Energy Reports 12 (2024) 2801–2811

Contents lists available at ScienceDirect

Energy Reports

journal homepage: www.elsevier.com/locate/egyr

Research paper

Green finance, green innovation, and industrial development in Africa

Tii N. Nchofoung [a,*], Ofeh Marilyn Edoh [b], Nara Monkam [c]

[a] Ministry of Trade, Cameroon
[b] Faculty of Economics and Management, University of Dschang, Cameroon
[c] Department of Economics, Faculty of Economic and Management Sciences, University of Pretoria, South Africa

ARTICLE INFO

Keywords:
Green finance
Green innovation
Renewable energy
Industrialization
Africa

ABSTRACT

The issue of promoting green industrial productivity has emerged as a pivotal concern in economic development, attracting substantial attention from scholars and policy makers alike. This study aims to scrutinize the impact of green finance on Africa's industrialisation, and further explore the potential moderating role of green innovation within the relationship between green finance and industrialisation in the African context, i.e., assessing the extent to which green innovation can influence the effect that green finance has on industrialisation. This study encompasses 41 African nations, spanning the period from 2000 to 2020. The research methodology employs the fixed effect model as proposed by Driscoll and Kraay (1998), in conjunction with the system Generalized Method of Moments (GMM) regression analysis. The results show that green finance enhances industrialization in Africa, while green innovations through renewable energy have a negative effect. Policy recommendations are discussed.

1. Introduction

The shift of African economies towards industrial development has persistently trailed behind that of other emerging economies and developed nations. A multitude of factors contribute to this slower pace of structural transition, which can be both endogenous and exogenous (Nkemgha et al., 2023). Endogenous factors encompass excessive governmental interference in national economies, ill-conceived investment initiatives, and overprotection of nascent industries. On the exogenous front, key contributors include a decrease in export revenues and output stagnation, both consequences of an unfavourable external environment. The difference between African industrialization drives and those of other developing nations is not only substantial but also accruing and trajectory dependent, due to the fact that their industrialisation path is different from past industrial miracles. Some African policymakers have argued in favour of adopting the Asian industrial strategy due to the success of rapidly expanding emerging economies, particularly China (Lall, 2004; Morris and Fessehaie, 2014). This strategy involves, among others, the intervention of the State in the national economy for structural transformation and defining clear industrial paths, moving from agriculture to industry and from labour-intensive sectors to high value-added industries.

For Africa to succeed in this drive and close its development gap, its economies should foster a competitive environment to attract both domestic and foreign investments which are crucial for structural transformation of their economies and reduction of unemployment. However, Africa finds itself in a predicament. While advanced economies have developed through industrialization, generating substantial greenhouse gas emissions in the process, African economies are embarking on their industrialization journey at a time when the global community is combatting environmental degradation through the implementation of stringent environmental regulations. Green industrialization thus serves as a pivotal gauge of a nation's ability to address environmental concerns, improve environmental performance, and simultaneously foster sustainable industrialization. Consequently, the question of how to stimulate green industrial productivity has emerged as a central issue in economic development, attracting significant attention from both scholars and policymakers (Lee and Lee, 2022; Acheampong and Tyce, 2024). Increased climate aid through climate finance is expected to shift investment priority from non-green innovations to green innovations which are ultimately expected to affect green industrial development. The effect of green innovation could consequently be negative or positive on industrialisation. Negatively, green innovation through renewable energy could harm industrial growth through its cost of setting up such technologies, especially in developing economies like Africa. In reality, industries take decisions

* Corresponding author.
E-mail addresses: ntii12@yahoo.com (T.N. Nchofoung), marilynedoh@gmail.com (O.M. Edoh), fn.monkam@up.ac.za (N. Monkam).

https://doi.org/10.1016/j.egyr.2024.08.066
Received 10 March 2024; Received in revised form 16 August 2024; Accepted 24 August 2024
Available online 3 September 2024
2352-4847/© 2024 The Author(s). Published by Elsevier Ltd. This is an open access article under the CC BY-NC license (http://creativecommons.org/licenses/by-nc/4.0/).

based on several factors such as return on investment, and if renewable energy options are less economically viable than the conventional energy, industries may be reluctant to switch or opt for the use of renewable technologies. On the contrary, adopting renewable energy can help reduce the carbon footprint in the economy. This can help reduce climate change and conserving natural capital, which attracts environmentally conscious consumers, and support long-term economic development.

Through capital allocation, green finance attempts to offer market-oriented funding guarantees for green innovations,[1] green projects, and green enterprises (Huang et al., 2022; Fang and Shao, 2022). Climate finance can reduce investment risk, boost return on investment, and attract worldwide investors to green energy projects, which consequently lead to sustainable industrialization (Tolliver et al., 2020; Fotio and Karim, 2024). However, finance has not always yielded positive results on industrialization (Laeven and Levine, 2011; Gennaioli et al., 2012; Kothakapa et al., 2020; Yu and Zhao, 2024).

Environmental innovations could result in more advanced environmentally friendly processes, technologies, and goods. These could ultimately increase long-term competitive advantage, cut total firm costs, and improve financial performance (Yang et al., 2011; Lee et al., 2018; Andries and Stephan, 2019; Adu-Yeboah et al., 2022). By improving energy supply and efficiency and lowering the environmental impact of the industrial sector, green innovation promotes sustainable industrial development and aids in the decoupling of economic expansion and environmental degradation. Furthermore, green innovation drives economic growth and productivity. As nations transition from fossil fuels to renewable energy sources, they achieve enhanced energy efficiency and bolster green industrial output. However, some studies contend that innovative green technology does not necessarily enhance industrialization and economic growth (Yan et al., 2020; Sohag et al., 2021). They suggest that the effectiveness of renewable energy in promoting green economic development hinges on the level of technological advancement, the cost of acquisition, and the requisite human capital skills to operate the new technology (Nkemgha et al., 2023; Wirajing et al., 2023). Therefore, the objectives of this study are as follows: (i) to examine the effect of green finance on industrialization in Africa; and (ii) to examine the modulating effect of green innovation in the green finance-industrialization nexus in Africa, i.e., gauge the extent to green innovation can influence the effect that green finance may have on industrialization.

