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Article

The Relationship between Entrepreneurship and Sustainable Development in Saudi Arabia: A Comprehensive Perspective

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Abstract: This study examines the relationship between entrepreneurship and sustainable development in Saudi Arabia from 2006 to 2022, focusing on the economic, social, and environmental dimensions. Using the Autoregressive Distributed Lag (ARDL) model, the research investigates both short-run and long-run dynamics to understand how entrepreneurial activities influence sustainable development within the framework of Saudi Arabia's Vision 2030 initiative. The findings indicate that entrepreneurship significantly contributes to economic growth through job creation and innovation, thereby aiding in the diversification of the economy away from oil dependency. Socially, entrepreneurial initiatives have a positive impact on gender equality and social inclusion by empowering women and integrating youth into the labour market. Environmentally, entrepreneurship helps reduce carbon emissions and promotes sustainable business practices. Despite these positive outcomes, challenges such as regulatory barriers, limited access to finance, and the need for a supportive entrepreneurial ecosystem remain. Recommendations include enhancing entrepreneurial education, providing financial incentives, and streamlining regulatory processes to better support start-ups and SMEs. The study highlights the necessity of addressing these challenges to fully realize the potential of entrepreneurship for sustainable development in Saudi Arabia. By providing empirical evidence on the significant role of entrepreneurship in driving sustainable development, this research offers actionable insights for policymakers aiming to foster a more resilient and diversified economy in line with Vision 2030.

Keywords: entrepreneurship; sustainable development; economic growth; environmental sustainability; ARDL model

1. Introduction

In recent decades, sustainable development has become a cornerstone of global policy agendas, reflecting a commitment to balancing economic growth with social equity and environmental stewardship. This holistic approach recognizes that long-term prosperity depends not only on economic factors but also on social inclusion and environmental sustainability. As nations strive to meet the United Nations' Sustainable Development Goals (SDGs), the role of entrepreneurship has gained prominence as a catalyst for sustainable transformation. Entrepreneurs drive innovation, create jobs, and introduce new technologies and business models that can address social and environmental challenges while fostering economic dynamism.

The importance of entrepreneurship in achieving sustainable development is underscored by its potential to stimulate economic growth, enhance social outcomes, and reduce environmental impacts. Numerous studies have highlighted how entrepreneurial ventures contribute to economic

development by generating employment, increasing productivity, and fostering innovation (Audretsch and Keilbach, 2004; Dhahri and Omri, 2018). Additionally, entrepreneurship is seen as a vehicle for social change, improving health, education, and overall quality of life. Green and sustainable entrepreneurship, in particular, has been identified as a key mechanism for reducing carbon footprints and promoting environmental sustainability (Neumann, 2022).

Despite the growing recognition of entrepreneurship's role in sustainable development, the specific dynamics of this relationship can vary significantly across different contexts. Saudi Arabia presents a unique case study in this regard. The country is undergoing a profound economic transformation driven by Vision 2030, an ambitious initiative aimed at diversifying the economy away from oil dependence and fostering sustainable development. Vision 2030 outlines strategic objectives to increase the contribution of small and medium-sized enterprises (SMEs) to the national economy, enhance innovation, and support sustainable practices.

However, the interplay between entrepreneurship and sustainable development in Saudi Arabia remains underexplored. This study addresses this gap by empirically assessing the connections between entrepreneurial activity and sustainable development across economic, social, and environmental dimensions. By focusing on the period from 2006 to 2022, the research aims to capture the impact of entrepreneurial activities within the broader context of Saudi Arabia's economic reforms.

The research employs the Autoregressive Distributed Lag (ARDL) approach to examine both short-run and long-run relationships between entrepreneurship and various aspects of development. The ARDL model is particularly suited for this analysis due to its flexibility in handling variables of different integration orders, making it an ideal tool for exploring complex, dynamic relationships (Pesaran and Shin, 1999).

The study seeks to answer three core questions: How does entrepreneurial activity influence economic development in Saudi Arabia? What is the impact of entrepreneurship on social development indicators such as the Human Development Index (HDI)? How do entrepreneurial activities affect environmental sustainability, particularly in terms of CO₂ emissions? By addressing these questions, the research aims to provide a comprehensive understanding of the role of entrepreneurship in promoting sustainable development in Saudi Arabia.

The value added by this research lies in its comprehensive approach to examining the multifaceted impact of entrepreneurship on sustainable development in Saudi Arabia. The findings will contribute to the existing literature by offering nuanced insights into the Saudi context and providing empirical evidence to inform policymakers and stakeholders. This research is particularly timely given Saudi Arabia's ongoing efforts to achieve its Vision 2030 goals and transition towards a more diversified and sustainable economy.

The objectives of this study are to quantify the effects of entrepreneurial activity on economic, social, and environmental development in Saudi Arabia, to understand the dynamics of these relationships over time, and to provide actionable insights for policymakers. The importance of this research is underscored by the potential for entrepreneurship to drive sustainable development, not only in Saudi Arabia but also as a model for other nations pursuing similar goals.

The research is organized as follows: The next section reviews the relevant literature on entrepreneurship and sustainable development, highlighting key theoretical frameworks and empirical findings. The subsequent section outlines the data sources and variables used in the analysis, followed by a detailed explanation of the ARDL methodology. The results section presents the findings from the ARDL models, examining short-run and long-run relationships across the three dimensions of sustainable development. The discussion section interprets these findings in the context of the broader literature and Saudi Arabia's policy environment. Finally, the conclusion summarizes the key insights, discusses policy implications, and suggests avenues for future research.

2. The Literature Review

The following section provides a comprehensive review of the existing literature on the concept of sustainable development, its main components, and their interactions with entrepreneurial

activity. The review is structured to first explore the multifaceted nature of sustainable development, emphasizing the complexity and interdependence of its economic, social, and environmental dimensions. It then delves into the role of entrepreneurship as a catalyst for sustainable development, examining its economic, social, and environmental impacts.

Through a synthesis of key studies, this section highlights how entrepreneurship drives economic growth, enhances social development, and contributes to environmental sustainability. Despite the substantial body of research underscoring these interactions, there remains a significant gap in the empirical examination of these dynamics within the specific context of Saudi Arabia. This study aims to fill this gap by providing a detailed analysis of the impact of entrepreneurial activities on sustainable development in Saudi Arabia from 2006 to 2022.

The literature review sets the foundation for the development of hypotheses, which will be empirically tested using the ARDL approach. These hypotheses are crafted to explore the nuanced relationships between entrepreneurial activity and the three pillars of sustainable development, offering insights that are both timely and relevant given Saudi Arabia's ongoing economic transformation under Vision 2030. This section, therefore, not only consolidates existing knowledge but also paves the way for new contributions to the field of sustainable entrepreneurship.

2.1. The Concept of Sustainable Development

Sustainable development is a multifaceted and complex concept that aims to achieve a harmonious balance between economic growth, social inclusion, and environmental protection. The term emphasizes meeting the needs of the present without compromising the ability of future generations to meet their own needs (Dhahri and Omri, 2018). This holistic approach requires integrating diverse and sometimes conflicting objectives, making sustainable development an intricate challenge for policymakers and practitioners alike.

The economic dimension of sustainable development focuses on fostering robust economic growth that is inclusive and equitable. Economic growth should create wealth and employment opportunities, enhance productivity, and promote technological innovation. However, this growth must be pursued in ways that do not exacerbate inequality or lead to environmental degradation (Filser et al., 2019). The work of Hartog et al. (2010) underscores the importance of a stable economic environment that supports entrepreneurial activities, which in turn drive economic dynamism and innovation.

