Innovations

Evaluating the Impact of Green Finance on Senegal's Economic Development

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Abstract: *As the global economy transitions towards a low-carbon, sustainable, and resilient future, green finance has emerged as a significant tool for fostering sustainable economic growth while addressing environmental challenges.This study evaluates the impact of green finance on Senegal's economic development from 2001 – 2022. Descriptive statistics, boxplots, cointegration tests, and NARDL analysis, were utilized to explore the interplay between the variables with the aid of EViews software. The results reveal the growth patterns of GDP, EGLC, POP, INFL, CE, FDI, and CC and their significance in driving economic progress in Senegal. The study concludes with actionable insights and recommendations for Senegal policymakers to address green finance, climate change, demographic, investments, institutional quality, and other economic issues.*

Keyword: *Green finance, Renewable energy consumption, Senegal, Economic Development, Carbon Footprints, Climate-related development, Climate change, Sustainability, and NARDL analysis.*

1.0. Introduction

As the global attention shifts towards sustainable development, green finance has emerged as a crucial tool for fostering economic growth while addressing environmental challenges. Limiting carbon emissions is critical as greenhouse gases reach record highs, impacting the ecological environment globally (UNDP, 2024). Green finance encompasses investments in eco-friendly projects that support sustainable development by promoting environmental protection and reducing carbon footprints. It includes instruments such as green bonds, loans, and equity investments aimed at reducing carbon emissions, conserving biodiversity, enhancing energy efficiency, promoting renewable energy sources and other eco-friendly projects, and fostering economic resilience (IFC, 2022, UNDP, 2024). It is essential for achieving Sustainable Development Goals (SDGs).

In regions like Sahel where Senegal is situated, characterised by economic dynamism and vulnerability to climate change, green finance can drive sustainable economic development and enhancing resilience to climatic shocks (Alliance Sahel, 2020; Marbuah, 2020). Senegal's development framework, "Plan

Senegal Emergent'', recognizes the crucial role of sustainable finance in achieving its economic objectives (Climate & Company, 2023). This framework stresses inclusive and sustainable growth while preserving natural resources. To attract more sustainable investments, Senegal has joined the International Platform on Sustainable Finance and is developing Africa's third green finance taxonomy, the first in the French language (Climate & Company, 2023).

This research aims to evaluate the impact of green finance on Senegal's economic development, addressing the following questions: (i) what is the current state of green finance in Senegal? (ii) How does green finance contribute to economic development in Senegal? (iii) What are the challenges and opportunities of green finance in Senegal? (iv) what is the relationship between green finance and economic growth in Senegal? (v) What are the key factors influencing green finance in Senegal. This research is highly relevant to policymakers, economists, businesses, and other stakeholders in Senegal.

Moreso, the study explore how green investments can contributes to economic growth, improve socio-economic conditions and environmental sustainability in the country (Alliance Sahel, 2020, Fu, C., Lu, L., & Pirabi, M., 2023; Wu, H., 2023; Green Policy Platform, 2014, World Bank, 2022; WEF, 2020; UNDP, 2024). By analysing data on green finance and other key economic indicators, the study seeks to provide evidence-based insights for policymakers and investors.

This research contributes to broader discourse on green finance development and its potential implications for Senegal's future growth. It provides a localised perspective on the impact of green finance and offers practical recommendations for policymakers. The findings can inform policy development aimed at enhancing economic stability and growth. For economists, this study offers empirical evidence that contributes to the literature on green finance and economic development, particularly within the context of a developing economy like Senegal. For businesses, it provides insights into market opportunities. Moreso, the insights gained can help to identify potential areas for intervention to improve green financing, harness opportunities, and consequently economic growth.

In summary, this research provides context-specific insights, empirical analysis, and actionable recommendations related to green finance and its impact on Senegal's economic development.

2.0. Literature review

As interest in green and sustainable finance gain momentum globally, nations recognize its potential in driving sustainable development and build resilient futures. Limiting carbon emissions is critical as greenhouse gases reach record highs, impacting the ecological environment.Green and sustainable finance is regarded as a way of meeting the needs of the environmentalism and capitalism simultaneously. The green bond market is expected to be worth over USD$609.64 billion by 2024 (Mordor Intelligence, 2024).It integrates environmental, social, and

governance (ESG) factors into financial decisions, fostering low-carbon economies and sustainable development. It benefits both financial and non-financial outcomes, such as building resilient infrastructure, improving socio-economic conditions, developing sustainable communities, and promoting inclusive industrialization (WEF, 2023; Chartered Banker, 2023).

Green finance allocates resources towards eco-friendly sustainable projects, including renewable energy, energy efficiency, pollution control, smart city, and sustainable agriculture. It comprises of various financial instruments like green bond, loans, equity, and grants (Chartered Banker, 2023; IFC, 2022; UNDP, 2024).Countries like Germany, Netherland, and China have successfully leveraged green finance to accelerate their transitions to sustainable economies. Germany's Energiewende (energy transition) and China's substantial investments in renewable energy are prime examples of effective green finance strategies. Senegal can draw lessons from these examples, identifying best practices, and adapting successful strategies to its unique socio-economic and environmental context.

2.1. Theoretical Framework

Green and sustainable finance is underpinned by theories of sustainable development and environmental economics, which argue for balancing economic growth with environmental protection. These theories highlight the need for integrating environmental considerations into economic decision-making processes. Sustainability theories posit that long-term economic growth can only be achieved throughresponsible use of natural resources and environmental stewardship. Endogenous growth theories also indicate that investment in green technologies and human capita can drive innovation and productivity, leading to sustainable economic development.Theoretical frameworks such as the sustainable finance framework, Green Growth Theory, Environmental Kuznets Curve (EKC), Endogenous Growth Model, and Circular Economy Theory provides a conceptual understanding of the interplay between green finance and economic growth. These frameworks emphasize integrating environment, social, and governance (ESG) factors into investment decisions, aligning financial interests and technological innovations with economic, environmental and social goals.