This study focuses on Africa due to unique factors relevant to the research question. Firstly, renewable energy is more expensive compared to fossil fuels, which are readily available in many parts of the continent. Additionally, Africa, being one of the world's poorest regions with underdeveloped human capital, faces challenges in affording and successfully implementing green technologies. Secondly, between 2020 and 2030, Africa's estimated climate finance needs amounted to $2.5 trillion. However, by 2020, only 12 % of this required sum was mobilized, and the continent receives barely 3 % of the current global climate finance. (Climate Policy Initiative, 2022). The African Development Bank (AfDB), however, asserts that Africa has significant space for expansion in terms of climate funding. For instance, private equity funds under management had reached a record of $6.3 trillion in 2021, while global pension fund assets in the 22 largest markets had hit a new high of $56.6 trillion by late 2022 (AfDB, 2023). Thirdly, it is anticipated that Africa, at a comparable stage of development, will have a larger proportion of tradable industries and mineral extraction than what is currently seen in advanced nations. For instance, Africa's wealth of tourism resources is still underutilised and has enormous growth potential, especially in the field of ecotourism and other sustainable industries (Brahmbhatt et al., 2017). This study therefore answers the following questions: (i) what is the effect of green finance on industrialization in Africa? and (ii) what is the modulating effect of green innovation in the green finance-industrialization nexus in Africa?

By exploring the role of climate finance and green innovations in industrial development, this study adds to the body of literature already available on the factors influencing industrialization by considering a global south perspective. Most of the studies on the subject are dominated by the global north view. A global south view is would contribute to a more diverse and representative understanding of the problem, which is crucial for a more holistic and inclusive knowledge base. This study is particularly important for Africa given that the world is progressively moving towards a new financial architecture and that, world leaders have acknowledged the need for the new financial architecture to be designed to serve the needs and aspirations of Africa, which is suffering more from the effects of climate change than she has contributed to its damage. Hence, it becomes crucial to evaluate how Africa will navigate its industrialization path in an era where green financing is expected to take precedence and clean energy is anticipated to power the continent. The results of the study show that green finance and green innovations have positive and negative effects on industrialization respectively. The rest of the study is further tailored around a literature review (Section 2), methodology of research (Section 3), results and discussions (Section 4), and conclusion and policy implications (Section 5).

2. Review of related literature

2.1. Theoretical underpinnings

Theories explaining the relationship between finance and growth (developmental aspects) have a long history, tracing back to Schumpeter's work on economic development in Schumpeter (1912). More recent perspectives, such as those of McKinnon (1973) and Shaw (1973), argue that government restrictions on the banking system, including interest rate ceilings, direct credit programs, and high reserve ratio requirements, impede financial development, subsequently reducing growth. Contemporary endogenous growth literature presents models on financial intermediation and the various services provided by financial intermediaries (such as liquidity provision, information gathering, etc.) and conclude that such intermediation positively influences growth and developmental components (Greenwood and Jovanovic, 1990; Bencivenga and Smith, 1991).

Bagehot (1873), in his study on Lombard Street, was among the pioneers to explore the connection between finance and industrial development. He posited that financial factors are exogenous variables influencing changes in industrial structure, a claim based on the British Industrial Revolution, which he attributed to the financial system's provision of capital for large-scale industrial projects. In line with Bagehot (1873), Rajan and Zingales (1998) tested a hypothesis on the fact that financial development encourages industrial growth via the reduction of cost of borrowing, which indicated a positive effect of financial development on industrial performance. However, in the 1990s, a new perspective emerged, suggesting that financial services are endogenous variables influencing industrial structures and facilitating change. This school of thought emphasized that financial development is a crucial pathway for industrial structural adjustment (Greenwood and Jovanovic, 1990; Bencivenga and Smith, 1991), a concept later validated and accepted by empirical studies (Vernon, 1966; King and Levine, 1993).

2.2. Empirical literature

2.2.1. Green finance and industrialization

According to the United Nations Environment Programme Finance

[1] Green innovations refer to all forms of invention that contribute to the development of essential goods or services that minimise their negative effects on the environment while also making the best use possible of its resources (Takalo and Tooranloo, 2021).

Initiative (2007), green finance refers to financial products or services with an environmental focus, such as loans, credit cards, insurances, or bonds. They attribute the growth of green finance to the overall development of the financial sector. Similarly, Noh (2010) and Hyomnyoktan (2012) suggest that green finance constitutes a significant portion of the finance sector, sourced primarily from international public finance, private sector finance, and domestic public finance. These sources supplement the financial sector of every economy. Wang et al. (2019) further define green finance as a manifestation of financial innovation, a novel policy instrument developed to address environmental issues. They note that green finance shares similar characteristics with traditional finance.

Therefore, akin to financial development, the evolution of green finance can also foster economic development. However, given its novelty, there are only a few empirical studies on this subject (Zhou et al., 2020). Given the limited literature on how green finance impacts industrialization, the following section will provide a few explanations on how green finance may influence industrialization, taking into account the role of financial development on industrialization.

Numerous studies investigating the connection between financial development and the growth of the manufacturing industry have yielded diverse conclusions. One prominent conclusion is that the development of the financial sector positively influences the growth of the manufacturing industry. Holmstrom and Tirole, (1997) believe that financial industry development promotes real growth via the reduction of internal and external financing cost. In 13 OECD countries, with the use of the VAR model, Neusser and Kugler (1998) examined the relationship between manufacturing and financial development. The results from the study revealed that for most of the developed countries, there exist a positive significant correlation between financial development and manufacturing output. A buoyant financial system has equally been shown to foster the upgrading of manufacturing industries' structure (Beck et al., 2000; Ross, 2005; Yi and Liu, 2015; Liang and Zhang; 2018; Zhao, 2003; Yu and Zhao, 2024). Yu and Zhao (2024) argue that to address the financial constraints of industrialisation, strategic measures could include expanding mobile payment options, diversifying financial institutions, enhancing financial infrastructure, and implementing more flexible financing options. From the standpoint of a developing economy, Doumbe and Zhongxiu (2017) explored the relationship between financial development and industrialization in Cameroon over the period 1970–2014. The Autoregressive Distributed lag (ARDL) technique, alongside the aggregate production framework were used and the results concluded that financial development influences investment, and consequently industrialization, which has recently been supported by the study of Appiah et al. (2023) for African countries.

Another strand of the literature argues that there is no obvious role played by financial development in boosting the development of the manufacturing industry. Rajan (2006) posits that financial development introduces vulnerabilities, including an overdependence on financial systems, misinformation, and inconsistent incentives across banks that can result in ill-advised risk ventures. In the event of bankruptcy, these vulnerabilities can trigger panic, compel liquidation, and subsequently disrupt the manufacturing industry through closures, significant financial losses, and production interruptions. Laeven and Levine (2011) support this finding as they concluded that economic development is significantly impeded by financial innovation. In Gennaioli et al. (2012), issues within financial institutions accumulate, leading to instability in the manufacturing industries. The study also found that external finance constrained the operation and advancement of manufacturing industries, effectively negating the financial sector's capacity to promote the development of the manufacturing industry (Da Rin and Hellmann, 2002). Kothakapa et al. (2020) analysed the link between financial development and industrialization in low- and middle-income countries from 1970–2014 and the results were inconclusive. The results revealed that financial development negatively affects industrialization up to a certain point, after which the resulting effect turns positive. This depicts a U-shaped relation, and the complexity of the correlation, which was recently supported by the work of Nkemgha et al. (2023), who argued of a change in sign in the relationship based on the level of human capital development.