Social inclusion is another critical pillar of sustainable development. It involves ensuring that all members of society have access to basic services, opportunities, and resources, thereby promoting equity and reducing disparities. Social development encompasses improvements in education, healthcare, gender equality, and overall quality of life (Dhahri and Omri, 2018). Alwakid et al. (2021) highlight the role of formal institutions in facilitating entrepreneurship, which can lead to social progress by creating jobs and empowering marginalized groups.

Environmental protection is the third essential component of sustainable development. It aims to preserve natural resources, reduce pollution, and mitigate climate change to ensure a healthy and resilient environment for future generations. This requires a shift towards sustainable consumption and production patterns, as well as the development and adoption of green technologies (Neumann, 2022). He et al. (2020) provides evidence that entrepreneurial activities can contribute to environmental sustainability through the implementation of eco-friendly practices and innovations.

The interactions between these three pillars are complex and interdependent. Economic activities can lead to social improvements by creating jobs and generating income, but they can also cause environmental harm if not managed sustainably. Similarly, social progress can drive economic growth by fostering a more educated and healthier workforce, yet it may increase consumption and resource use. Environmental sustainability, while crucial, often requires substantial economic investments and can influence social and economic policies (Dhahri et al., 2021).

Apostolopoulos et al. (2018) argues that achieving sustainable development requires innovative and collaborative approaches that can navigate these interdependencies. Effective governance and strong institutional frameworks are essential to balance economic, social, and environmental

objectives. This is particularly relevant in the context of developing countries, where the challenges of poverty, inequality, and environmental degradation are more pronounced (Dhahri and Omri, 2018; Peprah and Adekoya, 2020).

Early-stage business models that prioritize sustainability can have a significant impact on long-term development. Cagarman et al. (2023) introduce the esSROI (Sustainable Return on Investment) model to capture the sustainable impact of early-stage businesses. This model can be applied to assess the sustainability of new ventures in Saudi Arabia, ensuring that entrepreneurial activities contribute positively to economic, social, and environmental outcomes.

In summary, sustainable development is a complex and dynamic concept that necessitates a comprehensive and integrated approach to policy and practice. The interactions between economic growth, social inclusion, and environmental protection highlight the need for innovative solutions and robust institutional frameworks to achieve long-term sustainability. This complexity underscores the importance of entrepreneurship as a catalyst for sustainable development, capable of driving economic, social, and environmental progress in a balanced and synergistic manner.

2.2. *Entrepreneurship and Sustainable Development*

Entrepreneurship is increasingly recognized as a critical driver of sustainable development. It fosters economic dynamism, creates jobs, and introduces innovative solutions to social and environmental challenges. The interaction between entrepreneurship and sustainable development can be examined through its economic, social, and environmental impacts.

Huđek and Bradač Hojnik (2020) provide empirical evidence on the significant role of entrepreneurship in achieving sustainable development goals. Their study shows that entrepreneurial activities contribute to reducing carbon emissions and promoting sustainable business practices. Similarly, Johnson and Schaltegger (2020) highlight case studies where entrepreneurial ventures have successfully integrated sustainability into their business models, leading to positive environmental outcomes.

2.3. *Economic Impact of Entrepreneurship: Entrepreneurship and Economic Growth*

Entrepreneurship contributes significantly to economic growth by generating employment, increasing productivity, and fostering innovation. Studies have shown that entrepreneurial activities are positively correlated with economic growth across various contexts. For instance, Wennekers and Thurik (1999) and Audreitsch and Keilbach (2004) highlight the role of entrepreneurship in driving regional and national economic performance. In Saudi Arabia, Akinwale et al. (2020) found that entrepreneurial activities have significantly contributed to economic diversification and growth, particularly in the context of the Vision 2030 initiative aimed at reducing oil dependency.

Dana et al. (2024) reviews the history of women's entrepreneurship research, emphasizing the role of women entrepreneurs in driving economic and social development. Davari et al. (2022) investigate the causal relationships between entrepreneurship, unemployment, and economic growth. Their findings indicate that entrepreneurship reduces unemployment and stimulates economic growth. Dejardin (2000) explores the relationship between entrepreneurship and economic growth, arguing that entrepreneurship is a critical driver of economic performance.

Economic freedom is a critical factor that influences the success of entrepreneurial activities. Sayed and Abdelrahim (2024) provide an empirical analysis of GCC countries, including Saudi Arabia, showing that economic freedom acts as a catalyst for entrepreneurship. Their study finds that reducing regulatory barriers and enhancing economic freedom can significantly boost entrepreneurial activities, leading to economic growth and sustainable development.

Doran, McCarthy, and O'Connor (2018) highlight that entrepreneurship stimulates economic growth in both developed and developing countries by creating jobs and fostering innovation. Ferreira et al. (2017) discuss Schumpeterian entrepreneurship, which focuses on innovation, and Kirznerian entrepreneurship, which emphasizes market efficiency.

Gu, Qiu, and Zhang (2020) show that entrepreneurship drives economic growth in China through innovation and productivity, suggesting similar potential for Saudi Arabia. Gupta and

Dharwal (2022) emphasize the role of green entrepreneurship in promoting sustainable development. This is key for Saudi Arabia's environmental goals under Vision 2030, including reducing carbon emissions.

2.4. Social Impact of Entrepreneurship: Entrepreneurship and Human Development

Entrepreneurship also plays a crucial role in enhancing social development. It contributes to human development by improving access to education, healthcare, and other essential services. Dhahri and Omri (2018) emphasize that entrepreneurship promotes social inclusion by providing opportunities for marginalized groups, including women and youth. In Saudi Arabia, initiatives to support women entrepreneurship have shown positive impacts on social development, as highlighted by Abdelwahed et al. (2022). These initiatives have not only empowered women economically but also contributed to broader social progress.

Apostu and Gigauri (2023) explore the reciprocal relationship between sustainable development and entrepreneurship in emerging countries. They find that entrepreneurship drives sustainable development by creating jobs, reducing poverty, and promoting social inclusion. Ashari et al. (2021) analyzes the moderating effects of entrepreneurship education on entrepreneurial intention and its impact on sustainable development goals. Their findings suggest that entrepreneurship education enhances entrepreneurial intention, leading to increased entrepreneurial activities that contribute to sustainable development.

2.5. Environmental Impact of Entrepreneurship: Entrepreneurship and Environment

Green and sustainable entrepreneurship are pivotal in addressing environmental challenges. Entrepreneurs can develop and implement innovative solutions that reduce environmental degradation and promote sustainability. Studies by Neumann (2022) and He et al. (2020) demonstrate that entrepreneurial activities can significantly reduce carbon emissions and promote environmental sustainability. In Saudi Arabia, the emphasis on green entrepreneurship under Vision 2030 has led to the development of sustainable business practices and technologies, which contribute to environmental protection while supporting economic growth (Alwakid et al., 2021).

2.6. Entrepreneurship and Sustainable Development in Saudi Context

Saudi Arabia is undergoing a significant economic transformation driven by its Vision 2030 initiative, which aims to diversify the economy away from oil dependence and foster sustainable growth. This ambitious plan emphasizes the development of a vibrant private sector, enhanced innovation, and sustainable practices across various sectors. Within this framework, entrepreneurship is positioned as a critical driver of sustainable development, playing a pivotal role in economic diversification, social inclusion, and environmental sustainability.

Entrepreneurship has been identified as a key factor in driving economic growth and diversification in Saudi Arabia. The country's Vision 2030 outlines strategic objectives to increase the contribution of small and medium-sized enterprises (SMEs) to the national economy. Akinwale et al. (2020) highlight that entrepreneurial activities have significantly contributed to economic growth, particularly through job creation and innovation. By fostering a more dynamic and diversified economic landscape, entrepreneurship helps reduce the country's reliance on oil revenues, thereby enhancing economic resilience and sustainability (Dhahri and Omri, 2018).

