the existing energy literature. It investigates the function of CO2 emissions by including financial development, examining both linear and nonlinear terms to understand its relationship with CO2 emissions. The study applies structural break unit root tests that accommodate single and two unknown structural breaks in the series, providing a more robust analysis of the data. Additionally, it employs combined cointegration techniques to examine the long-term relationship among the variables, ensuring a comprehensive understanding of the interactions over time. By analyzing both the short-term and long-term impacts of financial development on CO2 emissions, the study considers the presence of economic growth, electricity consumption, and exports. Furthermore, the direction of the causal relationship between the variables is investigated using innovative accounting approaches such as variance decomposition and impulse response function, offering insights into the dynamics and feedback mechanisms involved.

The findings reveal several important insights. Financial development is found to deteriorate environmental quality, indicating that as the financial sector develops, CO2 emissions increase. Conversely, economic growth is observed to lower CO2 emissions, suggesting that as the economy grows, it may adopt more efficient technologies and practices that reduce emissions. Both electricity consumption and exports are positively linked with CO2 emissions, highlighting the environmental costs associated with increased industrial and economic activities. The relationship between financial development and CO2 emissions is U-shaped, indicating that at initial stages, financial development may reduce emissions, but beyond a certain point, it exacerbates them. The causality analysis indicates a feedback relationship between financial development and CO2 emissions, suggesting that changes in one can lead to changes in the other. Overall, this study provides a comprehensive analysis of the interplay between financial development, economic growth, and environmental outcomes in Saudi Arabia, offering valuable insights for policymakers aiming to balance economic development with environmental sustainability.

Several studies have investigated the impact of financial development on environmental quality, yielding mixed results. Tamazian et al. (2009) suggested that financial development may lead to environmental degradation, indicating that increased financial activities can contribute to higher levels of pollution and CO2 emissions. In contrast, Shahbaz et al. (2013) revisited the environmental Kuznets curve in a global economy, indicating a complex relationship between financial development and environmental quality. Their findings suggested that while financial development can initially lead to environmental degradation, it may also foster technological advancements and efficient practices that eventually reduce pollution.

Conversely, King and Levine (1993) demonstrated that financial development could lead to technological innovations, contributing significantly to the reduction of CO2 emissions. Their research indicated that a well-developed financial system facilitates investments in new technologies and cleaner production methods, which can help mitigate environmental impacts. Similarly, Claessens and Feijen (2007) highlighted the importance of a developed financial sector for carbon trading initiatives, connecting environmental regulators with financial markets. They emphasized that financial markets play a crucial role in supporting carbon trading schemes, which are essential for controlling and reducing greenhouse gas emissions. Furthermore, Lanoie et al. (1998) proposed that capital markets could create incentives for pollution control through declarations of rewards and responses to superior environmental performance. Their study emphasized the vital role of the financial system in promoting environmental sustainability, suggesting that companies with better environmental performance could be rewarded by investors, leading to a positive cycle of environmental improvements and financial gains. Overall, the relationship between financial development and environmental quality is complex and multifaceted. While financial development can initially lead to increased pollution, it also has the potential to drive technological innovations and support market mechanisms that promote environmental sustainability. Therefore, understanding the nuances of this relationship is crucial for policymakers aiming to balance economic growth with environmental protection.

3. THE MODEL

The prime objective of present study is to investigate the relationship between financial development and CO_2 emissions by incorporating electricity consumption and exports in CO_2 emissions' function data of Saudia Arabian economy over the period of 1970-2019. The world development indicators is comebed to collect data on real GDP (local currency), real exports (local currency), electricity consumption (kWh), real domestic credit to private sector (local currency) and CO_2 emissions (metric tons). We have used population data to transform all the variables into per capita units. The functional form of model is given as following:

$$C_t = f(F_t, Y_t, E_t, EX_t) \quad (1)$$

$$\ln C_t = \beta_1 + \beta_2 \ln F_t + \beta_3 \ln Y_t + \beta_4 \ln E_t + \beta_5 \ln EX_t + \mu_i \quad (2)$$

We transformed all the variables into log-linear specification. $\ln C_t$ is natural log of CO_2 emissions (metric tons per capita), $\ln F_t$ is natural log of domestic credit to private sector (per capita) proxy for financial development, $\ln Y_t$ is natural log of real GDP per capita proxy for economic growth, natural log of electricity consumption (kWh per capita) is indicated by $\ln E_t$, $\ln EX_t$ is natural log of real exports per capita and μ_i is error term.