The aforementioned discussion reveals conflicting outcomes regarding the relationship between financial development and the industrial sector. While some researchers argue that financial development positively impacts the industrial sector, others present evidence of its destabilizing effect, particularly on the manufacturing industry. Does this imply that green finance, based on the evidence presented, will yield similarly contradictory results across different countries and regions?

Proposals have been put forward asserting that the growth of green finance can be significantly bolstered through foreign direct investment, which in turn has a substantial impact on economic development and growth. Foreign direct investments in a country can stimulate its local entities, particularly manufacturing companies, to accelerate the development of innovative ideas and technological progress. Ultimately, this has the potential to increase employment opportunities as various sectors of the economy expand (Moran, 2012).

Wang and Wang (2021) conducted a study examining the impact of green finance on the upgrading of China's regional industrial structure from 2008 to 2020. They employed the gray correlation method to empirically assess the relationship between the variables. Following the gray correlation analysis, the GMM model was used to understand the direction and the degree of the impact of green finance on industrial structure upgrading. The findings were categorized based on different industrial levels. The correlation between green finance and output value was most pronounced in the tertiary industry, indicating that green finance has the most substantial effect in this sector in China, thereby promoting rapid development and facilitating the upgrade of the industrial sector. However, the results varied across different regions in China, although all demonstrated positive effects. The study concluded with robust policy recommendations, including the need to promote green technology development, train green finance agents, establish green finance infrastructure, and enhance foreign exchange cooperation.

The majority of existing research, as observed, has concentrated on developed nations, OECD countries, and the Asia-Pacific region, with relatively few studies addressing the relationship between green finance and industrialization in Africa and its regions. This presents an opportunity for the current study to bridge this gap and offer policy insights for the region, particularly in low-income countries.

2.2.2. *Green finance and green innovation*

Several studies have explored the impact of green finance on green innovation. Existing literature suggests that green policy, particularly in terms of credit, assists in regulating two high-polluting industries and one overcapacity industry in China, as indicated by Zhang et al. (2011). This viewpoint is further reinforced by Liu et al. (2017) who discovered that green loan policies can reduce investments in energy-intensive industries, thereby promoting green technologies. Similarly, Xu and Li (2020) and Liu et al. (2019) found that green credit policies and the development of green credit can lower debt financing costs for green enterprises undertaking green projects. Furthermore, Li et al. (2018) developed a green loan theory, emphasizing the effectiveness and significance of green bank loans in driving green innovation.

Yu et al. (2021) conducted a study to understand the impact of limited access to financial resources on the growth of China's green industries. The study also aimed to evaluate whether green finance policies could serve as a solution to this issue, particularly by fostering green innovations and mitigating the effects of financial constraints. The findings revealed that green finance policies significantly alleviate the impact of financial limitations on the innovation within green industries. However, this effect is more pronounced for state owned enterprises and very minimal for privately-owned enterprises seeking financial relief. Dong et al. (2022) found that green finance significantly

enhances green innovation across various Chinese companies from 2008 to 2020. Other studies concluded that access to green credit enhances corporate R&D, facilitates eco-innovation, promotes industrial structure upgrading, and technological innovation (Chen et al., 2019; Wu et al., 2019; He et al., 2018). Another argument in the literature suggests that direct financing (investment in green securities) is more effective that indirect financing (green credit) for the growth and development of green industries (Lin et al., 2018).

Huang et al. (2022) in their study explore mechanisms through which green finance influences green innovation. They used data from 30 Chinese provinces spanning 2009–2017 and constructed a green finance index. Using spatial Durbin and panel threshold models, they analysed the relationship between these variables. Their findings revealed a significant positive autocorrelation between green finance and green innovation. Both direct effect and indirect effect coefficients showed that green finance was found to have a significant positive effect on green innovation. Finally, for the threshold results, the effect of green finance on green innovation diminishes with the intensification of environmental regulation policies. Consequently, they recommend that governments implement trickle-down policies in dealing with green finance and consider easing of environmental regulations. Ma et al. (2023) corroborates the positive effect in Chinese high-carbon industries, with the effect most evident in green invention patents.

2.2.3. Green innovation and industrialization

While research on the relationship between green innovation and industrialization is limited, there is a body of work exploring the connection between green innovation and sustainable development goals (SDGs), particularly in developed countries. Given that green innovation is closely tied to SDG 9 (Industry, Innovation, and Infrastructure), it is reasonable to infer that green innovation can significantly influence industrialization. However, the lack of studies focusing on this relationship in developing countries presents an opportunity for further exploration in this area, which the present study attempts to do.

Sarkar (2013) highlights that most OECD governments already recognise eco-innovation as a strategic tool for achieving SDGs while maintaining economies and industries competitive. He cites the European Union as an example where eco-innovation is seen as a great driving force for achieving objectives such as improving industrial competitiveness, increasing resource efficiency and fostering overall growth.

Studies such as Dogaru (2020) and Habanabakize (2020) suggest that eco-innovation supports numerous sustainable development goals, including good health and well-being, zero hunger, clean water and sanitation, affordable clean energy, industry, innovation and infrastructure, economic growth, sustainable cities and communities, and climate action. Sadiq et al. (2023) found that green finance, eco-innovation, and creativity positively impact the SDGs in ASEAN countries. Lee et al. (2018) also found that eco-innovation enhances firm productivity and positively influences the SDG related to environmental performance, innovation, and economic growth. Recently for China, Yang et al. (2024) discovers that through agglomeration effects and legislation, the smart city pilot program might offer businesses a fresh incentive for their green innovation behaviour. They pointed to the need for the government to keep supporting green enterprise innovation through the creation of smart cities and to adopt smart city construction programs that take local conditions into account in order to support China's high-quality economic development.

When companies develop green innovations, they increase their competitiveness and experience product value increase because of the use of more technically efficient innovations. They also benefit from a reduction in raw material cost, shape future regulations, raise their competitors' costs, and reduce community and public pressure for efficiency and clean production (Murty and Kumar, 2003; Yang et al., 2011; Andries and Stephan, 2019). Asadi et al. (2020) discovered that green innovation has the potential to promote and improve sustainable performance in the hotel industry. For Africa, Nkoa and Fonguen-Kong-Ngoh (2024) reiterated the importance of renewable energies in achieving the twin goals of environmental protection and industrialisation, and suggest the creation of a comprehensive international funding mechanism with several stakeholders aimed at supporting energy transition and green industrialisation. Despite these observations, other studies argue that innovative green technology does not necessarily enhance industrialisation and economic growth (Yan et al., 2020; Sohag et al., 2021).