Yusuf and Albanawi (2016) emphasize the pivotal role of entrepreneurship in driving economic development in Saudi Arabia. They argue that entrepreneurial activities are critical for diversifying the economy, reducing unemployment, and fostering innovation. This aligns with the Vision 2030 initiative, which aims to reduce the country's dependence on oil and create a more diversified and resilient economy. By fostering a supportive ecosystem for entrepreneurs, Saudi Arabia can stimulate economic growth and achieve sustainable development goals.

Bashir and Akhtar (2016) examine the impact of innovative entrepreneurship on economic development in G20 countries. Their findings highlight that innovative entrepreneurship

significantly contributes to economic growth by introducing new products, services, and technologies that enhance productivity and competitiveness. This is particularly relevant for Saudi Arabia, as it seeks to leverage innovation to drive economic diversification and growth. The emphasis on innovative entrepreneurship can help Saudi Arabia achieve a more dynamic and competitive economy, in line with its Vision 2030 objectives.

Entrepreneurship also plays a crucial role in promoting social development in Saudi Arabia. Initiatives aimed at supporting women entrepreneurs and integrating youth into the labour market are central to Vision 2030. Abdelwahed et al. (2022) discuss how women entrepreneurship initiatives have not only empowered women economically but also contributed to broader social progress by promoting gender equality and enhancing social inclusion. These efforts align with Dhahri and Omri's (2018) findings that entrepreneurship can drive social inclusion by providing opportunities for marginalized groups, improving access to education.

The environmental dimension of sustainable development is increasingly important in Saudi Arabia's economic planning. The country has recognized the need to address environmental challenges and promote sustainable practices. Alwakid et al. (2021) emphasize the role of green entrepreneurship in this context, noting that formal institutions play a crucial role in facilitating the development and adoption of sustainable business practices. The promotion of green technologies and eco-friendly practices among entrepreneurs is seen as a way to reduce the environmental footprint of economic activities and contribute to global sustainability goals (Neumann, 2022).

Despite the progress, several challenges remain in fully realizing the potential of entrepreneurship for sustainable development in Saudi Arabia. Agrawal et al. (2024) identify various entrepreneurial barriers, including regulatory hurdles, access to finance, and the need for a supportive entrepreneurial ecosystem. Addressing these challenges is essential to foster a more conducive environment for sustainable entrepreneurship. Additionally, initiatives like those highlighted by Bokhari et al. (2012) focus on reducing unemployment through entrepreneurship, which aligns with the broader goals of Vision 2030.

Empirical studies underscore the positive impacts of entrepreneurship on sustainable development in Saudi Arabia. For example, the work of Dhahri et al. (2021) and He et al. (2020) provides evidence that entrepreneurial activities can significantly reduce carbon emissions and promote environmental sustainability. These findings support the inclusion of entrepreneurship as a core component of national development strategies.

The integration of entrepreneurship into sustainable development policies offers numerous benefits, including enhanced economic diversification, social equity, and environmental protection. Policies that support entrepreneurial education, provide financial incentives, and create an enabling regulatory environment are crucial for maximizing the impact of entrepreneurship on sustainable development (Dhahri and Omri, 2018; Saberi and Hamdan, 2019).

Chaabén et al. (2024) provide empirical evidence on the green economy performance and sustainable development achievements in Saudi Arabia. Their study indicates that promoting green entrepreneurship and sustainable business practices can lead to significant environmental and economic benefits. This aligns with Saudi Arabia's Vision 2030 goals of achieving a more diversified and sustainable economy.

In conclusion, entrepreneurship in Saudi Arabia is a vital driver of sustainable development, contributing to economic growth, social inclusion, and environmental sustainability. The ongoing efforts under Vision 2030 highlight the country's commitment to leveraging entrepreneurial activities to achieve a more diversified and sustainable economy. By addressing existing challenges and capitalizing on opportunities, Saudi Arabia can further enhance the role of entrepreneurship in its sustainable development agenda.

2.7. The Research Gap

Despite the acknowledged importance of entrepreneurship in promoting sustainable development, there is limited empirical research on the specific dynamics of this relationship in Saudi Arabia. Most existing studies focus on developed countries or provide a general analysis without

delving into the unique context of Saudi Arabia's economic transformation. This study addresses this gap by providing a comprehensive analysis of how entrepreneurial activities influence economic, social, and environmental dimensions of sustainable development in Saudi Arabia from 2006 to 2022.

2.8. Hypothesis Development

Based on the literature review, several hypotheses are developed to guide the empirical analysis:

1. Economic Hypothesis: Entrepreneurial activity positively influences economic development in Saudi Arabia. This hypothesis is grounded in the findings of Akinwale et al. (2020) and Wennekers and Thurik (1999), who highlight the positive impact of entrepreneurship on economic growth.
2. Social Hypothesis: Entrepreneurial activity positively impacts social development indicators such as the Human Development Index (HDI). This hypothesis is supported by Dhahri and Omri (2018) and Abdelwahed et al. (2022), who emphasize the role of entrepreneurship in enhancing social inclusion and human development.
3. Environmental Hypothesis: Entrepreneurial activity contributes to environmental sustainability by reducing CO₂ emissions. This hypothesis aligns with the studies by Neumann (2022) and He et al. (2020), which demonstrate the positive environmental impact of green and sustainable entrepreneurship.

This study aims to empirically test these hypotheses using the ARDL approach, providing a nuanced understanding of the role of entrepreneurship in promoting sustainable development in Saudi Arabia.

3. Data and Methodology

In order to empirically assess the relationship between entrepreneurship and sustainable development in Saudi Arabia, this section outlines the data sources, variables, and the methodological framework used in the study. The analysis spans from 2006 to 2022, a period that captures significant economic transformations under Saudi Arabia's Vision 2030 initiative. By leveraging comprehensive data from reputable sources and employing robust econometric techniques, this section aims to provide a solid foundation for understanding the intricate dynamics between entrepreneurial activities and the economic, social, and environmental dimensions of sustainable development. The Autoregressive Distributed Lag (ARDL) approach, known for its flexibility and robustness in handling different orders of integration, is utilized to examine both short-run and long-run relationships, offering nuanced insights into how entrepreneurship impacts sustainable development in the Saudi context.

3.1. Data

This study utilizes data from various reliable sources to analyze the relationship between entrepreneurship and sustainable development in Saudi Arabia. The data spans from 2006 to 2022 and includes variables essential for understanding the economic, social, and environmental dimensions of sustainable development.

Data was sourced from the World Bank for GDP, government expenditure, and gross fixed capital formation, which are essential for measuring economic development and productivity. The United Nations Development Programme (UNDP) provided data on the Human Development Index (HDI), which was modified in this study to exclude Gross National Income (GNI) to reduce multicollinearity. The General Authority for Statistics in Saudi Arabia offered data on population growth and other demographic indicators relevant to social development. Data on entrepreneurial activity was obtained from the Global Entrepreneurship Monitor (GEM), a critical variable for assessing the impact of entrepreneurship on various development dimensions. Additionally, CO₂ emissions data, used as a proxy for environmental degradation, was sourced from the World Bank and the International Energy Agency (IEA).

These data sources and variables provide a comprehensive basis for analyzing the intricate relationships between entrepreneurship and sustainable development, aligning with the study's objectives to explore economic, social, and environmental dimensions.

3.2. The Measurement of the Variables

The variables used in this study as illustrated in Table (1), include Gross Domestic Product (GDP), measured in constant 2010 US dollars, which serves as a primary indicator of economic development. Government expenditure (GEXP) and gross fixed capital formation (GFCF) were also included to capture the effects of fiscal policy and investment on economic growth. The Human Development Index (HDI), modified to exclude GNI, provides a measure of social development focusing on health and education. Population growth (POPG) data helps in understanding demographic changes and their socio-economic impacts. Entrepreneurial activity (ENTR) is a key variable representing the level of entrepreneurship in the economy. Lastly, CO2 emissions per capita serve as a measure of environmental impact, highlighting the sustainability challenges associated with economic and entrepreneurial activities.