2.2. Empirical Studies

Empirical research globally highlights the crucial role of green and sustainable finance in promoting sustainable economic growth by supporting clean energy development and reducing carbon footprints. Studies show that green finance significantly influences the development of renewable energy and eco-friendly projects across various regions, with similar potential in Senegal (World Bank, 2022; AFDB, 2022; AFC, 2022; WEF, 2023). Tolossa and Gota (2023) found that green finance drives innovation in green technology, energy efficiency, and environmentally responsible practices, contributing to sustainable development. In EU, Kwiliński et al. (2023) established that regional characteristics impact green finance's spatial spillover effects on Sustainable Development Goals (SDGs).

Zakari et al. (2022) emphasized the importance of green in promoting sustainability in OECD countries. More research indicates its positive impact on sustainable energy development and emphasize the significance of robust green financial market (Liu et al., 2020; Zhang et al., 2019; Mohd. and Kaushal, 2018; Hassain, 2022).While green finance is not yet fully established subsystem within the global financial system, it plays a significant role in financing renewable energy and energy-efficient technologies (Porfir'ev, 2016; Jha and Bakhshi, 2019).

Moreso, Bakhsh et al. (2024) reveals that green finance, along with environmental governance, fiscal policy, and population growth, significantly contributes to SDGs advancement. But geopolitical risks and uncertainty can hinder progress, partially negating the benefits of green finance initiatives.

Additional studies by (Vardar et al., 2023; Goffner et al., 2019; Adamou et al., 2021; Mirzabaev et al., 2022; Sachs et al., 2019; Wang et al., 2023; Bouchene et al., 2021; Huan et al., 2022) and others contribute to the understanding of how green finance impact sustainable development. despite challenges like regulatory barriers and limited resources, green finance has positively impacted sustainable energy development in Africa, especially in Kenya and South Africa (IFC, 2022). However, local studies indicates that Senegal faces unique challenges in implementing green finance initiatives (UNDP, 2024). This study aims to evaluate these impacts and propose actionable solutions for Senegal's context.

2.3. Historical Context of Green Finance in Senegal

Over the years, Senegal green finance policies have evolved, recognizing the essential role of sustainable finance in its development goals.Early efforts in the 2000sfocused on integrating environmental sustainability into economic planning and decisions, leading to key initiatives like the National Strategy for Sustainable Development (2005), Great Climate Fund projects, and the Plan Sénégal Émergent (2014) (Alliance Sahel, 2020). These initiatives spurred green investments and public-private collaboration (UNDP, 2024). Senegal, in partnership with German Development Cooperation (GIZ) and local organizations, is now developing Africa's third green finance taxonomy, highlighting sectors relevant to its socio-economic context and guiding sustainable investments. Additionally, initiatives like the Great Green Wall project and collaborations with international bodies have further advanced green finance, aligning with global sustainability goals (IFC, 2022; UNDP,2024).

2.4. Economic Development in Senegal

Senegal's economic development has shown resilience, with GDP growth from 3.5% in 2010 to over 4% in recent years, despite multiple crises (World Bank, 2023). In 2023, the economy grew by 4.3%, driven by agriculture, fishing, and mining. Inflation declined to 5.9%, and foreign direct investments, especially in agriculture and mining. The Plan Sénégal Emergent has been crucial in improving economic stability. However, challenges such as climate change, low productivity, and the impacts on agriculture persist, necessitating adaptation strategies like drought-resistant crops and integrated improved water management. Senegal's

reliance on agriculture and natural resources is being supplemented by investments in renewable energy and infrastructure (The Africa Report, 2020). However, climate change impacts in Senegal extend beyond agriculture. The other sectors affected are: (i) Coastal Zones – rising sea levels (forecasted up to one meter by 2100) impact the urban coastal zones, home to 67% of the population and 90% of industrial production. Flooding, erosion, and impaired water quality pose risks, (ii) Health – Heat stress, malaria prevalence shifts, and respiratory diseases due to climate pollutants may increase morbidity and mortality, (iii) Fisheries – overfished coastal ecosystems face extra stress from climate change. Rising water temperatures and ocean acidification alter species reproduction and migration, affecting livelihoods and nutrition, (iv) Mangroves – these key coastal resources protect against storms, stabilise soil, and provide habitat. Climate change threaten mangroves, affecting biodiversity and wildlife (USAID, 2023). Thus, Senegal must adopt a system-change approach to address climate-related challenges, focusing natural climate solutions and resource management. This comprehensive strategy is crucial for ensuring long-term economic resilience and sustainable development in Senegal (UNDP, 2024; IMF, 2022; The Africa Report, 2020; Alliance Sahel, 2020; FAO, n.d; USAID, 2023).

Additionally, economic development progress in Senegal in terms of key economic indicators can be view at a glance from the World Bank report below:

INDICATOR	SENEGAL	SUB-SAHARAN AFRICA	LOWER MIDDLE INCOME	NOTE
Bertelsmann Transformation Index, 2024	49	89	80	Ranking out of 137 economies
Competitive Industrial Performance Index, 2021	102	125	99	Ranking out of 150 economies
Corruption Perception Index, 2023	70	128	121	Ranking out of 180 economies
Doing Business, 2019	123	150	125	Ranking out of 190 economies
EIU Democracy Index (Score), 2022	5.72	3.84	4.18	0 (Authoritarian) to 10 (Full Democracy)
Environmental Performance Index, 2022	136	134.5	133.5	Ranking out of 180 economies
Fragile States Index, 2023	80	38	59	Ranking out of 179 economies
Global Competitiveness Index, 2019	114	121.5	107.5	Ranking out of 141 economies
Global Gender Gap Index, 2023	104	92	103	Ranking out of 146 economies
Global Innovation Index, 2022	99	117	100.5	Ranking out of 132 economies
Human Development Index (Score), 2021	0.51	0.53	0.62	Best score = 1
INFORM Risk Index (Score), 2024	4.1	4.5	4.1	Best Score = 0 (Low Risk)
Mobile Connectivity Index (Score), 2022	45.72	36.15	51.31	Best Score = 100
Political Stability (Percentile Rank), 2022	40.57	26.89	33.26	Best Score = 100
Press Freedom Index, 2023	104	98	122	Ranking out of 180 economies
Travel and Tourism Development Index, 2021	105	103	91.5	Ranking out of 117 economies
Women, Business & Law Index (Score), 2022	72.5	76.56	75	Best Score = 100

Source: World Bank/Prosperity360

2.5. Current State of Green Finance in Senegal

Senegal's green finance landscape is rapidly evolving, supported by a variety of financial instruments such as green loans, bonds, and grants (IFC, 2022). National banks, international institutions like the African Development Bank (AFDB), IFC, Green Climate Fund, and other partners play crucial roles in funding eco-friendly projects. Key initiatives include renewable energy development and sustainable agriculture, backed by both local and international partners (Climate & Company, 2023; Green Policy Platform, 2023). These projects aim to mitigate climate change impacts and encourage economic growth through sustainable means.