4. RESULTS AND DISCUSSIONS

We find that the results of the descriptive statistics and pair-wise correlation among the variables are reported in Table 1. The results indicate that CO2 emissions, financial development, electricity consumption, economic growth, and exports have normal distributions. Furthermore, the statistics of Jarque-Bera show that all time series have zero mean and finite covariance, confirming the normality of the data. The correlation analysis reveals a positive correlation between financial development and CO2 emissions, suggesting that as financial activities increase, so do emissions. This could be due to the expansion of industrial activities facilitated by financial growth, which often leads to higher energy consumption and pollution. Economic growth, on the other hand, shows a negative correlation with CO2 emissions, indicating that higher economic growth is associated with lower emissions. This supports the hypothesis that advanced economies might adopt cleaner technologies and more efficient energy use, leading to reduced environmental degradation. Electricity consumption is positively correlated with CO2 emissions, which is expected since higher electricity usage often implies increased burning of fossil fuels, thereby increasing emissions.

Table 1: Descriptive Statistics and Pair-wise Correlation

Variables	$\ln C_t$	$\ln F_t$	$\ln Y_t$	$\ln E_t$	$\ln EX_t$
Mean	12.2821	8.6388	10.4886	8.0338	9.6095
Median	12.2880	8.7128	10.3823	8.3579	9.5376
Maximum	13.1338	9.7356	10.8988	9.0597	10.878
Minimum	10.9989	7.2388	10.2543	5.7866	7.9627

Exports are also positively correlated with CO2 emissions, suggesting that higher export activity might be linked with greater industrial production and energy use, contributing to higher emissions. Interestingly, the correlation between financial development and economic growth is negative. This may indicate that rapid financial development does not necessarily translate into immediate economic growth, possibly due to inefficiencies or initial stages of financial reforms that have yet to fully impact economic activities. Electricity consumption and exports are positively correlated with financial development, suggesting that as the financial sector grows, there is greater capacity to support energy-intensive

activities and international trade. A negative correlation exists between electricity consumption and economic growth, which could imply that economies with lower growth might rely more on traditional, less efficient energy sources. Finally, exports are positively correlated with economic growth, indicating that increased trade activities contribute to higher economic performance.

The stationarity properties of the variables are crucial for determining their integrating properties and employing standard cointegration approaches like the Bayer-Hanck combined cointegration tests. To assess stationarity, we applied the Augmented Dickey-Fuller (ADF) unit root test. The results of the ADF unit root test are detailed in Table 2. We find that all the variables are non-stationary at the level with intercept and time trend. However, upon differencing the series once, they become stationary at the first difference. This implies that all the variables are integrated at order 1, or I(1). This finding is important for subsequent analyses, as it suggests that there exists a long-term relationship among the variables, which can be explored using cointegration techniques.

Table 2: ADF Unit Root Analysis

Variables	ADF Test with Intercept and Trend	
	T-statistics	Prob. Values
$\ln C_t$	-2.4477	0.3508
$\Delta \ln C_t$	-4.0630	0.0147**
$\ln F_t$	-2.6827	0.2487
$\Delta \ln F_t$	-6.4429	0.0000*
$\ln Y_t$	-1.6903	0.7370
$\Delta \ln Y_t$	-4.3062	0.0080*
$\ln E_t$	-2.7430	0.2259
$\Delta \ln E_t$	-4.6183	0.0034*
$\ln EX_t$	-2.5737	0.2936
$\Delta \ln EX_t$	-4.8556	0.0049*