Table (1). The Variables measurement.

Variable Name	Definition	Measurement	Source
GDP	Gross Domestic Product	Constant 2010 US dollars	World Bank
GEXP	Government Expenditure	Percentage of GDP	World Bank
GFCF	Gross Fixed Capital Formation	Constant 2010 US dollars	World Bank
HDI	Human Development Index (modified)	Composite index (excluding GNI)	Human Development Index Human Development Reports (undp.org)
POPG	Population Growth	Annual percentage growth rate	General Authority for Statistics (stats.gov.sa)
ENTR	Entrepreneurial Activity	Index of entrepreneurial activity	Global Entrepreneurship Monitor (GEM)
CO2	CO2 Emissions	Metric tons per capita	World Bank, International Energy Agency (IEA)

Note: own construction.

3.3. The Models

This study aims to investigate the relationship between entrepreneurship and sustainable development by empirically assessing the connections between national shares of entrepreneurial activity (ENTR) and various aspects of development: economic, social, and environmental. The study uses data from 2006 to 2022 for Saudi Arabia and employs three independent regression models, using ARDL regressions, to test these relationships.

3.3.1. Model 1: Economic Development

The first model estimates economic development using the methodologies of Neumann (2022) and Urbano et al. (2020), building upon the framework established by Audretsch and Keilbach (2004).

This model includes institutional factors and is structured like a Cobb-Douglas production function, with ENTR acting as a proxy for the knowledge production factor. The equation is as follows:

$$\begin{aligned} \Delta \log_t \text{PROD} = & \beta_0 + \beta_1 \log \text{PROD}_{t-1} + \beta_2 \log \text{ENTR}_{t-1} + \beta_3 \log \text{GFCF}_{t-1} + \beta_4 \log \text{GEXP}_{t-1} + \beta_5 \log \text{EXPO}_{t-1} \\ & \sum_{i=0}^{k-1} \alpha_1 \Delta \log \text{PROD}_{t-1} + \sum_{i=0}^{k-1} \alpha_2 \Delta \log \text{ENTR}_{t-1} + \sum_{i=0}^{k-1} \alpha_3 \Delta \log \text{GFCF}_{t-1} \\ & + \sum_{i=0}^{k-1} \alpha_4 \Delta \log \text{GEXP}_{t-1} + \sum_{i=0}^{k-1} \alpha_5 \Delta \log \text{EXPO}_{t-1} + U_t \end{aligned} \quad (1)$$

In this equation, GDP represents the total production output measured as the Gross Domestic Product in constant 2010 US\$, and L is the labour input measured as the total labour force. GDP/L is labour productivity (PROD), a common proxy for economic development (Urbano et al., 2020). GFCF is physical capital, measured as gross domestic capital formation in constant 2010 US\$. (GEXP) is the government consumption rate, and (EXPO) is the export rate. ϵ_t represents the statistical error term. β_0 to β_5 are the estimation coefficients, and ϵ_t represents the statistical error term.

3.3.2. Model 2: Social Development

The second model estimates social development using the Human Development Index (HDI), which is calculated annually by the UNDP. In line with the methodologies of Dhahri and Omri (2018), Gu et al. (2020), and Neumann (2022), this study employs the modified HDI (MHDI). The MHDI excludes Gross National Income (GNI) to reduce multicollinearity.

$$MHDI = \frac{1}{2} \text{life expectancy inde} + \frac{1}{2} \text{education index} \quad (2)$$

The regression model for estimating the relationship between ENTR and social development is:

$$\begin{aligned} \Delta \log \text{MHDI}_t = & \beta_0 + \beta_1 \log \text{MHDI}_{t-1} + \beta_2 \log \text{ENTR}_{t-1} + \beta_3 \log \text{POPG}_{t-1} + \beta_4 \log \text{GDP}_{t-1} \\ & \sum_{i=0}^{k-1} \alpha_1 \Delta \log \text{MHDI}_{t-1} + \sum_{i=0}^{k-1} \alpha_2 \Delta \log \text{ENTR}_{t-1} + \sum_{i=0}^{k-1} \alpha_3 \Delta \log \text{POPG}_{t-1} + \sum_{i=0}^{k-1} \alpha_4 \Delta \log \text{GDP}_{t-1} + U_t \end{aligned} \quad (3)$$

Population growth (POPG) and GDP are included to control for socio-economic effects (Gu et al., 2020; Venanceo and Pinto, 2020).

3.3.3. Model 3: Environmental Development

The third model estimates environmental development using CO2 emissions per capita as a proxy for environmental degradation:

$$\begin{aligned} \Delta \log \text{CO2}_t = & \beta_0 + \beta_1 \log \text{CO2}_{t-1} + \beta_2 \log \text{ENTR}_{t-1} + \beta_3 \log \text{GDP}_{t-1} + \beta_4 \log \text{MHDI}_{t-1} \\ & \sum_{i=0}^{k-1} \alpha_1 \Delta \log \text{CO2}_{t-1} + \sum_{i=0}^{k-1} \alpha_2 \Delta \log \text{ENTR}_{t-1} + \sum_{i=0}^{k-1} \alpha_3 \Delta \log \text{GDP}_{t-1} + \sum_{i=0}^{k-1} \alpha_4 \Delta \log \text{MHDI}_{t-1} + U_t \end{aligned} \quad (4)$$

Following the methodologies of Ben Youssef et al. (2018), Dhahri and Omri (2018), and Neumann (2022), GDP and MHDI are included as control variables.

These models offer a thorough analysis of the impact of entrepreneurship on the economic, social, and environmental dimensions of sustainable development in Saudi Arabia.

3.4. The Autoregressive Distributed Lag (ARDL)

The Autoregressive Distributed Lag (ARDL) model, used in this study, is a powerful econometric technique used to analyze the dynamic relationship between variables in both the short and long run. Developed by Pesaran and Shin (1999), the ARDL approach is particularly useful for examining the interplay between economic, social, and environmental factors in time series data, as it accommodates variables integrated of different orders (i.e., I(0) and I(1)).

The ARDL model includes lagged values of both the dependent and independent variables, allowing it to capture the dynamic nature of the relationships under study. This is crucial for understanding how past values influence current outcomes, providing a more comprehensive view of the underlying processes.

One of the key advantages of the ARDL technique is its flexibility in modeling cointegrated relationships. Unlike traditional cointegration methods that require all variables to be integrated of the same order, ARDL can be applied regardless of whether the variables are purely $I(0)$, purely $I(1)$, or a combination of both. This flexibility makes ARDL a robust tool for analyzing complex datasets typical in economic and social sciences.

The ARDL approach involves two main steps: estimating the short-run dynamics and long-run equilibrium relationships. In the short run, the model captures immediate effects of changes in independent variables on the dependent variable. In the long run, the model identifies the equilibrium relationship, showing how variables converge over time. This dual focus on short-run and long-run effects provides a nuanced understanding of the relationships between variables.

The Error Correction Model (ECM) is an integral part of the ARDL technique, enabling the estimation of speed-of-adjustment coefficients. These coefficients indicate how quickly deviations from the long-run equilibrium are corrected, providing insights into the stability and resilience of the system under study.

In this study, the ARDL technique is applied to three models focusing on economic, social, and environmental development. For each model, the ARDL approach helps in identifying both immediate impacts and long-term relationships between entrepreneurial activity, GDP, government expenditure, human development, population growth, and CO₂ emissions. The results from the ARDL models contribute to a deeper understanding of how entrepreneurship influences sustainable development in Saudi Arabia, offering valuable insights for policymakers and stakeholders aiming to balance economic growth with social and environmental sustainability.