Regarding the relationship between green finance, green innovation, and industrialization, with green innovation playing the modulating role, based on our knowledge, the literature appears to be sparse. While studies have examined the relationship between sustainable development, green finance and industrial structure (Wang and Wang, 2021), and the mechanisms linking green finance and green innovation (Huang et al., 2022), the specific triadic relationship remains largely unexplored.

Other research has examined the mediating role of green supply chain integration in the relationship between green manufacturing practices and sustainable performance (Afum et al., 2020), the impact of environmental tax regulations on industrialization (Tchapchet Tchouto et al., 2022), and gender inequality moderating the role of green financing on eco-innovations (Saha et al., 2022). Despite the lack of literature specifically addressing the relationship between green finance, green innovation, and industrialization, the studies presented in this section suggest a potential connection between these variables. Therefore, conducting this study could contribute to the debate regarding the nexus of green finance and industrialization.

3. Methodology

3.1. Econometric strategy

Drawing from the existing literature on the factors influencing industrialization (1999; Nkemgha et al., 2023), the empirical model is specified as in Eq. 1. Where IND is the measure of industrialization of country *i* at time, t, *Green-Fi* is green (climate) finance, *Green_inn* is green innovation and X is the vector of explanatory variables including foreign aid (ODA), trade openness (Trade), foreign direct investments (FDI), and natural resources rents. υ is the time fixed effect and γ is the individual effect.

$$IND_{it} = \beta_0 + \beta_1 Green\_Fi_{it} + \beta_2 Green\_inn_{it} + \beta_2 X_{it} + \upsilon_t + \gamma_i + \varepsilon_{it} \quad (1)$$

3.1.1. Dependent variable

The dependent variable in this study is industrialization, measured initially as the total industrial value added as a percentage of GDP. To ensure the robustness of the findings, additional measures are used such as manufacturing value added, agricultural value added, and service value added. The data for these variables has been collected from the World Bank's World Development Indicators. Fig. 1 below shows the evolution of industrial value added across selected countries over the study period.

3.1.2. Independent variables of interest

The first independent variable of interest is green finance, measured as the total mitigation-related development finance (2020 thousand USD) received, and it is collected from the OECD database. Climate finance can reduce investment risk, boost return on investment, and attract worldwide investors to green energy projects, which consequently lead to sustainable industrialization (Tolliver et al., 2020; Wang and Wang, 2021). This variable is therefore expected to have a positive sign in this study. The second variable of interest is green innovation, proxied by renewable energy consumption (% of total energy consumption). The role of renewable energy in fostering green economic development hinges on several factors. These include the level of

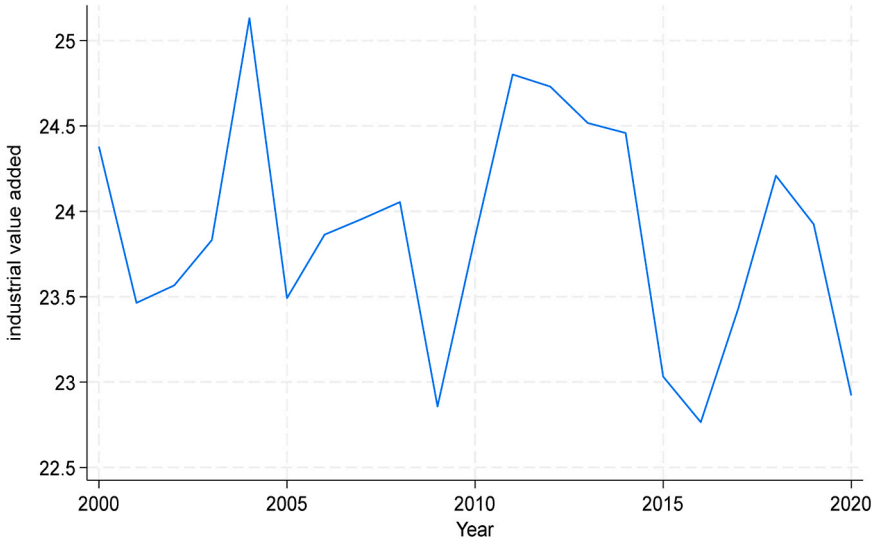

Fig. 1. Evolution of average industrial value added (% of GDP) for 41 African countries, 2000–2020.

technological advancement, the cost of acquiring the technology, and the requisite human capital skills needed to operate this new technology (Nkemgha et al., 2023). Considering Africa's current state, characterized by a significant deficit in human capital development and a high poverty rate, coupled with the relatively higher cost of clean energy on the continent, we anticipate that the impact of renewable energy may be inversely related to sustainable industrialization. Fig. 2 illustrates the trend of climate finance in Africa over the years 2000–2020.

3.1.3. Control variables

The first control variable considered is trade openness. Measured as the sum of exports and imports relative to GDP, the variable is expected to exhibit a positive sign consistent with the findings of Bankole and Oladapo (2019) and Choi et al. (2021). The next control variable is foreign direct investment inflows (%GDP). Drawing on the work of Mamba et al. (2020), we expect this variable to either be neutral or positively influence structural transformation. The third control variable is natural resource rents, proxied by total natural resource rents (% GDP). Nkemgha et al. (2022) argue for a positive effect of natural resources on the structural transformation of the industrial sector. The rationale is that rents from natural resources can facilitate investment in other industrial sectors, thereby fostering overall industrialization. The last but not the least control variable is foreign aid, measured by the net official development assistance received (%GNI). The variable is expected to produce a negative sign in line with the findings of Nchofoung et al. (2022) who posited that foreign aid tends to reduce industrial employment in Africa.

Incorporating the moderating influence of green innovation, represented by the consumption of renewable energy, Eq. (1) is specified as follows:

$$IND_{it} = \beta_0 + \beta_1 Green\_Fi_{it} + \beta_2 Green\_Inn_{it} + \beta_3 (Green\_Fi * Green\_Inn)_{it} + \beta_j X_{it} + \upsilon_t + \gamma_i + \varepsilon_{it} \quad (2)$$

Where β_3 is the coefficient of the indirect effect, and the rest of the variables and coefficients are defined as in Eq. 1. In some cases, the direct and indirect effects produce the same signs, leading to synergy effects. However, in case both the direct and indirect effects are significant and opposite in signs, a net effect should be computed as in (3).

$$Net\ effect = \beta_1 + \beta_3 \overline{Green\_Inn} \quad (3)$$

In this specification, $\overline{Green\_Inn}$ is the average of the modulating variable (green innovation), and the rest of the coefficients are defined as above. Fig. 3 shows the fitted scattered plot of the relationships under investigation.