Senegal significant green finance strides include publishing its inaugural sustainable financing framework to enable mobilization of dedicated financing from international capital markets and financial institutions, AFDB approval of a partial credit guarantee of EUR400 million for Senegal's green and social investments, and the development of Africa's third Green Finance Taxonomy to promote sustainable investments(AFDB, 2023; Senegal Finance Ministry, 2024).Climate & Company and the Consortium pour la Recherche Economique et Sociale (CRES) are leading the taxonomy effort. These initiatives show Senegal's commitment to sustainable development and alignment with the Sustainable Development Goals (SDGs) (Senegal Finance Ministry, 2024; AFDB, 2023; UNDP, 2024; Climate & Company, 2023).

2.6. Green Finance Projects

Senegal has made significant progress in green finance, focusing on renewable energy, sustainable agriculture, and climate resilience.Key projects include the Taiba Ndiaye Wind Farm, Senergy 2 Solar Plant, and Bokhol Solar Park, which have advanced the country's renewable energy goals, reduced carbon emissions, and strengthening energy security (Climate & Company, 2023; Alliance Sahel, 2021; The Africa Report, 2020; UNDP, 2024). The Plan Senegal Émergent (PSE) highlight expanding reliable and affordable electricity access, achieving a 75% electrification rate in 2022 (IEA, 2024).

Senegal's green finance achievements include developing a green finance taxonomy, supporting agribusiness via International Finance Corporation (IFC), and initiatives like the sustainable Cities project with UNIDO to promote renewable energy and integrated waste management (Climate & Company, 2023; IFC, 2022; UNIDO, 2023). Additionally, investment in the Senegal River Basin supports hydroelectricity and water supply, while the Scaling Solar project aims to develop 200 MW of solar energy valued around USD$80 million, emphasize Senegal's commitment to sustainable development, supporting economic growth and environmental conservation(Investment Climate/Ecowas, 2019; United Nations, 2022).

2.7. Impacts of Green Finance on Economic Development

Green finance is crucial for Senegal's economic development. By promoting eco-friendly projects, green finance contributes to sustainablegrowth, stimulate investments, create employment, improve productivity, and generate income. It

enhances climate resilience and fosters environmental and social benefits, such as reduced greenhouse gas emissions, and improved public health.Between 2014 and 2018, Senegal witnessed robust GDP growth of around 6% annually, and continue to grow. But, challenges like poverty, unemployment, and dependence on natural resources persist. A smooth transition to a green economy is crucial for Senegal's long-term prosperity (UNEP, 2022; Alliance Sahel, 2021; Bakhsh et al., 2024; Fu et al., 2023; Climate & Company, 2023; IFC, 2022; UNDP, 2024).

2.8. Challenges and Opportunities of Green Finance

Implementing eco-friendly projects in Senegal present both challenges and opportunities. the country faces obstacles such as regulatory, institutional, financial, and technical challenges. Key challenges include the lack of a robust policy framework and limited institutional capacity. Strengthening regulatory frameworks, enhancing political will, and ensuring effective coordination among institutions are essential (World Bank, 2024; Alliance Sahel, 2020). Financial and technical challenges include high investment costs and insufficient technical expertise. Expanding access to green finance, and developing technical expertise are crucial (IFC, 2022). Furthermore, integrating climate risks into sectoral policies is crucial for effective adaptation (Ibrahima Sy, 2024). Other barriers include unequal access to climate finance across sectors and regions, the need to build local expertise and prioritize community-specific adaptation strategies, and the need to establish a robust framework for monitoring, evaluating, reporting, and verifying climate policy implementations, such as the MRV system.

Despite these challenges, opportunities exist for investment in renewable energy, sustainable agriculture, water, sanitation, and eco-tourism, that can be driven by international funding, and innovative financial instruments like loans, grants, bonds, and equities. These sectors align with Senegal's Sustainable financing framework and offer significant potential for both economic growth and environmental sustainability (UNDP, 2024; AFDB, 2023; The African Climate Foundation, 2022; Global Cad, 2024; UNEP, 2024).

2.9. Role of International Cooperation and Funding

The success and scalability of green finance initiatives in Senegal relies heavily on international cooperation and funding. Partnership with global financial institutions and donor agencies are crucial in providing the resources and expertise needed to support sustainable development (UNDP, 2024; Alliance Sahel, 2020; AFDB, 2023; IFC, 2022).Senegal's Ministry of Finance and Budget launched a sustainable financing framework in 2023, which facilitates the mobilization of dedicated funds from international capital markets and financial institutions (Senegal Ministry of Finance and Budget, 2024).

Senegal's partnership and collaboration for green financing and investment include: (i) African Development Bank's EUR400 million partial credit guarantees for Senegal'sgreen and social investments (AFDB, 2023). (ii) A USD$2.7 billion Just Energy Transition Partnership (JETP) with the International Partners Group (IPG) for transitioning to a low-carbon economy (African Climate Foundation, 2022). (iii)

A collaboration with German Development Cooperation (GIZ) to develop Africa's third green finance taxonomy, the first in French, aimed at attracting sustainable investments (European Investment Bank, 2023). (iv) Capacity-building support for local institutions like Banque Agricole and Ecobank Senegal to enhance green financing (Green Economy Coalition, 2024).