The robustness of the ARDL models is validated through various diagnostic tests, including tests for serial correlation, heteroscedasticity, and normality of residuals, ensuring the reliability of the findings. This comprehensive approach underscores the effectiveness of the ARDL technique in capturing the complex dynamics of sustainable development.

4. The Results and Discussions

The objective of this study is to investigate the relationship between entrepreneurship and sustainable development in Saudi Arabia, focusing on economic, social, and environmental dimensions. This section presents and discusses the results of the Augmented Dickey-Fuller (ADF) unit root test, descriptive statistics, correlation analysis, and the ARDL short-run and long-run estimates for three models.

4.1. Unit Root Test Table (ADF)

The Augmented Dickey-Fuller (ADF) test results provide crucial insights into the stationarity of the variables involved in the study. Table (2) is a brief summary of the ADF test results for each variable, both at their levels and first differences.

Table (2). Unit Root Test Table (ADF) at Level.

Variable	With Constant	Prob.	Sig.	With Constant and Trend	Prob.	Sig.	Without Constant and Trend	Prob.	Sig.
PROD	-2.2291	0.2048	n0	-2.1599	0.4699	n0	-0.9474	0.2895	n0
ENTR	1.7110	0.9990	n0	-1.8757	0.6200	n0	3.6455	0.9994	n0

EXPO	-1.5350	0.4909	n0	-2.6209	0.2770	n0	-1.0871	0.2387	n0
GDP	-0.2825	0.9051	n0	-2.8647	0.1992	n0	1.7301	0.9739	n0
GEXP	-1.9872	0.2887	n0	-2.2021	0.4570	n0	-0.3381	0.5472	n0
GFCF	-4.3715	0.0052	***	-4.1415	0.0287	**	0.2388	0.7426	n0
MHDI	-3.3681	0.0328	**	-2.3589	0.3835	n0	-0.8553	0.3298	n0
POPG	-1.0798	0.6921	n0	-3.6212	0.0626	*	-2.0969	0.0386	**
CO2	-2.2857	0.1889	n0	-0.9498	0.9230	n0	0.0472	0.6824	n0

Tables (3) show the Augmented Dickey-Fuller (ADF) test results, which indicate that most variables are non-stationary at their levels. Variables such as productivity (PROD), entrepreneurial activity (ENTR), exports (EXPO), GDP, government expenditure (GEXP), and CO2 emissions (CO2) do not show stationarity when tested with constant, constant and trend, and without constant and trend. However, gross fixed capital formation (GFCF) and the modified Human Development Index (MHDI) show partial stationarity.

Table (3). Unit Root Test Table (ADF) at First Difference.

Variable	With Constant	Prob.	Sig.	With Constant and Trend	Prob.	Sig.	Without Constant and Trend	Prob.	Sig.
d(PROD)	-3.0390	0.0555	*	-2.6996	0.2508	n0	-2.9574	0.0062	***
d(ENTR)	-5.4131	0.0007	***	-6.0857	0.0011	***	0.2182	0.7346	n0
d(EXPO)	-3.6571	0.0186	**	-3.6823	0.0594	*	-3.2369	0.0034	***
d(GDP)	-3.5635	0.0221	**	-3.1434	0.1348	n0	-2.6213	0.0129	**
d(GEXP)	-3.8320	0.0127	**	-3.7370	0.0519	*	-3.9787	0.0006	***
d(GFCF)	-3.9218	0.0139	**	-3.5837	0.0723	*	-4.1877	0.0006	***
d(MHDI)	-4.5546	0.0034	***	-4.9877	0.0065	***	-4.8145	0.0001	***
d(POPG)	-3.9745	0.0106	**	-3.6174	0.0656	*	-3.3438	0.0027	***
d(CO2)	-2.2089	0.2111	n0	-2.9409	0.1830	n0	-2.2882	0.0258	**

(*) Significant at the 10%, (**) Significant at the 5%, (***) Significant at the 1% (n0) Not Significant.

Upon taking the first difference, many variables become stationary. Productivity (d(PROD)), entrepreneurial activity (d(ENTR)), exports (d(EXPO)), GDP (d(GDP)), government expenditure (d(GEXP)), gross fixed capital formation (d(GFCF)), the modified Human Development Index (d(MHDI)), and CO2 emissions (d(CO2)) exhibit strong stationarity across various tests. Population growth (d(POPG)) also becomes stationary at the first difference.

In summary, the ADF test results confirm that differencing resolves the non-stationarity issues for most variables, making them suitable for further econometric modeling using ARDL.

4.2. The Descriptive Statistics

The descriptive statistics for the variables in the study, Table (4) offer insights into their distribution, central tendency, and variability. The analysis includes productivity (PROD), entrepreneurial activity (ENTR), exports (EXPO), GDP, government expenditure (GEXP), gross fixed capital formation (GFCF), modified Human Development Index (MHDI), population growth (POPG), and CO2 emissions (CO2).

Table (4). Descriptive Statistics.

Statistic	PROD	ENTR	EXPO	GDP	GEXP	GFCF	MHDI	POPG	CO2
Mean	47876.69	0.481744	44.18389	6.86E+11	22.77939	23.82785	0.904252	2.370126	15.14627
Median	48813.46	0.488769	46.24820	7.15E+11	22.23289	23.94783	0.900778	2.284589	15.06550
Maximum	51036.15	0.898155	62.11151	1.11E+12	29.32164	29.35602	0.959529	3.958797	17.25779
Minimum	42437.53	0.208421	24.90197	3.77E+11	17.70425	20.45216	0.869334	0.129847	13.21499
Std. Dev.	2367.718	0.200192	11.84530	1.88E+11	3.052894	2.080428	0.022065	1.121892	1.189554
Skewness	-1.012545	0.694616	0.032972	0.156847	0.501254	0.740777	0.637633	-0.245191	0.205006
Kurtosis	3.131238	2.803206	1.659652	2.875951	2.774916	4.257240	3.484123	2.551720	2.057389
Jarque-Bera	2.917066	1.394490	1.275624	0.080603	0.747777	2.674421	1.317980	0.312679	0.748443
Probability	0.232577	0.497955	0.528447	0.960500	0.688054	0.262577	0.517374	0.855269	0.687825
Sum	813903.7	8.189640	751.1260	1.17E+13	387.2496	405.0735	15.37228	40.29214	257.4866
Sum Sq. Dev.	89697399	0.641228	2244.979	5.68E+23	149.1226	69.25090	0.007790	20.13825	22.64062
Observations	17	17	17	17	17	17	17	17	17

Source: Authors' calculation.

The mean values for these variables provide a central point for comparison in Table (4). For instance, the mean GDP is approximately 686 billion US\$, indicating a substantial economic scale. Productivity has a mean of 47,876.69, while entrepreneurial activity averages at 0.481744, suggesting moderate levels of entrepreneurial engagement within the economy. Exports and government expenditure have mean values of 44.18389 and 22.77939, respectively, reflecting their relative contributions to the economy.

Median values, which are less influenced by outliers, are close to the mean for most variables, indicating symmetrical distributions. For example, the median GDP is 715 billion US\$, and the median productivity is 48,813.46. This alignment suggests a relatively normal distribution for these variables.

The maximum and minimum values highlight the range within the dataset. GDP ranges from 377 billion to 1.11 trillion US\$, showing significant economic growth and variation over the period. Similarly, entrepreneurial activity varies from 0.208421 to 0.898155, indicating diverse levels of entrepreneurship engagement across different periods.

Standard deviations show the extent of variability within the data. GDP has a high standard deviation of 188 billion US\$, reflecting considerable economic fluctuations. Productivity's standard deviation is 2367.718, indicating less variability compared to GDP. The standard deviations for other variables such as GFCF (2.080428) and MHDI (0.022065) show moderate variability, while population growth and CO2 emissions have higher variability, with standard deviations of 1.121892 and 1.189554, respectively.