Fig. 3 shows an initial insignificant relationship between green finance and industrialisation. However, an econometric regression correcting for possible biases assess better the relationships under study.

Due to data limitations on key variables of interest, our study

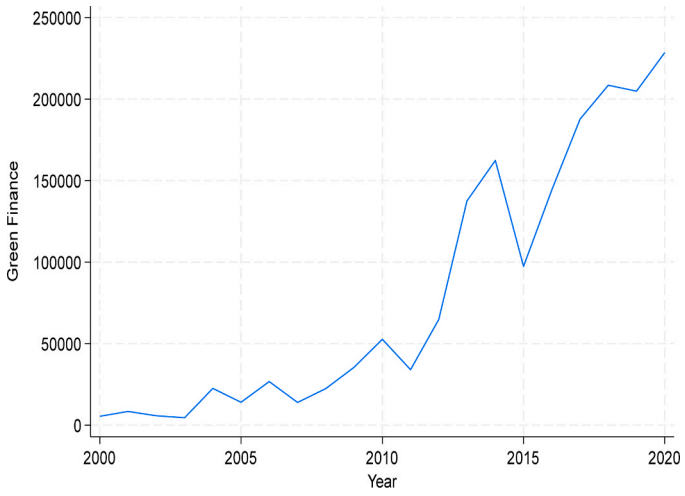

Fig. 2. Trend of green finance for 41 African countries.

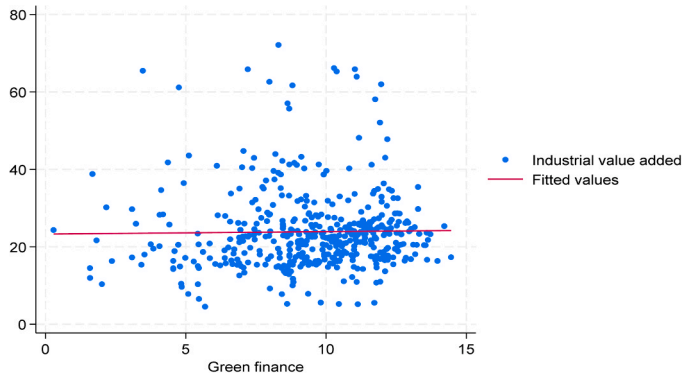

Fig. 3. Fitted scatted plot on the relationship between green finance and industrialisation.

comprises 41 African countries,[2] with data spanning from 2000 to 2020. Table 1 shows the descriptive statistics of the variables used in the model, while the corresponding correlation matrix is presented on Table 2.

Table 1 shows that the logarithm of the industrial value added varies between 3.24 and 72.15, while that of green finance varies between 0.286 and 17.711. The percentage of renewable energy in total energy consumption varies between, 0.06–98.34, with just about 31 % of renewable energy present in total energy consumption between the years 2000–2020. Table 2 shows that the explanatory variables have a very low correlation coefficient within themselves, as a result, there is very low risk of multicollinearity with our data. Given this observation, we proceed to estimate our model.

3.2. Estimation method

Initially, Eq. 1 is estimated using the fixed effect Driscoll and Kraay (1998) standard error procedure. This method proves robust when dealing with a large time dimension, as it can withstand extensive types of cross-sectional and temporal dependencies. Furthermore, the correlation analysis between the dependent variable (industrial value added) and its first period lag yields a correlation coefficient of 0.981, underscoring the significance role that initial levels of industrialization play in in explaining economic development (Barro and Sala-i-Martin, 1992; Barro, 2019). We therefore make the assumption that our sample's industrial growth outcomes are dynamic and can be specified as:

$$IND_{it} = \beta_0 + \beta_1 IND_{i(t-1)} + \beta_2 Green\_Fi_{it} + \beta_3 Green\_inn_{it} + \beta_j X_{it} + \upsilon_t + \gamma_i + \varepsilon_{it} \quad (4)$$

The literature has long recognized, since the works of Nickell (1981) and Anderson and Hsiao (1982), that employing Ordinary Least Squares (OLS) to estimate dynamic panel equations can lead to biased and inconsistent estimates. In response to this challenge, Arellano and Bond (1991) proposed the use of a Generalized Method of Moments (GMM) estimator as a more suitable alternative in such scenarios. According to Roodman (2009), the cross-sectional dimension (41) must be greater than the time dimension (21) for a GMM estimator to be utilised in a regression, which is the case with our data. When the instruments are weak, Blundell and Bond (1998) demonstrated via Monte Carlo simulations that the GMM estimator in the first differentiation will produce biased findings in finite samples. Two-step estimates of standard errors contain a large downward bias despite being asymptotically more accurate. Windmeijer (2005) created a finite-sample correction to the two-step covariance matrix to make up for this.

The issues of identification, simultaneity, and restrictions are likely problems with the GMM estimation. In this sense, all of our explanatory variables are handled as endogenous in accordance with current scholarship, with the suspicion that they are a source of endogeneity (Arellano and Bond, 1991; Arellano and Bover, 1995; Blundell and Bond, 1998; Roodman, 2009). Also, period fixed effects are used as instruments, and in order to limit instrument proliferation, the instruments are collapsed in line with Roodman (2009).

Table 1
Descriptive Statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
Industrial value added (log)	841	26.022	11.903	3.243	72.153
Green finance (log)	794	9.462	2.58	.286	14.711
Renewable energy	861	23.312	31.682	.06	98.34
Trade	800	62.459	26.498	9.955	163.619
Natural resource rents	861	11.505	9.953	.195	59.684
Foreign direct investment	861	3.864	7.692	−18.918	103.337
Foreign aid	861	7.931	8.76	−.188	92.141
Manufacturing value added (log)	783	8.806	1.115	5.268	12.4
Agricultural value added (log)	787	7.103	.986	5.434	9.875
Service value added (log)	780	8.379	.758	6.369	9.935

[2] Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Congo Dem. Rep., Congo Rep., Côte d'Ivoire, Egypt, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe.

4. Results and discussion

The baseline estimation using the Fixed effect Driscoll and Kraay (1998) estimator, the dynamic model estimate using the system GMM, the results of the robustness regression, and finally the indirect effect results are all covered in this section.

4.1. Direct effect results

The baseline results are presented in Table 3, and they show that green finance has an enhancing effect on industrialization in Africa. Similar positive effects are apparent for trade openness, natural resource rents, and foreign direct investment. Conversely, green innovations (renewable energy) and foreign aid present negative effects as expected.