International collaboration provides access to valuable knowledge, best practices, and technical expertise. Secondly, facilitates access to climate finance mechanismssuch as the Great Green Wall Fund, Green Climate Fund (GCF) and bilateral agreements. Third, enhance capacity-building, and allows the adoption of innovative climate adaptation solutions like clean energy technologies transfer, weather monitoring systems, and early warning tools. Fourth, participation of Senegal in global climate negotiations (for example, attending COP and other climate meetings) to advocates for its priorities can help the country in term of policy alignment and advocacy efforts. Ultimately, these collaborations enhance Senegal's climate resilience and sustainable development initiatives.

In summary, research suggests that green finance is essential for driving renewable energy and eco-friendly projects, but success depends on regional characteristics, resources, partnerships, strong green financial market, and improve policy frameworks tailored to local needs (UNDP, 2024; Climate & Company, 2023; World Bank, 2022; Chavi and Ishrita, 2023; WEF, 2023; AFDB, 2023; IFC, 2022).

2.10. Research Gaps

While interest in green is growing globally, the literature reviewed suggests a scarcity of studies focusing specifically on Senegal. Most research address global contexts or other regions, with few studies examining Africa in depth. Moreover, many studies use variables that may not adequately capture the impacts of key explanatory variables on the dependent variable. The robustness of estimation methods in these studies also remains a point of contention. Moreover, additionally, comprehensive analyses that incorporate up-to-date data and focus on Senegal's current green finance realities are lacking.

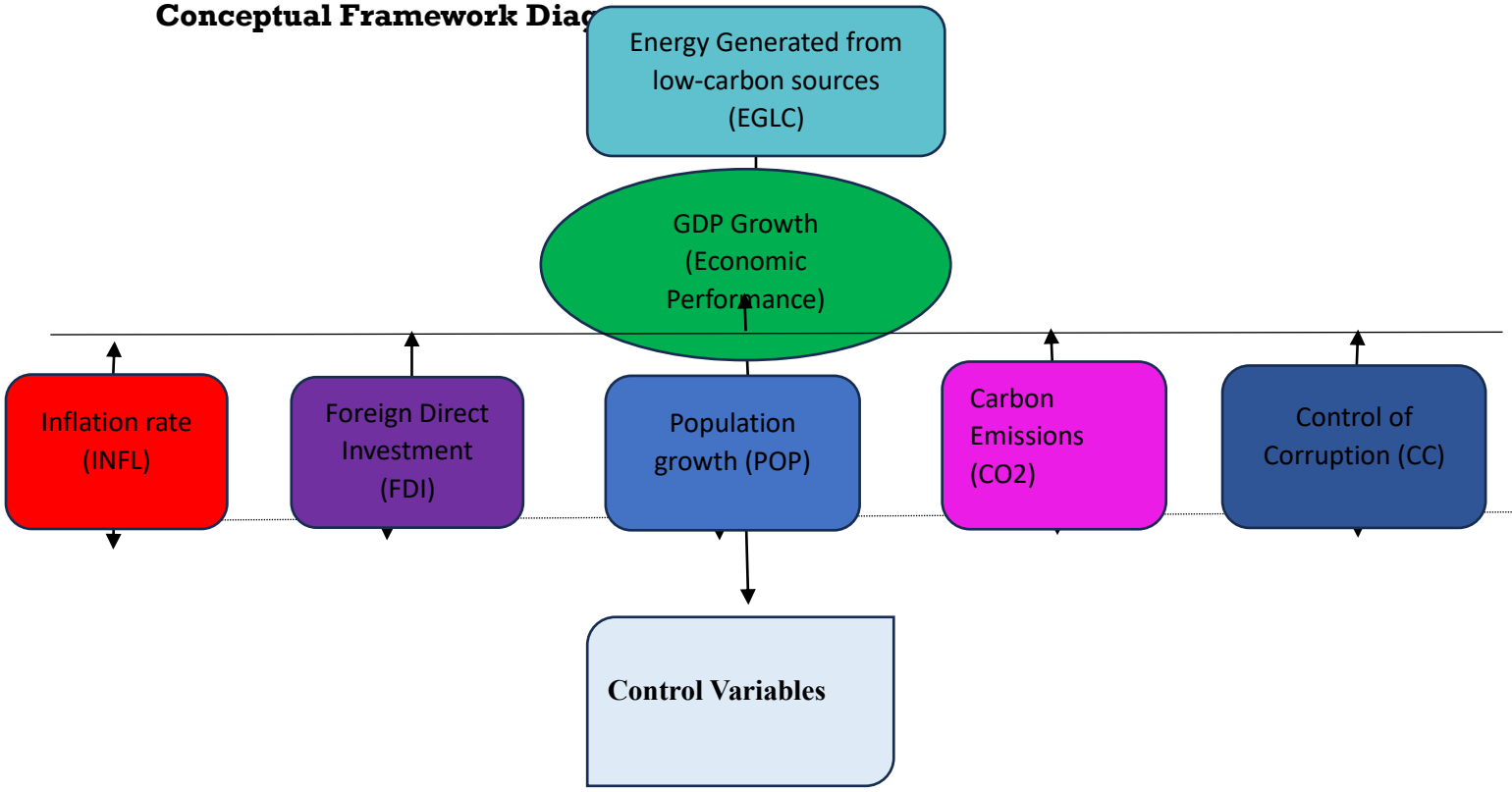
This study aims to bridge these gaps by conducting an in-depth analysis of green finance in Senegal, covering its trajectory, challenges, opportunities, policy frameworks, partnerships, and collaborations, focusing on current realities, and the use of up-to-date data to provide nuanced understanding of green finance and economic development interplay in Senegal. It introduces energy generated from low-carbon sources (EGLC) as a primary explanatory variable, a rarely used metric in such research. Furthermore, advanced estimation techniques will be employed to capture the interactions between variables, offering more robust results. This research will provide valuable insights for policymakers and contribute to the existing literature.

2.11. Conceptual Framework

The conceptual framework for this study describes the interaction between the primary explanatory variables green finance measured by energy generated

from low-carbon sources (EGLC), control variables (Inflation rate, Foreign direct investment, Population growth rate, Carbon emissions, Control of corruption, and the dependent variable (per capita GDP growth rate).