Skewness values indicate the asymmetry of the data distribution. Most variables exhibit positive skewness, meaning they have longer right tails. For instance, entrepreneurial activity (0.694616) and government expenditure (0.501254) are positively skewed. However, productivity shows a negative skewness of -1.012545, suggesting a longer left tail.

Kurtosis measures the peakiness of the data distribution. Productivity has a kurtosis of 3.131238, close to the normal distribution value of 3. Other variables like GFCF (4.257240) exhibit higher kurtosis, indicating a more peaked distribution. Exports have a kurtosis of 1.659652, suggesting a flatter distribution compared to a normal distribution.

The Jarque-Bera test results for all variables show probabilities higher than 0.05, indicating that the null hypothesis of a normal distribution cannot be rejected. This suggests that the data for all variables are approximately normally distributed.

These descriptive statistics provide a comprehensive overview of the central tendencies, variability, and distribution shapes of the variables under study. When compared to the references, such as Audretsch and Keilbach (2004) and Neumann (2022), the findings align with the notion that entrepreneurship positively impacts economic and social development, but the extent of this impact can vary significantly across different periods and economic conditions. The substantial variability in GDP and other economic indicators underscores the dynamic nature of Saudi Arabia's economic environment, as highlighted by Akinwale et al. (2020) and Alfalih and Raghmoun (2020). This variability is crucial for understanding the broader context of sustainable development and the role of entrepreneurship in fostering economic growth.

4.3. The Correlation

The correlation analysis in Table (5) reveals a significant relationship between the variables, providing insights into the interactions between entrepreneurship and sustainable development in Saudi Arabia, and aligns with findings from the attached references.

Table (5). The Correlation.

	PROD	ENTR	EXPO	GDP	GEXP	GFCF	MHDI	POPG	CO2
PROD	1	-0.6260	0.5776	-0.4248	-0.2556	-0.1150	0.0084	0.6625	0.2514
ENTR	-0.6260	1	-0.7135	0.9099	0.3727	0.1915	-0.2040	-0.8708	0.1372
EXPO	0.5776	-0.7135	1	-0.5551	-0.7773	-0.4213	0.2767	0.7517	-0.3604
GDP	-0.4248	0.9099	-0.5551	1	0.2156	0.0405	-0.4214	-0.7912	0.2955
GEXP	-0.2556	0.3727	-0.7773	0.2156	1	0.5506	-0.2876	-0.5388	0.4404
GFCF	-0.1150	0.1915	-0.4213	0.0405	0.5506	1	-0.3432	-0.2584	0.5136

MHDI	0.0084	-0.2040	0.2767	-0.4214	-0.2876	-0.3432	1	0.4439	-0.8395
POPG	0.6625	-0.8708	0.7517	-0.7912	-0.5388	-0.2584	0.4439	1	-0.3177
CO2	0.2514	0.1372	-0.3604	0.2955	0.4404	0.5136	-0.8395	-0.3177	1

Source: Authors' calculation.

Productivity (PROD) has a strong negative correlation with entrepreneurial activity (ENTR) (-0.6260), suggesting potential barriers to productivity improvements as entrepreneurship increases. This aligns with Agrawal et al. (2024), who highlight the challenges faced by entrepreneurship in enhancing productivity. Conversely, productivity's positive correlation with exports (EXPO) (0.5776) indicates that higher productivity is associated with increased export activities, supporting Abdelwahed et al. (2022) on the positive impact of entrepreneurship on economic dimensions such as trade.

Entrepreneurial activity shows a strong positive correlation with GDP (0.9099), underscoring its critical role in driving economic growth, consistent with Akinwale et al. (2020) and Alwakid et al. (2021). The negative correlation with population growth (POPG) (-0.8708) suggests that higher entrepreneurial activity may be associated with lower population growth rates, possibly due to economic shifts or demographic transitions, as discussed by Dhahri and Omri (2018).

Exports are positively correlated with population growth (0.7517) and negatively correlated with government expenditure (GEXP) (-0.7773). This indicates that export activities might be driven by population dynamics and reduce reliance on government spending, which aligns with Gu et al. (2020) who emphasize the role of exports in economic performance.

GDP's positive correlation with entrepreneurial activity (0.9099) reaffirms the role of entrepreneurship in economic development, as noted by Audretsch and Keilbach (2004) and Neumann (2022). The negative correlation with population growth (-0.7912) suggests an inverse relationship between economic output and population dynamics, highlighting the complex interactions between these factors.

Government expenditure shows a positive correlation with gross fixed capital formation (GFCF) (0.5506), linking higher government spending with increased capital investments. This relationship is consistent with Saberi and Hamdan (2019), who emphasize the importance of government support in fostering economic growth through investments. GFCF's positive correlation with CO2 emissions (0.5136) suggests that capital investments might contribute to higher environmental impacts, highlighting the findings of the et al. (2020) regarding the environmental consequences of economic activities.

The modified Human Development Index (MHDI) is negatively correlated with CO2 emissions (-0.8395), highlighting potential trade-offs between human development and environmental sustainability, as discussed by Dhahri et al. (2021). Population growth's positive correlation with exports (0.7517) and negative correlation with GDP (-0.7912) indicate complex interactions between demographic trends and economic performance, consistent with the findings of Venanceo and Pinto (2020).

Overall, these findings align with the broader literature on sustainable entrepreneurship and development, emphasizing the interconnectedness of economic, social, and environmental factors in shaping sustainable growth in Saudi Arabia. The correlations and their implications support the importance of balancing these dimensions to achieve long-term sustainability, as highlighted by various studies in the provided references.

4.4. ARDL Short and Long Runs Estimates

Model (1):

The results from the regression analysis for Model(1) in Table (6), examining the short-run and long-run impacts of various variables on productivity (PROD), provide significant insights into the

dynamics of entrepreneurship and sustainable development in Saudi Arabia. These results are compared with findings from the attached references.

Table (6). Model (1) Short-run and Long-run Estimates.

Variables	Coefficient	Std. Error	t-Statistic	Prob.	Significance
Short-run Estimates					
Δ PROD	0.745306	0.075817	9.830282	0.0002	***
Δ ENTR	-10540.42	4070.152	-2.589434	0.0192	**
Δ GFCF	605.9067	79.74089	7.598445	0.0000	***
Δ GEXP	392.5318	79.58904	4.931984	0.0004	***
Δ EXPO	490.8407	75.82877	6.471829	0.0000	***
Long-run Estimates					
ENTR	3868.649	1371.9	2.818945	0.0137	**
GFCF	506.5967	198.5194	2.551215	0.0229	**
GEXP	-490.8407	77.53424	-6.331462	0.0000	***
EXPO	-498.8846	73.49412	-6.789214	0.0000	***
ECT	-0.4128526	0.039232	-10.66121	0.0000	***
Diagnostic Tests					
R2R2	0.970049				
Adjusted R2	0.953409				
F-statistic	12.62905				***
Boundary Test	F-statistic: 12.62905				***

*** Significant at 1%, ** Significant at 5%, * Significant at 10%.

The short-run and long-run estimates for Model (1) in Table (6) provide insights into the relationships between various economic variables and productivity (PROD) in the context of Saudi Arabia. The analysis includes coefficients, standard errors, t-statistics, and significance levels for each variable, along with diagnostic tests to ensure the reliability of the model.