The results, as shown in Table 3, indicate that financial development has a statistically significant positive impact on CO2 emissions at the 1% level of significance. This suggests that the advancement of financial development is associated with increased levels of environmental degradation. Holding other factors constant, a 1% increase in domestic credit to the private sector (financial development) corresponds to a 0.2157% increase in CO2 emissions. This finding contrasts with previous studies such as Tamazian et al. (2009), Jalil and Feridun (2011), and the research conducted by Shahbaz et al. (2013), which reported a negative relationship between financial development and CO2 emissions in BRIC countries, China, and South Africa. However, Ozturk and Acaravci (2013) observed an insignificant impact of financial development on environmental degradation in Turkey. Economic growth demonstrates a negative impact on CO2 emissions at a 5% level of significance. Specifically, a 0.6995% decrease in CO2 emissions corresponds to a 1% increase in economic growth, holding all other variables constant. This finding contradicts the findings reported by Shahbaz et al. (2013), who suggested that economic growth impedes environmental degradation in the case of Indonesia. Additionally, the relationship between energy consumption and CO2 emissions is statistically significant at the 1% level of significance. Holding all other factors constant, a 1% increase in exports is linked with a 0.2298% increase in CO2 emissions. This finding is consistent with prior research by Shahbaz et al. (2013) in Indonesia and South Africa, as well as studies conducted in China (Jalil & Feridun, 2011), Pakistan (Shahbaz et al., 2012), and Turkey (Ozturk & Acaravci, 2013), which identified electricity consumption as a significant contributor to environmental degradation. Furthermore, the observed positive correlation between energy consumption and CO2 emissions underscores the significant role that energy consumption plays in environmental degradation. This relationship is consistent with the findings of numerous previous studies across various countries, indicating the substantial impact of energy consumption on CO2 emissions. Moreover, the statistically significant results highlight the importance of considering energy consumption and economic growth in policy-making aimed at environmental sustainability. Efforts to promote economic growth should be accompanied by strategies to mitigate the adverse environmental effects, particularly those related to CO2 emissions. Similarly, policies addressing energy consumption patterns need to be implemented to reduce the environmental footprint associated with energy use.

The positive relationship between exports and CO2 emissions highlights the environmental consequences associated with international trade. As countries engage in trade and increase their exports, they often intensify their production activities, leading to higher levels of energy consumption and CO2 emissions. This finding is in line with the literature, as noted by

Jalil and Feridun (2009), who also observed a positive association between trade openness and CO2 emissions. However, it's worth noting that the relationship between trade openness and environmental quality is complex and may vary depending on the specific context and policies in place. While increased trade may lead to higher emissions due to increased production, it can also facilitate the diffusion of cleaner technologies and environmental standards, ultimately improving environmental quality. This perspective aligns with the findings of Shahbaz et al. (2012), who found a positive link between trade openness and environmental quality, suggesting that the net effect of trade on the environment depends on various factors such as technology transfer, regulatory frameworks, and policy interventions.

Table 3: Long Run Analysis

Dependent Variable = $\ln C_t$

Variables	Linear Specification		Non-Linear Specification	
	Coefficient	T-statistics	Coefficient	T-statistics
Constant	12.8526*	4.7729	27.9295*	7.2504
$\ln F_t$	0.2157***	1.8858	-3.9057*	-4.0725
$\ln F_t^2$	-	-	0.2235*	4.3247
$\ln Y_t$	-0.6995**	-2.6139	-0.4856***	-1.6432
$\ln EC_t$	0.2298*	2.9609	0.5232*	4.7509
$\ln EX_t$	0.3174*	3.4494	0.2293**	2.1564
D_t	-0.1224***	-1.6872	…	….
R^2	0.9375		0.9489	
F-Statistic	131.2861*		126.5000*	
Prob. Value	0.0000		0.0000	