The positive effect of green finance on industrialization corroborates the results of Tolliver et al. (2020) and Wang and Wang (2021). On its part, Green innovation (renewable energy) has a negative effect on industrialization in line with the findings of Zhang et al. (2020) and Xie et al. (2022) who discovered that engagements in green innovation tends to diminish firm value due to the high costs associated with such initiatives.

To further check the validity of our results, we use a dynamic model as described in Table 4.

Results in Table 4 validate the positive and negative effects of green finance and renewable energy, respectively, on industrialization. The results further show the absence of both first- and second-order autocorrelation in our model, with the instruments valid from Hansen's statistics. Also, the first period lag of industrialization is positive and significant, corroborating the results of Barro and Sala-i-Martin (1992), indicating that African economies will eventually catch up with the industrialized economies.

Looking at the control variables, trade openness enhances industrialization, this is consistent the study by Mignamissi and Nguekeng (2022) for Africa. Trade leads to technological spillover and an increase in economic productivity and competition. In the African context, export structures are predominantly dominated by primary industries. Trade openness has catalysed technological development, particularly within the tertiary industrial sector. This sector is witnessing a faster growth trajectory compared to the secondary sector on the continent. Also, natural resources enhance industrialization in Africa, corroborating the result of Nkemgha et al. (2022) for African economies. African countries are rich in natural resources, and rents from resource exploitation act as additional capital for the economy, which can be channelled for investment into other industrial sectors. Foreign aid is harmful for industrial development in line with the study by Nchofoung et al. (2022), who argued that aid has been looted by public authorities in Africa and that the share successfully used for development purposes on the continent has mostly been used towards non-productive sectors. Additionally, Gennaioli et al. (2012) argued that external financing sources limit the functioning and upgrading of manufacturing industries. This is mostly true for a region like Africa with many low-income countries which depend on external aid. Overreliance on these external sources could potentially precipitate a sudden economic downturn, especially

Table 2
Matrix of correlations.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) industrial value added	1.000									
(2) Green finance	−0.137*	1.000								
(3) Renewable energy	0.458***	0.138	1.000							
(4) trade	0.525	−0.130	0.281**	1.000						
(5) natural resource rents	0.625	−0.274***	−0.007	0.255	1.000					
(6) foreign direct investment	0.047***	0.040**	−0.101***	0.330	0.105*	1.000				
(7) foreign aid	−0.429*	−0.189	−0.432	−0.217	0.117	0.051	1.000			
(8) Manufacturing value added	0.744**	−0.019	0.634	0.367*	0.271	−0.056	−0.543	1.000		
(9) Agricultural value added	0.256**	0.117*	0.705	0.061	−0.066	−0.114	−0.593	0.518	1.000	
(10) Service value added	0.492*	0.107	0.809*	0.252**	0.007	−0.095*	−0.563	0.836	0.669	1.000

* p<0.1
** p<0.05,
*** p<0.01,

Table 3
Baseline regression.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	Dependent variable: Industrial value added						
Green finance	0.111*		0.265***	0.159**	0.283***	0.280***	0.206**
	(0.0589)		(0.0706)	(0.0693)	(0.0839)	(0.0811)	(0.0829)
Renewable energy		−0.143***	−0.212***	−0.136***	−0.0741**	−0.0744**	−0.0722**
		(0.0408)	(0.0331)	(0.0296)	(0.0281)	(0.0275)	(0.0258)
Trade				0.104***	0.0297**	0.0240*	0.0243
				(0.0188)	(0.0105)	(0.0133)	(0.0146)
Natural resource rents					0.446***	0.451***	0.485***
					(0.0467)	(0.0476)	(0.0447)
Foreign direct investment						0.0429	0.0313
						(0.0733)	(0.0769)
Foreign aid							−0.184***
							(0.0355)
Constant	24.91***	29.41***	28.63***	22.05***	19.01***	19.19***	20.80***
	(0.605)	(1.065)	(1.053)	(1.744)	(1.027)	(1.006)	(1.188)
Period FE	Yes	Yes	Yes	Yes	Yes	yes	yes
Observations	778	841	778	727	727	727	727
Number of countries	41	41	41	41	41	41	41
Fisher	3.572*	12.26**	26.08***	29.12***	42.61***	59.65***	88.14***

Standard errors in parentheses
* p<0.1
** p<0.05,
*** p<0.01,

during global shocks. This was evident during the COVID-19 pandemic, when international donors scaled back their aid commitments, with some even nearing a complete cessation of financial assistance to Africa. Such scenarios underscore the vulnerability of economies heavily reliant on external aid.

4.2. Robustness checks

To affirm the robustness of our findings, our regression is performed again, substituting the dependent variable with alternative measures of industrialization, including the value added across the agricultural, manufacturing, and service sectors. The results, as presented in Table 5, consistently show the positive effect of green finance and the negative effect of renewable energy on industrialization across these different specifications.

4.3. Indirect effect results

We further verify the hypothesis that green innovation is the mechanism through which green finance affects industrialization in Africa, as presented in Table 6. The results show that green finance interacts with renewable energy, producing positive net effects[3] across all industrial sectors except the agricultural sector, which exhibits a positive synergy effect. For the overall industrial sector and the manufacturing sector, renewable energy interacts with green finance, producing positive direct effects and negative indirect effects. However, the positive direct effect outweighs the negative indirect effect, producing overall positive net effects. For the service sector, the positive indirect effect outperforms the negative direct effect, producing a positive net effect.

The observed positive synergy effect within the agricultural sector can be attributed to how green finance investments in renewable energy temper the adverse impact of non-renewable energy sources on climate change, a factor that has traditionally impeded agricultural productivity. In the manufacturing sector, substantial energy investments are essential for efficient operations. However, the relatively higher cost of clean energy sources can deter the pursuit of green industrialization within this sector. Despite this, a significant portion of green finance is

[3] The net effect is calculated as specified in Eq. 3 and our interest centers is the sign of the total effect and not its coefficient in line with findings by Nkemgha et al. (2023).

Table 4
System GMM estimation results.