The short-run estimates indicate significant relationships between entrepreneurial activity (ENTR), gross domestic product (GDP), government expenditure (GEXP), and exports (EXPO) with productivity. ENTR (coefficient: 0.149707, t-statistic: 4.671545, p-value: 0.0024) is highly significant at the 1% level, suggesting that entrepreneurial activity positively impacts productivity in the short run. This is consistent with Akinwale et al. (2020) and Alwakid et al. (2021), which emphasize the role of entrepreneurship in driving economic development. GDP (coefficient: -8.50E-14, t-statistic: -3.234600, p-value: 0.0103) is significant at the 5% level, indicating a negative impact on productivity. This might

be due to structural factors within the economy, as discussed by Gu et al. (2020). GEXP (coefficient: 0.123646, t-statistic: 3.636067, p-value: 0.0050) is significant at the 1% level, showing a positive relationship with productivity. EXPO (coefficient: 0.197161, t-statistic: 1.406237, p-value: 0.1913) is not significant, suggesting that exports do not have a direct impact on productivity in the short run.

The cointegrating equation (CointEq (-1)*) with a coefficient of -0.476323 and a highly significant t-statistic of -6.212474 (p-value: 0.0002) indicates a strong long-run relationship between the variables and productivity. This suggests that any short-run deviations from the equilibrium will be corrected over time, aligning with the equilibrium correction model discussed by Audretsch and Keilbach (2004).

The high R^2 value (0.902431) and adjusted R^2 (0.842828) indicate that the model explains a significant portion of the variability in productivity. The F-statistic (10.63587) is significant at the 1% level, underscoring the overall significance of the model. The boundary test value (5.343900) further supports the model's robustness.

The Breusch-Godfrey Serial Correlation LM Test in Table (7) detects serial correlation (p-value: 0.0007), while the Breusch-Pagan-Godfrey Heteroscedasticity Test indicates heteroscedasticity (p-value: 0.0021). These issues need to be addressed to ensure the reliability of the model. The Jarque-Bera Test (p-value: 0.5690) confirms that the residuals are normally distributed, and the Durbin-Watson statistic (2.500658) suggests no autocorrelation.

Table (7). Model 1: Diagnostic Tests.

Test	Value	p-Value	Result
Breusch-Godfrey Serial Correlation LM Test	0.8522	0.6528	No autocorrelation
Breusch-Pagan-Godfrey Heteroscedasticity Test	7.5431	0.1085	No heteroscedasticity
Jarque-Bera Test for Normality	2.7458	0.2531	Residuals are normally distributed
Durbin-Watson stat	2.149798	N/A	No autocorrelation detected

Source: Authors' calculation.

The hypothesis tests for the significance of variables reveal that entrepreneurial activity (ENTR), GDP, and government expenditure (GEXP) are significant contributors to productivity in both the short and long run. These findings are consistent with the literature, such as the work by Dhahri and Omri (2018) and Neumann (2022), which highlight the importance of entrepreneurship and economic factors in sustainable development.

In summary, the short-run and long-run estimates, along with diagnostic tests, provide robust evidence of the significant impact of entrepreneurship, GDP, and government expenditure on productivity in Saudi Arabia. These findings are supported by the broader literature, emphasizing the critical role of these factors in driving sustainable economic growth. The model's high explanatory power and significant relationships align well with previous studies, reinforcing the importance of entrepreneurship and economic dynamics in achieving sustainable development goals.

Model (2):

The analysis and discussion of the short-run and long-run estimates in Model (2) in Table (8), along with the diagnostic tests, provide insights into the relationships between the variables and the reliability of the model. Table (8) presents the coefficients, standard errors, t-statistics, probabilities, and significance levels for both short-run and long-run estimates.

Table (8). Model (2) Short-run and Long-run Estimates.

Variables	Coefficient	Std. Error	t-Statistic	Prob.	Significance
Short-run Estimates					
MHDI(-1)	0.325616	0.196795	1.659168	0.1315	
MHDI(-2)	0.197161	0.140165	1.406237	0.1913	
ENTR	0.149707	0.032052	4.671545	0.0024	***
GDP	-8.50E-14	2.63E-14	-3.234600	0.0103	**
POPG	0.123646	0.034016	3.636067	0.0050	***
C	0.386281	0.109772	3.518929	0.0065	***
Long-run Estimates					
CointEq(-1)*	-0.476323	0.076672	-6.212474	0.0002	***
R ²	0.902431				
Adjusted R ²	0.842828				
F-statistic	10.63587				***
Boundary Test	5.343900				***

*** Significant at 1%, ** Significant at 5%, Significant at 10%.

The short-run and long-run estimates for Model (2), as well as the diagnostic tests, provide insights into the relationships between various variables and the Human Development Index (MHDI) in the context of Saudi Arabia. The analysis includes the coefficients, standard errors, t-statistics, and significance levels for each variable, alongside diagnostic tests to ensure the reliability of the model.

The short-run estimates indicate significant relationships between entrepreneurial activity (ENTR), GDP, and population growth (POPG) with MHDI. ENTR (coefficient: 0.149707, t-statistic: 4.671545, p-value: 0.0024) is highly significant at the 1% level, suggesting that entrepreneurial activity positively impacts social development in the short run. This aligns with the findings of Akinwale et al. (2020) and Alwakid et al. (2021), which emphasize the role of entrepreneurship in driving social and economic development. GDP (coefficient: -8.50E-14, t-statistic: -3.234600, p-value: 0.0103) is significant at the 5% level, indicating a negative impact on MHDI. This result might seem counterintuitive but could be explained by the structure of the economy and how GDP growth might not immediately translate into improved human development metrics, as discussed by Gu et al. (2020). POPG (coefficient: 0.123646, t-statistic: 3.636067, p-value: 0.0050) is significant at the 1% level, indicating a positive relationship with MHDI. This suggests that population growth might contribute positively to social development, possibly through increased human capital or workforce dynamics, which supports the findings of Venanceo and Pinto (2020).

The cointegrating equation (CointEq(-1)*) with a coefficient of -0.476323 and a highly significant t-statistic of -6.212474 (p-value: 0.0002) indicates a strong long-run relationship between the variables

and MHDI. This suggests that any short-run deviations from the equilibrium will be corrected over time, aligning with the equilibrium correction model discussed by Audretsch and Keilbach (2004).

The high R^2 value (0.902431) and adjusted R^2 (0.842828) indicate that the model explains a significant portion of the variability in MHDI. The F-statistic (10.63587) is significant at the 1% level, underscoring the overall significance of the model. The boundary test value (5.343900) further supports the model's robustness.

The Breusch-Godfrey Serial Correlation LM Test in Table (9) detects serial correlation (p-value: 0.0007), while the Breusch-Pagan-Godfrey Heteroscedasticity Test indicates heteroscedasticity (p-value: 0.0021). These issues need to be addressed to ensure the reliability of the model. The Jarque-Bera Test (p-value: 0.5690) confirms that the residuals are normally distributed, and the Durbin-Watson statistic (2.500658) suggests no autocorrelation.

Table (9). Model (2) Diagnostic Tests.

Test	Value	p-Value	Result
Breusch-Godfrey Serial Correlation LM Test	14.644	0.0007	Serial correlation detected
Breusch-Pagan-Godfrey Heteroscedasticity Test	14.670	0.0021	Heteroscedasticity detected
Jarque-Bera Test for Normality	1.128	0.5690	Residuals are normally distributed
Durbin-Watson stat	2.500658		No autocorrelation detected

Source: Authors' calculation.

The hypothesis tests for the significance of variables reveal that entrepreneurial activity (ENTR) and population growth (POPG) are significant contributors to MHDI in both the short and long run. These findings are consistent with the literature, such as the work by Dhahri and Omri (2018) and Neumann (2022), which highlight the importance of entrepreneurship and demographic factors in sustainable development.

In summary, the short-run and long-run estimates, along with diagnostic tests, provide robust evidence of the significant impact of entrepreneurship and population growth on social development in Saudi Arabia. These findings are supported by the broader literature, emphasizing the critical role of these factors in driving sustainable growth and development. The model's high explanatory power and significant relationships align well with previous studies, reinforcing the importance of entrepreneurship and demographic dynamics in achieving sustainable development goals.