Figure 1:
Conceptual Framework Diag



Source: Author

The conceptual framework diagram depicts the interplay between green finance proxy by energy generated from low-carbon sources and economic development, along with other significant control variables that impact economic performance in Senegal. Each variable is colour-coded for clarity. EGLC (Aqua) measure the impact of green finance on GDP growth. GDP growth (Green) denotes the overall economic performance. Population growth rate (Blue) shows demographic trends affecting labour supply, and available market. Inflation rate (Red) highlights the cost of living/purchasing power, and economic stability. Foreign direct investment (Purple) denotes external economic inputs influencing growth. Carbon emissions (Pink) measure the impact of greenhouse gas on the environment and economic performance. Control of corruption (Navy blue) measure institutional quality.

The arrow from energy generated from low-carbon sources (EGLC) to GDP growth indicates the direct impact of green finance on economic performance in Senegal. The arrow from the other independent variables to GDP growth indicate their roles as control variables impacting economic performance. Energy generated from low-carbon sources is expected to have a significant positive impact on GDP growth. Control variables are included to isolate and understand

the net effect of EGLC on economic performance in Senegal. The framework helps in simplifying and understanding the direct and indirect effects of various economic factors on the performance of Senegal's economy. By analysing these variables using appropriate econometric techniques and up-to-date data, the framework aims to illustrates how green finance dynamics and key economic variables impact economic performance in Senegal, offering insights and recommendations for policy development and strategic planning for sustainable economic development.

3.0. Research Methodology

As a significant potential driver of economic growth, investigating green finance, it's determinants and how it influences economic growth is essential in making effective and balanced policies for better economic performance, and resilience future, given the current global economic conditions, shift in economic landscape, effect of climate change, current regional crisis/geopolitics, post-pandemic impacts, and diverse socioeconomic landscape in Senegal.Thus, this section empirically examines the interplay between green finance proxy by energy generated from low-carbon sources alongside key control variables, and economic performance in Senegal using quantitative methods, and time series data from World Bank, Macro Trends,United Nations,OurWorldInData, International Energy Agencycollected for the analysis for the period 2002 to 2022.With green finance proxy by energy generated from low-carbon sources (Nuclear and Renewable – solar, wind, hydropower, biomass and waste, geothermal, wave and tidal, etc.) serving as primary explanatory variable alongside some key control variables (Inflation, FDI, Population growth, Carbon emissions, and Control of corruption, and per capital GDP serving as dependent variable, a multiple regression model based on the time series data on Senegal is constructed.

The basic model for this study is specified as:

$GDP = \beta_0 + \beta_1 EGLC + \beta_2 X + \varepsilon$ ..... (i)

Empirically the model is specified as:

$(GDP)_t = \beta_0 + \beta_1(EGLC)_t + \beta_2(INFL)_t + \beta_3(FDI)_t + \beta_4(POP)_t + \beta_5(CE)_t + \beta_6(CC)_t + \varepsilon_t$ ..... (ii)

Where;

GDP_t = represent Per capital GDP growth in Senegal at time t

$EGLC_t$ = denotes energy generated from low-carbon sources growth at time t in Senegal

$INFL_t$ = denotes inflation rate in Senegal at time t

FDI_t = signifies foreign direct investment (%GDP) at time t in Senegal

POP_t = represent total Population growth rate at time t in Senegal

CE_t = signifies per capita carbon emissions growth at time t in Senegal

CC_t= denotes control of corruption at time t in Senegal

β_0 = Intercept

β_1 to β_6 are the coefficients representing the marginal impacts of the corresponding variables on long-term sustainable economic growth (GDP) in Senegal.

ϵ_t = Error term, capturing the unobserved factors affecting long-term sustainable economic growth (GDP) in Senegal. t = 2001 to 2022.

The above model in eqn (i) is a regression model that estimates the relationship between GDP and green finance (EGLC) while controlling for other factors (X) that may affect economic growth (GDP). The coefficients β_1 and β_2 in equation (i) are the parameters of interest, representing the interplay between green finance dynamics and economic performance in Senegal.

A positive coefficient for β_1 would indicate that green finance has a positive impact on GDP, while a negative coefficient for β_1 would indicate a negative impact on GDP. In eqn (ii) this study includes GDP per capita as a proxy for economic growth, energy generated from low-carbon sources (EGLC) growth rate to capture the impact of green finance dynamics on economic performance in Senegal, Inflation rate to gauge the influence of price levels and consumer purchasing power, Foreign direct investments to capture the rate of investment inflow and the investors' confidence in Senegal's economy, Population growth to measure demographic trends, and how it affect labour supply and available market, Carbon emissions to capture the impact of climate change on the environment and economic performance. Control of corruption to measure institutional quality/ governance frameworks in Senegal.

The study is guided by this hypothesis: **Ha0**: There is no positive significant relationship between green finance and long-term sustainable economic growth in Senegal. **Ha1**: There is a positive significant relationship between green finance and long-term sustainable economic growth in the Senegal. **H0b**: Green finance does not significantly help to reduce carbon emissions in Senegal. **Hb1**: Green finance help to significantly reduce carbon emissions, fostering long-term sustainable economic growth in Senegal. **Hc0**: inflation rate,foreign direct investment, population growth rate, carbon emissions, and control of corruption have no significant influence on long-term sustainable economic growth in Senegal. **Hc1**: inflation, foreign direct investment, population growth, carbon emissions, and control of corruption exert a significant influence on long-term sustainable economic growth in Senegal.

The study employs econometric techniques to test these hypotheses. The combination of regression analysis and econometric modelling was utilized to analyze the interaction between the variables of the study in Senegal. Specifically, descriptive statistics analysis, boxplots analysis, stationarity tests, cointegration analysis, and NARDL analysis was carried out.NARDL approachwas use to capture the interactions among in the short-run and long-run.

The study provides policy implications for Senegal and other stakeholders (Businesses, investors and others). The findings will help policymakers to understand the interplay between the variables of the study, and inform strategic

policy decisions relating to green finance dynamics, inflation, foreign direct investment, population growth, carbon emissions, control of corruption, andeconomic development in Senegal. The results of the empirical analysis are presented under the results and discussion section below.