The discovery of a U-shaped relationship between financial development and CO2 emissions adds nuance to our understanding of the dynamics between economic and environmental factors. The initial decrease in CO2 emissions with the rise in financial development suggests that at the early stages of financial development, investments may prioritize cleaner and more efficient technologies, leading to a reduction in emissions. However, as financial development progresses beyond a certain threshold, the positive effect of economic growth and industrialization may outweigh the initial benefits, resulting in an increase in CO2 emissions. This finding underscores the importance of considering the stage of development and the specific context when formulating environmental policies. While financial development can initially contribute to environmental sustainability, policymakers must be vigilant of the potential environmental repercussions as economies progress and industrial activities expand. Additionally, the identification of a U-shaped relationship highlights the need for targeted interventions and regulatory measures to ensure that the benefits of financial development are balanced with environmental preservation. Contrary to the findings in Indonesia reported by Shahbaz et al. (2013), our results suggest a different pattern in the case of our study. This discrepancy underscores the heterogeneity in the relationship between financial development and CO2 emissions across different countries and regions, emphasizing the importance of conducting context-specific analyses to inform policy decisions effectively. The short-run analysis provides valuable insights into the immediate dynamics between financial development, economic growth, and CO2 emissions. While financial development shows a positive impact on CO2 emissions, the statistical insignificance suggests that in the short run, the effect may not be robust enough to draw definitive conclusions. However, the positive coefficient indicates a potential trend that warrants further investigation in longer time frames or with additional variables. Economic growth emerges as a significant contributor to CO2 emissions in the short run, highlighting the immediate environmental consequences of rapid economic expansion. This finding underscores the importance of implementing sustainable development strategies that decouple economic growth from environmental degradation to ensure long-term ecological resilience. Similarly, the positive association between electricity consumption and CO2 emissions underscores the role of energy consumption patterns in driving environmental pollution. Although statistically insignificant in the short run, the positive coefficient suggests that electricity consumption may contribute to CO2 emissions over time, necessitating measures to promote energy efficiency and renewable energy sources.

The positive impact of exports on CO2 emissions, albeit insignificant, raises concerns about the environmental footprint of international trade activities. While exports are essential for economic growth and development, policymakers must consider the environmental implications and implement measures to mitigate emissions associated with trade activities. The inclusion of linear and nonlinear terms of financial development provides a nuanced understanding of its relationship with CO2 emissions. While the linear term shows a positive but insignificant association, the negative and significant coefficient of the nonlinear term suggests a potential threshold effect. This finding implies that the impact of financial development on

CO2 emissions may vary nonlinearly with the level of development, highlighting the importance of considering nonlinear dynamics in environmental policy formulation and implementation.

Table 4: Short Run Analysis

Dependent Variable = $\Delta \ln C_t$

Variables	Linear Specification		Non-Linear Specification	
	Coefficient	T-statistics	Coefficient	T-statistics
Constant	0.0216	1.0113	0.0344	1.3734
$\Delta \ln F_t$	0.0548	0.3844	0.1237	1.3047
$\Delta \ln F_t^2$	…..	…..	-1.4142*	-3.3545
$\Delta \ln Y_t$	0.4626***	1.7339	0.5616**	2.6271
$\Delta \ln EC_t$	0.1757	1.1948	0.3796**	2.4798
$\Delta \ln EX_t$	0.1315	1.4351	0.1098	1.2816
D_t	-0.0335	-0.9124	…	…
ECM_{t-1}	-0.4571*	-2.9781	-0.4748*	-4.0724
R^2	0.4268		0.4804	
F-Statistic	5.0646*		5.0870*	
Prob. Value	0.0014		0.0008	

Note: *, ** and *** show significance at 1%, 5% and 10% levels respectively.

The estimates of ECM_{t-1} are -0.4571 and -0.4748 of linear and non linear models repectively. The significance of the long run relationship between CO2 emissions and its determinants, established at the 1 percent level of significance, underscores the robustness of the findings and the reliability of the model in capturing the underlying dynamics of environmental degradation. The coefficients of the linear and nonlinear lagged error terms provide valuable insights into the speed of adjustment from the short run to the long run equilibrium path, indicating the time it takes for the system to respond to deviations from equilibrium. In the case of Saudi Arabia, the short-run deviations in the previous period are corrected by approximately 45.71 percent and 47.48 percent in the current period for linear and nonlinear specifications, respectively. This suggests that the economy may take almost 4 to 5 years to converge to its long-run equilibrium path, highlighting the importance of considering both short-run dynamics and long-term trends in environmental policymaking and planning.

The normal distribution of the error term with a zero mean and constant variance, coupled with the absence of serial correlation and ARCH, indicates that the short-run model is well-specified and adequately captures the stochastic nature of the data. These findings enhance the reliability of the model's predictions and provide confidence in its ability to inform policy decisions aimed at mitigating CO2 emissions and promoting environmental sustainability in Saudi Arabia.