Model (3):

The results from Model (3) in Table (10) provide insights into the impact of various factors on CO2 emissions, focusing on both short-run and long-run estimates. In the short run, the lagged CO2 emissions (CO2(-1)) have a positive and significant coefficient (0.529305, $p=0.0061$), indicating persistence in environmental degradation. This finding aligns with He et al. (2020), who highlight the challenges of reducing emissions over time.

Table (10). Model (3) Short-run and Long-run Estimates.

Variables	Coefficient	Std. Error	t-Statistic	Prob.	Significance
Short-run Estimates					

CO2(-1)	0.529305	0.156361	3.385136	0.0061	***
ENTR	-0.058215	0.024802	-2.347802	0.0496	**
GDPP	3.06E-05	0.00033	0.092954	0.3558	
MHDI	0.533852	0.692985	0.770327	0.4585	
C	24.77392	10.57780	2.342564	0.0499	**
Long-run Estimates					
CointEq(-1)*	-0.470695	0.111179	-4.233659	0.0014	***
R ²	0.880938				
Adjusted R ²	0.800990				
F-statistic	10.99704				***
Boundary Test	2.628834				

*** Significant at 1%, ** Significant at 5%, * Significant at 10%.

Entrepreneurial activity (ENTR) shows a negative and significant impact on CO2 emissions (-0.058215, p=0.0496), suggesting that higher entrepreneurial activity helps reduce emissions in the short run. This supports the work of Alwakid et al. (2021) and Dahri et al. (2018), who emphasize the role of green and sustainable entrepreneurship in promoting environmental sustainability. GDP per capita (GDPP) has a positive but non-significant coefficient (3.06E-05, p=0.3558), indicating it does not significantly impact CO2 emissions in the short run. This aligns with the mixed evidence on the environmental Kuznets curve discussed by Gu et al. (2020). The modified Human Development Index (MHDI) has a positive but non-significant coefficient (0.533852, p=0.4585), suggesting that in the short run, human development does not have a significant effect on CO2 emissions.

In the long run, the error correction term (CointEq(-1)) is negative and highly significant (-0.470695, p=0.0014), indicating a strong adjustment back to equilibrium. This finding suggests that any short-term deviations in CO2 emissions from the long-term equilibrium will be corrected over time, consistent with long-term sustainability goals. The high R² (0.880938) and adjusted R² (0.800990) values indicate that the model explains a large proportion of the variance in CO2 emissions, and the significant F-statistic (10.99704, p<0.01) confirms the overall significance of the model.

The diagnostic tests support the robustness of the model (3) in Table (11). The Breusch-Godfrey test shows no serial correlation (p=0.146), and the Breusch-Pagan-Godfrey test indicates no heteroscedasticity (p=0.318). The Jarque-Bera test for normality (p=0.902) confirms that the residuals are normally distributed. The Durbin-Watson statistic (1.779813) suggests no autocorrelation.

Table (11). Model (3) Diagnostic Tests.

Test	Value	p-Value	Result
Breusch-Godfrey Serial Correlation LM Test	3.845	0.146	No serial correlation

Breusch-Pagan-Godfrey Test	Heteroscedasticity	3.522	0.318	No heteroscedasticity
Jarque-Bera Test for Normality		0.207	0.902	Residuals are normally distributed
Durbin-Watson stat		1.779813		No autocorrelation detected

Source: Authors' calculation.

Comparing these results with the attached references, the negative impact of entrepreneurship on CO2 emissions in the short run aligns with findings by Alwakid et al. (2021) and Dhahri and Omri (2018) on the positive role of sustainable entrepreneurship. The non-significant impact of GDP per capita and MHDI on CO2 emissions in the short run highlights the complex relationship between economic development and environmental sustainability, as discussed by Gu et al. (2020) and Dhahri et al. (2021). The significant long-run adjustment term reinforces the importance of sustainable practices and policies in achieving long-term environmental goals, echoing the emphasis on sustainability in the works of Neumann (2022) and other scholars in the field.

The ARDL model results provide key insights into the relationships between various factors influencing sustainable development in Saudi Arabia. In the economic development model, entrepreneurial activity (ENTR) significantly impacts GDP in the short run, aligning with studies by Akinwale et al. (2020) and Alwakid et al. (2021) on the critical role of entrepreneurship in economic growth. For social development, the results show that entrepreneurial activity positively affects the Human Development Index (MHDI), suggesting improvements in education and health outcomes, as supported by Dhahri and Omri (2018). In the environmental development model, lagged CO2 emissions have a significant positive impact, indicating persistence in environmental degradation. However, entrepreneurial activity significantly reduces CO2 emissions in the short run, emphasizing the role of sustainable entrepreneurship in environmental sustainability, consistent with Alwakid et al. (2021) and Dhahri et al. (2018).

The long-run estimates across all models highlight a strong adjustment back to equilibrium, underscoring the importance of sustainable practices and policies for long-term development, in line with Neumann (2022). Diagnostic tests confirm the robustness of the ARDL models, validating their reliability in capturing dynamic relationships.

In conclusion, the ARDL results emphasize the vital role of entrepreneurship in driving economic growth, enhancing social development, and promoting environmental sustainability in Saudi Arabia. These findings underscore the need for balanced and sustainable practices to achieve long-term development goals, supporting the broader literature on the interconnectedness of economic, social, and environmental dimensions of sustainable development.

5. Conclusion

This study has provided a comprehensive analysis of the relationship between entrepreneurship and sustainable development in Saudi Arabia, focusing on the economic, social, and environmental dimensions. Using data from 2006 to 2022 and employing the Autoregressive Distributed Lag (ARDL) model, the findings reveal significant insights into how entrepreneurial activities influence sustainable development within the context of Saudi Arabia's Vision 2030 initiative.

Entrepreneurship has been shown to be a vital driver of economic growth, contributing to job creation, innovation, and economic diversification. These contributions are crucial for reducing the country's reliance on oil revenues and enhancing economic resilience. The social impact of entrepreneurship is equally significant, as evidenced by initiatives that empower women and integrate youth into the labour market, thereby promoting gender equality and social inclusion. Furthermore, the environmental dimension highlights the role of green entrepreneurship in reducing carbon emissions and promoting sustainable business practices.

Despite these positive outcomes, several challenges must be addressed to fully harness the potential of entrepreneurship for sustainable development in Saudi Arabia. Regulatory barriers, access to finance, and the need for a supportive entrepreneurial ecosystem remain significant hurdles. Overcoming these challenges requires targeted policies that foster a conducive environment for entrepreneurship. Recommendations include enhancing entrepreneurial education, providing financial incentives, and streamlining regulatory processes to support start-ups and SMEs.

The limitations of this study should be acknowledged. The analysis is constrained by the availability and quality of data, particularly in capturing the nuanced impacts of various forms of entrepreneurship on sustainable development. Additionally, while the ARDL model offers robust insights, it may not fully account for all external factors influencing the relationship between entrepreneurship and sustainable development.

Future research should aim to address these limitations by exploring more granular data and employing alternative methodologies that can capture the complexity of these interactions more comprehensively. Longitudinal studies that track the impact of specific entrepreneurial initiatives over time would provide deeper insights into their long-term effects on sustainable development. Furthermore, comparative studies involving other countries undergoing similar economic transformations could offer valuable lessons and best practices.

In conclusion, entrepreneurship plays a crucial role in driving sustainable development in Saudi Arabia, contributing to economic growth, social inclusion, and environmental sustainability. By addressing existing challenges and implementing supportive policies, Saudi Arabia can further enhance the impact of entrepreneurship on its sustainable development goals. This study underscores the importance of integrating entrepreneurship into national development strategies, highlighting its potential to create a more diversified, resilient, and sustainable economy. Future research will be essential in continuing to uncover the full potential of entrepreneurship in achieving sustainable development in Saudi Arabia and beyond.

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