4.0. Results and discussion

4.1. Descriptive Statistics Results

Table 2: Descriptive Statistics

	GDP	EGLC	POP	INFL	CE	FDI	CC
Mean	4.69	4.08	2.67	2.05	3.60	3.02	-0.16
Median	4.68	0.61	2.72	1.57	4.06	2.18	-0.05
Maximum	22.11	49.17	2.76	9.70	27.91	9.39	0.25
Minimum	-12.63	-23.29	2.41	-2.25	-22	0.69	-0.64
Std. Dev.	8.07	19.19	0.11	2.68	9.16	2.50	0.24

Table 2 present descriptive statistics for key economic, social and environmental indicators in Senegal. The mean per capita GDP growth rate is 4.70%, with a median of 4.68%, indicating average per capita GDP growth. The per capita EGLC growth rate is 4.08%, with standard deviation of 19.9%, suggesting the need for sustainable energy policies. Population growth rate is 2.67%, indicating stable growth. Mean inflation rate is 2.05%, implying average price level. The carbon emissions average 3.60%, highlighting environmental impacts. FDI averages 3.02% of GDP. Mean control of corruption is -0.16, with standard deviation of 0.24. Fluctuations in these variables emphasize the need for sustainable economic, energy, social, and environmental policies in Senegal.

4.2. Boxplot Analysis

Figure 2: Boxplot results

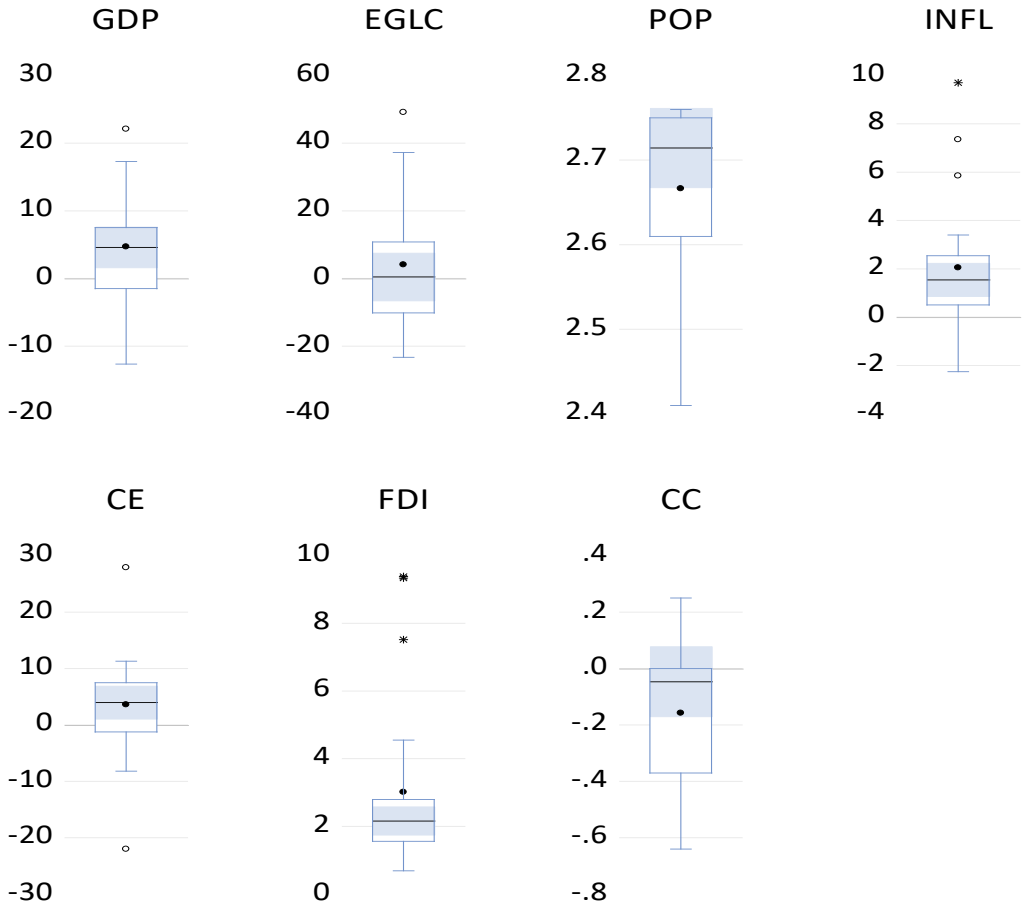


Figure 3 provides a visual representation for each variable (GDP, EGLC, POP, INFL, CE, FDI, CC), using boxplots to depict the spread, mean, median, interquartile range, and outliers. High variability and significant outliers in GDP, EGLC, INFL, and CE stresses the need for policies aimed at stable macroeconomic environment, sustainable energy use and efficiency, and environmental protection. Moreover, low variability in POP and CC suggests stable growth, and policies can focus on maintaining this stability while addressing demographic challenges, and improving institutional quality for control of corruption (CC).

4.3.Stationarity (Augmented Dickey-Fuller Unit Root) Tests Results

Table 2. Unit Root (Augmented Dickey Fuller Test) Results

VARIABLES	ADF. LEVEL	ADF. 1ST DIFF.	ADF. 2ND DIFF.	ORDER	REMARK
GDP	-3.6718	-	-	I(0)	Stationary @
P-Value	(0.0128)				level
EGLC	-3.8006		-	I(0)	Stationary @
P-Value	(0.0112)				level

POP	-0.8171	0.6661	-5.6759	I(2)	Stationary @
P-Value	(0.7898)	(0.9875)	(0.0003)		2nd diff.
INFL	-2.674	-4.6801	-	I(1)	Stationary @
P-Value	(0.0951)	(0.0016)			1st diff.
CE	-4.3842	-	-	I(0)	Stationary @
P-Value	(0.0027)				level
FDI	1.6084	-2.5359	-4.5032	I(2)	Stationary @
P-Value	(0.9990)	(0.1224)	(0.0025)		2nd diff.
CC	-1.8977	-5.0772	-	I(1)	Stationary @
P-Value	(0.3265)	(0.0007)			1st diff.