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Dependent variable: Industrial value added				
Industrial value added (−1)	0.707***	0.787***	0.975***	0.538***	0.915***
	(0.0273)	(0.105)	(0.0192)	(0.0251)	(0.0223)
Green finance	0.162*	0.319**	0.0444*	0.0145	
	(0.0941)	(0.155)	(0.0254)	(0.0260)	
Renewable energy	−0.0648**	−0.0278	−0.0443*		−0.0329*
	(0.0304)	(0.146)	(0.0229)		(0.0189)
Trade	0.0222*	0.00695			
	(0.0130)	(0.0368)			
Natural resources rents	0.205***	0.301***			
	(0.0233)	(0.0878)			
Foreign direct investment	0.227***	0.0771			
	(0.0283)	(0.0644)			
Foreign aid	−0.00581	−0.220*			
	(0.0471)	(0.130)			
Constant	3.263**	0.367	1.002	11.18***	2.834***
	(1.282)	(5.189)	(0.640)	(0.908)	(0.801)
Time Fixed effect	No	Yes	Yes	Yes	Yes
Observations	699	699	748	748	800
Number of countries	41	41	41	41	41
Prop>AR1	0.000138	0.000255	0.000367	0.00111	0.000588
Prop>AR2	0.133	0.213	0.120	0.132	0.153
Instruments	34	40	29	26	24
Prop>Hansen	0.162	0.681	0.299	0.222	0.120
Fisher	308.8***	675.4***	1098***	251.4***	902.5***

Standard errors in parentheses
* p<0.1
** p<0.05,
*** p<0.01,

directed towards the renewable energy sector and other green industrial products. The effective utilization of these products necessitates manufacturing, which explains why the direct effect is outpaced by the indirect effect.

4.4. Further discussion of results

In essence, green finance can enhance industrialization through several mechanisms: the development of new financial products, financing new industries and technologies, reducing investment risk, and the efficiency of eco-friendly industries. Braguinsky et al. (2021) argue that product innovation is a key to firms' growth as a result of product diversification. Besides, financing new industries means financial industries themselves are developed in the process, which makes it possible to leverage and redirect public funds through government bonds, public-private partnerships, and development banks by expanding the financial sector. The financial industry is in charge of developing mechanisms such as payment systems as well as capabilities such as credit assessment and risk analysis. These public mechanisms will be unable to function as planned unless they are supported by a stable financial system (Bell and Rousseau, 2001; Gennaioli et al., 2012). Neal (1994) and Laeven and Levine (2011) emphasized the connection between finance and industrial development and cited the sluggish growth of the stock market and banks as the main source of slow industrialization. In this context, climate finance could potentially augment the financial resources available for industrial development, thereby enhancing the existing capital stock available for industrial investment and growth.

Table 5
Robustness checks.

	(1)	(2)	(3)
	Dependent variable		
VARIABLES	Manufacturing value added	Agricultural value added	Service Value added
Manufacturing valued added (−1)	0.674***		
	(0.0505)		
Green finance	0.00715***	0.00179**	0.00138*
	(0.00138)	(0.000818)	(0.000796)
Renewable energy	−0.00376**	−0.000159	−0.00104
	(0.00160)	(0.000715)	(0.000718)
Agricultural valued added (−1)		0.978***	
		(0.0192)	
Service Value added (−1)			0.596***
			(0.0286)
Constant	7.409***	0.238*	3.410***
	(0.459)	(0.130)	(0.223)
Control variables	Yes	Yes	yes
Time Fixed effect	Yes	Yes	yes
Observations	650	653	647
Number of countries	41	41	41
Prop>AR1	0.065	3.92e−05	0.0127
Prop>AR2	0.431	0.737	0.806
Instruments	33	33	33
Prop>Hansen	0.208	0.228	0.203
Fisher	49.09***	8622***	171.9***

Standard errors in parentheses
* p<0.1
** p<0.05,
*** p<0.01,

The study highlights a negative effect of green innovation, proxied through renewable energy on industrialisation. Several factors can explain this negative relationship, moving from high costs of initial investment, human capital development required for its operation, limited infrastructures and intermittency of renewable energy sources. Firstly, Africa is a continent grappling with significant underdevelopment in terms of human capital and a precarious poverty rate. Given the relatively higher cost of clean energy in Africa, the negative correlation between green innovation and industrialization becomes even more pronounced. Compared to unclean energy, renewable energy use will reduce industrialization due to increase in the cost of production. Le Roux (2016) echoes this sentiment, emphasizing the high cost of renewable energy and its consequent unaffordability for the typical African citizen. Secondly, operating renewable energy technologies requires skilled labour, which is still underdeveloped in Africa, making the effective use of renewable energy technologies for industrial purposes inefficient. This is in line with Ukoba et al. (2023) who argued that before introducing large-scale renewable energy technologies and facilities in Africa, there needs to be a focus on advancing education and fostering small-scale innovation, particularly within rural communities. Their argument hinges on the fact that most renewable energy sources are prohibitively expensive for the average African. Thirdly, the cost issue is further exacerbated by Africa's limited manufacturing capacity. Poor infrastructure especially in rural Africa limits access to renewable resources. Lack of proper roads, connectivity or transmission lines to the main grid can hinder the deployment of renewable energy technologies in such areas, or limit the integration of renewable energy sources into the grid. This deprives the local communities from easily engaging in green industrial productivity.

5. Conclusion and policy implications

The structural transition of African economies towards industrial development has consistently lagged behind that of other emerging

Table 6
Indirect effect.

	(1) Dependent variable:	(2)	(3)	(4)
VARIABLES	Industrial value added	Manufacturing valued added	Agricultural value added	Service value added
Industrial value added (−1)	0.645***			
	(0.0276)			
Green finance	0.102***	0.00555***	0.00885***	−0.00180**
	(0.0264)	(0.00135)	(0.00149)	(0.000758)
Renewable energy (A)	0.0447**	−0.00185**	0.000826	−0.00150**
	(0.0179)	(0.000725)	(0.00144)	(0.000696)
Trade	0.0116	0.00119***	−0.000166	−0.000167
	(0.0134)	(0.000351)	(0.000454)	(0.000222)
Natural resource rents	0.292***	−0.00100	−0.00251***	−0.000161
	(0.0278)	(0.000937)	(0.000828)	(0.000402)
Foreign direct investment	0.0857***	−0.000427	−0.000259	−0.000519
	(0.0301)	(0.000523)	(0.000572)	(0.000357)
Foreign aid	−0.0675***	0.000418	−0.00328***	9.86e−05
	(0.0138)	(0.000842)	(0.00106)	(0.000316)
Green finance*A	−0.00355***	−6.97e−05*	0.000240***	0.000123***
	(0.000892)	(3.75e−05)	(3.66e−05)	(1.37e−05)
Manufacturing valued added (−1)		0.783***		
		(0.0581)		
Agricultural value added (- 1)			0.536***	
			(0.0256)	
Service value added (−1)				0.662***
				(0.0164)
Constant	4.409***	1.897***	3.195***	2.887***
	(1.546)	(0.509)	(0.202)	(0.129)
Time Fixed Effect	Yes	Yes	Yes	Yes
Net effect	0.01924	0.00393	s.e	0.001067
Observations	699	650	653	647
Number of countries	41	41	41	41
Prop>AR1	0.000151	0.0225	5.88e−05	0.00898
Prop>AR2	0.129	0.549	0.720	0.985
Instruments	36	35	35	35
Prop>Hansen	0.232	0.280	0.500	0.244
Fisher	336.2***	130.2***	301.4***	1987***

Standard errors in parentheses
* p<0.1
** p<0.05,
*** p<0.01,

economies and developed nations. To bridge these gaps, African economies must enhance their competitiveness to attract foreign direct investments, which can facilitate structural transformation and reduce unemployment. However, Africa faces a unique challenge. While advanced economies have developed through industrialization, often accompanied by significant greenhouse gas emissions, African economies are embarking on their industrialization journey at a time when the world is grappling with environmental degradation and implementing stringent environmental regulations.