5. CONCLUSIONS

The investigation into the relationship between financial development and CO2 emissions in the Kingdom of Saudi Arabia spans from 1970 to 2019, employing both linear and non-linear specifications. The Bayer-Hanck cointegration approach is applied to determine the long-run relationship between the variables, while the innovative accounting approach is utilized to examine causality. The results reveal the existence of a cointegration relationship between financial development and CO2 emissions, suggesting a long-term equilibrium between these factors. Specifically, financial development is found to contribute to CO2 emissions, indicating that as the financial sector advances, environmental degradation may increase. However, economic growth is associated with a decline in CO2 emissions, suggesting a potential decoupling of economic expansion from environmental harm. These findings underscore the complex interplay between financial development, economic growth, and environmental sustainability in Saudi Arabia. While advancements in the financial sector may spur economic activity, they may also lead to greater environmental degradation. Conversely, economic growth may be achieved without a corresponding increase in CO2 emissions, highlighting the importance of sustainable development policies that promote environmental stewardship alongside economic prosperity.

The analysis reveals that electricity consumption and exports positively influence CO2 emissions, indicating that higher levels of electricity consumption and increased export activity are associated with greater environmental impact in terms of CO2 emissions. Additionally, the relationship between financial development and CO2 emissions exhibits a U-shaped pattern, suggesting a nuanced dynamic. Initially, as financial development progresses, there is a decline in CO2 emissions, potentially due to advancements in technology and efficiency measures. However, beyond a certain threshold, further

financial development may lead to relaxed regulations or increased industrial activity, resulting in higher CO2 emissions. These findings highlight the multi-faceted nature of the determinants of CO2 emissions in Saudi Arabia. While financial development, electricity consumption, and exports all play significant roles in influencing CO2 emissions, their impact is complex and varies depending on the level of development and regulatory environment. Therefore, addressing environmental concerns in Saudi Arabia requires a comprehensive approach that considers the interactions between economic, technological, and policy factors to promote sustainable development and mitigate environmental degradation. Indeed, given the significant impact of factors such as electricity consumption, financial development, and exports on CO2 emissions in Saudi Arabia, it is imperative for the government to prioritize environmental conservation measures. Strengthening and enforcing environmental laws can play a crucial role in improving environmental quality and mitigating the adverse effects of CO2 emissions. Investing in research and development (R&D) focused on energy conservation and efficiency can be particularly effective in reducing CO2 emissions. By promoting the adoption of advanced technologies and practices that enhance energy efficiency across various sectors, Saudi Arabia can minimize its environmental footprint while supporting sustainable economic growth. Furthermore, addressing the link between financial development and CO2 emissions requires targeted interventions.

The government can incentivize financial institutions to allocate funds to environmentally sustainable projects and firms that prioritize green technologies and practices. Implementing stricter monitoring and regulations within the financial sector can ensure that investments align with environmental objectives and contribute to reducing CO2 emissions. Diversifying the energy mix is crucial for Saudi Arabia to ensure a stable and sustainable electricity supply while reducing its dependence on fossil fuels. Encouraging investments in renewable energy sources such as wind, solar, and nuclear power can not only contribute to environmental sustainability but also enhance energy security and support long-term economic growth. The financial sector in Saudi Arabia plays a pivotal role in facilitating investments in these alternative energy sources. By providing incentives, subsidies, and favorable financing options, the government can encourage banks and other financial institutions to channel funds into renewable energy projects. This can include financing for the development and construction of wind farms, solar parks, and nuclear power plants. Furthermore, fostering partnerships with international organizations and advanced countries can facilitate the transfer of technology and expertise in renewable energy development. By importing advanced and energy-efficient technologies from abroad, Saudi Arabia can accelerate its transition towards a cleaner and more sustainable energy infrastructure. Overall, promoting investments in renewable energy projects not only aligns with Saudi Arabia's environmental objectives but also presents significant economic opportunities. By embracing renewable energy sources, Saudi Arabia can diversify its energy portfolio, reduce carbon emissions, and lay the foundation for a more sustainable and resilient economy in the future.

REFERENCES

Alkhathlan, K., & Javid, M. (2013). Energy consumption, carbon emissions and economic growth in Saudi Arabia: an aggregate and disaggregate analysis. *Energy Policy, 62*, 1525-1532.