Stationarity test result show that the variables are stationary at level, first difference and second difference. Having known the order of integration of the variables, a differencing was applied for stationarity before further analysis.

4.4. Cointegration Test Results

Table 4: F-Bounds Test Result for Cointegration				
Null Hypothesis: No level relationship				
Test Statistics	**Value**	**Significance**	I(0)	I(1)
F-Statistic	37.72	10%	1.92	2.89
K	7	5%	2.17	3.21
		1%	2.73	3.9

The cointegration test checks for long-term equilibrium relationship amongtime series variables. The results confirm the existence of a stable long-term relationship among GDP, EGLC, POP, INFL, CE, FDI and CC in Senegal.

4.5. NARDL Long-run Form Estimated Results

Table 5: NARDL Long-run Form Estimated Results			
Dependent variable: **GDP**			
VARIABLES	**Coefficients**	**t-ratio**	**P-Value**
EGLC_POS(-1)	0.2635	4.0868	0.015
EGLC_NEG(-1)	-0.3551	-2.3008	0.0829

D(POP(-1))	-15.7782	-0.4657	0.6657
D(INFL(-1))	0.3022	1.0018	0.3731
D(CE(-1))	-0.4006	-6.5179	0.0029
D(FDI(-1))	-1.6348	-1.9766	0.1193
D(CC(-1))	-27.7047	-5.3858	0.0057
C	0.1482	0.1444	0.8922

Table 5 results reveal significant findings regarding the interactions between economic growth and various economic indicators in Senegal. The positive change in energy generated from low carbon sources (EGLC) has a significant impact on GDP, with a long-run coefficient of 0.2635 and p-value of 0.0150. this implies that increase in EGLC positively affect per capita GDP. On the other hand, negative change in EGLC has a significant negative influence on GDP, with a coefficient of -0.3551 and p-value of 0.0829. this suggests that decreases in energy generated from low carbon adversely affect per capita GDP. This highlights the pivotal role of energy in economic development.

Change in population growth rate (POP) negatively impact economic growth, though not significant, with a coefficient of -15.7782 and p-value of 0.6657, while change in inflation rate has a positive but insignificant effect on GDP with a coefficient of 0.3022 and p-value of 0.3731. Carbon emissions have a significant negative impact on GDP with a coefficient of -0.4006 and p-value of 0.0029. This suggests that increased carbon emissions adversely affect economic growth. foreign direct investment (FDI) has a negative but insignificant impact on GDP with a coefficient of -1.6348 and p-value of 0.1193. also, change in control of corruption has a significant negative effect on GDP with a coefficient of -27.7047 and p-value of 0.0057. this implies that higher corruption levels significantly impede economic growth.

Th long-run results highlight the crucial factors influencing economic development, particularly energy generated from low-carbon sources, carbon emissions, FDI, and control of corruption. Thus, policy interventions aiming energy access and efficiency, stable macroeconomic environment, environmental sustainability, institutional quality and business climate improvements are critical for promoting sustainable economic growth. by addressing these pertinent areas, policymakers can improve economic stability and foster long-term development in Senegal.

4.6. NARDL Short-run/ECM Estimated Results

Table 6: NARDL Short-Run ECM Estimated Results			
Dependent variable: **GDP**			
Variables	**Coefficient**	**t-ratio**	**P-Value**
D(EGLC_POS(-1))	0.2915	14.1145	0.0001
D(EGLC_NEG(-1))	-0.4083	-10.9164	0.0004
D(POP(-1),2)	-92.7561	-6.0949	0.0037
D(CE(-1),2)	-0.1694	-9.3907	0.0007
D(FDI(-1),2)	0.9822	1.9286	0.1260
D(CC(-1),2)	-27.2707	-17.5945	0.0001
ECM_{t-1}	-1.4307	-31.9147	0.0000
R-squared	0.9915		
Adjusted R-squared	0.9873		
Durbin-Watson stat.	1.6000		

Table 6 display the dynamic short-run/error correction results for the variables. the error correction term represents the speed at which equilibrium is restored after a disturbance, aligning with expectation by being negative and significant at 1% level. The value of -1.4307 suggests the rate at which a shock to economic growth will be quickly adjusted in the next period. The positive change in low-carbon energy (EGLC) has a highly significant positive impact on GDP, with a coefficient of 0.2915 and p-value of 0.0001. this implies that increases in EGLC boost per capita GDP in the short run. The negative change in EGLC has a highly significant negative effect on GDP, with a coefficient of -0.4083 and p-value of 0.0004, indicating that decreases in EGLC significantly reduce per capital GDP in the short run. These results are in line with long-run results, further stressing the pivotal role of energy in economic development.

Change in population growth rate has a highly significant negative influence on GDP, with a coefficient of -92.7561 and p-value of 0.0037, suggesting that previous changes in population growth can have a substantial negative impact on economic performance. Change in carbon emissions has a highly significant negative impact on GDP with a coefficient of -0.1694 and p-value of 0.0007, implying that increases in carbon emissions adversely affect economic growth in the short run. Change in foreign direct investment (FDI) has a positive but insignificant influence on GDP with a coefficient of 0.9822 and p-value of 0.1260, suggesting

that while FDI can positively affect GDP, its impact is statistically insignificant in the short run. Change in control of corruption has a highly significant negative impact on GDP with a coefficient of -27.2707 and p-value of 0.0001. this indicates that higher levels of corruption significantly hinder economic performance in the short run in Senegal. Diagnostic statistics indicate a good model fit, validating the model.

4.7. Diagnostic Tests

4.7.1 Residual Normality Test

Figure 3: Residual Normality test results

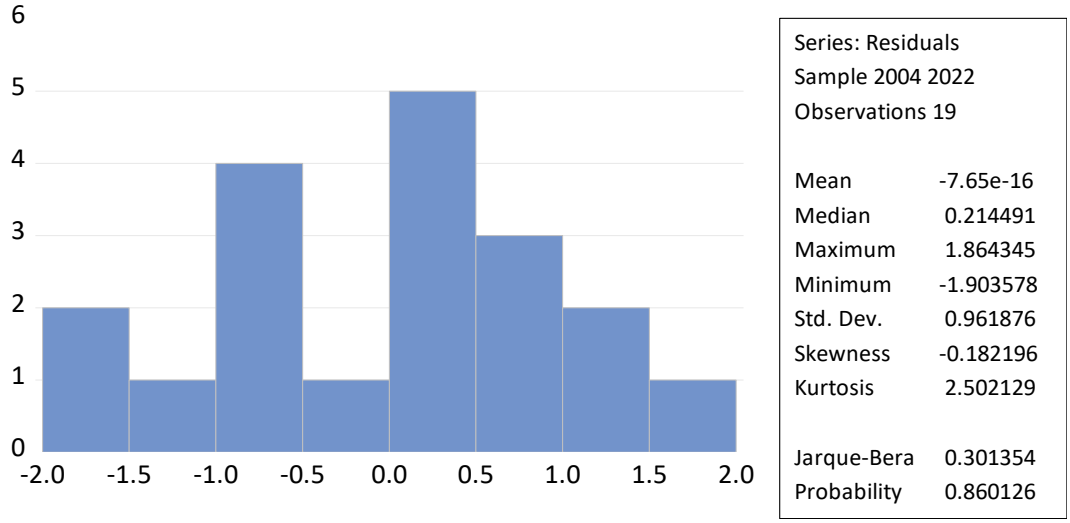


Figure 4 shows that there is no evidence to reject the null hypothesis of multivariate normality of the residuals at 5% significance level. This supports the robustness of the statistical inference of the model, its use in economic policy formulation andanalysis.

4.7.3.Breusch-Godfrey Heteroskedasticity Test

Table 7: Breusch-Pagan-Godfrey Heteroskedasticity Test Results			
Null hypothesis: Homoskedasticity			
F-statistic	0.73359	**Prob. F (14,4)**	0.7038
Obs*R-squared	13.67424	**Prob. Chi-Square (14)**	0.4743
Scaled explained SS	0.45519	**Prob. Chi-Square (14)**	1.0000

The Breusch-Pagan-Godfrey test results in table 7 confirm the presence of homoskedasticity in the model, suggesting that the variance of the residuals is constant, validating the reliability of the model's estimates.

4.8.Policy Implications

The descriptives statistics, boxplots analysis, and NARDL results emphasizes the need for targeted policy interventions to address economic, environmental and

investment-related challenges inSenegal. GDP data suggest economic instability with fluctuations in outputs, influenced by past performance.

The significant negative coefficient of ECM_{t-1} suggests a stable long-run relationship between EGLC, POP, INFL, CE, FDI, CC, and GDP, with deviations corrected quickly in the next period. Policymakers can use the long-run coefficients to evaluate the impact of changes in these variables on economic growth. Attention to the adjustment process is essential., requiring measures such as structural reforms, counter-cyclical policies, and efforts to maintain stable macroeconomic environment.

Short-run impacts of fluctuations in these explanatory variables on GDP are shown by significant coefficients of their differences. Policymakers can use these to assess short-run GDP dynamics in response to shocks and interventions. The F-bounds test confirms a cointegration relationship among the variables, indicating a long-term causal association with GDP. These insights can help policymakers identify growth sources and potential instability in Senegal's economic development.

Efficient policy interventions are crucial for sustainable energy consumption and economic development. Significant coefficients of energy generated from low carbon sources underscore energy's role in economic progress. This call for policies to enhance green financing, energy access, affordability, efficiency, attract investment in energy sector, improving existing energy infrastructure, and promoting sustainable energy sources to support economic growth.

Population growth, though has insignificant effect in the long-run, have significant negative impact on GDP in the short-run, suggesting the need for policies that effectively manage population growth and ensure that economic resources and infrastructure are sufficient to support a growing population to avoid demographic change challenges. Though, inflation coefficient is insignificant, maintaining stable and low inflation through sound monetary policies will provide a conducive climate for economic activities.

The significant negative impact of carbon emissions on GDP indicates that reducing emissions through strict environmental regulations, encouraging green investments, and promoting clean technologies will benefit economic performance. Moreso, policies aimed at balancing economic development with environmental sustainability should be prioritized to ensure long-term prosperity in Senegal. Although the effect of FDI is insignificant in the short-run, encouraging foreign direct investment and improving business climate through favourable policies can contribute to economic growth in the long-run. The significant negative impact of corruption (CC) on GDP emphasizes the importance of strengthening governance frameworks, improving transparency, and implementing robust anti-corruption measures to improve economic performance in Senegal. Overall, efficient planning and targeted policy designs/interventions are essential for addressing present and future needs to ensure a sustainable growth and resilient future.

5.0. Conclusion and recommendations

This study evaluates the short-run and long-term impacts of green finance alongside other key variables on economic performance in Senegal from 2001 to 2022, using time series data from World Bank, Macrotrends, United Nations, OurWorldInData, and International Energy Agency. Despite mixed global findings, specific studies on Senegal are limited. This research contributes to the literature by focusing on the green finance's role in Senegal's economic development. Analytical techniques such as Descriptive statistics, Boxplots, Cointegration tests, and NARDL estimation were used to analyse the data. The results reveal the growth patterns and significance of the variables in driving economic development in Senegal. In line with the findings, this study recommends implementing policies enhancing stable macroeconomic environment, boosting productivity, green growth, energy efficiency, environmental sustainability, human capital development, and quality of life as well as diversify the growth drivers and sources (i.e., invest in agriculture, tourism, services, and technology). (ii) increasing green financing initiatives, improving energy access and affordability, and more investment in renewable energy and low-carbon technologies. (iii) effectively manage population growth and ensure that economic resources and infrastructure are sufficient to support a growing population to avoid demographic change challenges. (iv) maintain stable and low inflation through sound monetary policies for sustainable economic growth. (v) pursue environmental policies that reduce carbon emissions, and mitigate climate change impacts while balancing economic development with environmental sustainability to ensure long-term prosperity. (vi) encourage foreign direct investment and improving business climate through favourable policies. Finally, strengthening governance frameworks, improving transparency, and implementing robust anti-corruption measures to improve economic performance in Senegal.

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