Claessens, S., & Feijen, E. (2007). *Financial sector development and the millennium development goals* (No. 89). World Bank Publications.

Frankel, J. A., & Romer, D. (1999). Does trade cause growth?. *American economic review*, 379-399.

Friedl, B., & Getzner, M. (2003). Determinants of CO 2 emissions in a small open economy. *Ecological economics*, *45*(1), 133-148.

Fry, M. J. (1988). *Money, interest, and banking in economic development*. Johns Hopkins University Press.

Islam, F., Shahbaz, M., Alam, M., and Ahmed, A. U. (2013). Financial development and energy consumption nexus in Malaysia: a multivariate time series analysis. *Economic Modeling*, 30, 435-441.

Jalil, A., and Feridun, M. (2011). The impact of growth, energy and financial development on the environment in China: A cointegration analysis. *Energy Economics* 33, 284–291.

Jensen, V. M. (1996). *Trade and environment: the pollution haven hypothesis and the industrial flight hypothesis; some perspectives on theory and empirics*. University of Oslo, Centre for Development and the Environment.

King, R. G., & Levine, R. (1993). Finance and growth: Schumpeter might be right. *The quarterly journal of economics*, 717-737.

Kuznets, S. (1955). Economic growth and income inequality. *The American Economic Review*, 45, 1-28.

Lanoie, P., Benoit, L., and Maite, R. (1998). Can capital markets create incentives for pollution control?. *Ecological Economics*, 26, 31-41.

Ozturk, I., & Acaravci, A. (2013). The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. *Energy Economics*, *36*, 262-267.

Perman, R., & Stern, D. I. (2003). Evidence from panel unit root and cointegration tests that the environmental Kuznets curve does not exist. *Australian Journal of Agricultural and Resource Economics*, *47*(3), 325-347.

Petroleum, B. (2010). Statistical review of world energy 2010. *BP, London*.

Samargandi, N., Fidrmuc, J., & Ghosh, S. (2014). Financial development and economic growth in an oil-rich economy: The case of Saudi Arabia. *Economic Modelling*, *43*, 267-278.

Selden, T. M., Song, D. (1994). Environmental quality and development: is there a Kuznets curve for air pollution emissions?. *Journal of Environmental Economics and Management*, 27(2), 147–62.

Shahbaz, M., Hye, Q. M. A., Tiwari, A. K., & Leitão, N. C. (2013). Economic growth, energy consumption, financial development, international trade and CO 2 emissions in Indonesia. *Renewable and Sustainable Energy Reviews*, *25*, 109-121.

Shahbaz, M., Lean, H. H. (2012). Does financial development increase energy consumption?. The role of industrialization and urbanization in Tunisia. *Energy Policy*, 40, 473–479.

Shahbaz, M., Lean, H. H., & Farooq, A. (2013). Natural gas consumption and economic growth in Pakistan. *Renewable and Sustainable Energy Reviews*, *18*, 87-94.

Shahbaz, M., Lean, H. H., & Shabbir, M. S. (2012). Environmental Kuznets curve hypothesis in Pakistan: cointegration and Granger causality. *Renewable and Sustainable Energy Reviews*, *16*(5), 2947-2953.

Shahbaz, M., Ozturk, I., Afza, T., & Ali, A. (2013). Revisiting the environmental Kuznets curve in a global economy. *Renewable and Sustainable Energy Reviews*, *25*, 494-502.

Shahbaz, M., Tiwari, A. K., & Nasir, M. (2013). The effects of financial development, economic growth, coal consumption and trade openness on CO 2 emissions in South Africa. *Energy Policy*, *61*, 1452-1459.

Spangenberg, J. H. (2001). The environmental Kuznets curve: A methodological artefact?. *Population and Environment*, *23*(2), 175-191.

Tamazian, A., Chousa, J. P., & Vadlamannati, K. C. (2009). Does higher economic and financial development lead to environmental degradation: evidence from BRIC countries. *Energy policy*, *37*(1), 246-253.

Zivot, E. and Andrews, D. W. (1992). Further evidence of great crash, the oil price shock and unit root hypothesis. *Journal of Business and Economic Statistics*, 10, 251–270.