Green industrialization, therefore, emerges as a critical indicator of a nation's ability to manage environmental issues, improve environmental performance, and promote sustainable industrialization. Consequently, the question of how to foster green industrial productivity is of paramount importance in the economic development literature, attracting significant interest from academics and policymakers (Lee and Lee, 2022). Green finance can enhance green innovations, leading to economic growth and productivity, especially as countries transition from fossil fuels to renewable energy, thereby improving energy efficiency and green industrial productivity.

This study aimed to: (i) examine the effect of green finance on industrialization in Africa, and (ii) investigate the moderating effect of green innovation in the green finance-industrialization nexus in Africa. Due to data limitations, we collected data for 41 African countries for the period 2000–2020 and implemented the fixed effect Driscoll and Kraay (1998) and the system GMM regression methodologies.

Our findings indicate that green finance bolsters industrialization in Africa, while green innovations through renewable energy have a negative impact on industrialization. Climate finance could supplement the sources of finance for industrial development by augmenting the existing capital stock available for industrial investment and development. It is important to note that the effective use of renewable energy technologies for industrial purposes is hampered by the underdeveloped skilled labour force in Africa. Our results also reveal that green finance interacts with renewable energy to produce positive net effects on industrialization, with similar outcomes evident across the manufacturing and service sectors. Notably, positive synergy effects were observed in the agricultural sector.

These findings yield several policy implications. Firstly, to reap the benefits of sustainable industrialization, Africa needs reforms at the levels of multilateral development agencies, development banks, and national governments in terms of climate financing. As stated by the president of the African Development Bank at the June 2023 summit on the Global Financial Architecture, Africa currently faces a climate financing gap of USD 242.4 billion per year, which is expected to persist until 2030. This gap has hindered the goal of sustainable industrialization on the continent.

To reverse this trend, more financial resources need to be channelled towards climate finance. This can be achieved by mobilizing more private sector donors, while national governments should strive to mobilize other sources of climate finance. Environmental taxation is one of the most efficient ways for governments to combat climate change, by mobilizing finance through climate actions. Furthermore, for the benefits of green innovation and green industrialization to be fully realized in Africa, governments must address the needs of local communities, which are still significantly lacking in innovative facilities and structures, and as a result, rely heavily on non-renewable energies for their needs.

To maximise the effects of green finance and green innovation on industrialization in Africa, a multi-faceted approach is required. A key focus should be on education and capacity building, particularly within rural communities, to foster small-scale innovation and prepare for the introduction of large-scale renewable energy technologies. Subsidising these technologies and investing in research and development can make them more affordable and efficient, addressing the current cost and manufacturing capacity challenges. Leveraging green finance for industrial development is crucial, requiring robust regulatory frameworks and dedicated management entities. A skilled workforce is also essential, necessitating investment in vocational training and higher education programs that focus on green technologies.

Furthermore, environmental taxation can serve as a powerful tool to mobilize finance for climate actions, while promoting local manufacturing of renewable energy technologies can reduce costs and create jobs. Strengthening regional cooperation can facilitate the sharing of best practices, pooling of resources, and coordinated efforts towards green industrialization. This could involve establishing regional centres of excellence for renewable energy research and development or forming regional alliances to negotiate better terms for green finance. These strategic actions, if effectively implemented, could significantly enhance Africa's journey towards sustainable industrialization.

Future studies on the subject could incorporate other variables such as government policies, international trade relations, and economic stability as modulating variables, which could significantly influence the effectiveness of green finance. Including these factors might provide a more comprehensive view of the challenges and opportunities in enhancing green industrial productivity. Future studies could also consider country specific studies and different time spans, which could help in understanding the evolving trends and in making more robust policy decisions that support sustainable industrialisation over time.

CRediT authorship contribution statement

Ofeh Marilyn Edoh: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Data curation, Conceptualization. **Nara Monkam:** Writing – review & editing, Writing – original draft, Validation, Supervision, Conceptualization. **Tii Nchofoung:** Writing – review & editing, Writing – original draft, Validation, Software, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare no conflict of interest.

Data availability

Data will be made available on request.

Acknowledgements

This paper was presented at the 2023 African Economic Conference in Addis Ababa. We thank the conference participants for their observations and suggestions that helped to enhance the quality of this manuscript. We further thank the anonymous reviews for their comments and suggestions.

References

Acheampong, T., Tyce, M., 2024. Navigating the energy transition and industrial decarbonisation: Ghana's latest bid to develop an integrated bauxite-to-aluminium industry. Energy Res. Soc. Sci. *107*, 103337.

Adu-Yeboah, S.S., Jiang, Y., Frempong, M.F., Hossin, M.A., Amoako, R., 2022. Corporate sustainability and firm performance in small and medium enterprises in Ghana: mediating role of green innovation. J. Psychol. Afr. *32* (4), 311–318.

AfDB (2023). Africa: Climate finance facing global macroeconomic challenges; time for private sector support. Available at: ⟨https://www.afdb.org/en/news-and-events/africa-climate-finance-facing-global-macroeconomic-challenges-time-private-sector-support-60566⟩.

Afum, E., Osei-Ahenkan, Y.V., Agyabeng-Mensah, Y., Owusu, A.J., Kusi, Y.L., Ankomah, J., 2020. Green manufacturing practices and sustainable performance among Ghanaian manufacturing SMEs: the explanatory link of green supply chain integration. *Manag. Environ. Qual.*: Int. J. © Emerald Publ. Ltd. 1477–7835. https://doi.org/10.1108/MEQ-01-2020-0019.

Anderson, T.W., Hsiao, C., 1982. Formulation and estimation of dynamic models using panel data. J. Econ. *18* (1), 47–82.

Andries, P., Stephan, U., 2019. Environmental innovation and firm performance: how firm size and motives matter. *Sustainability* 2019 11, 3585 doi:10.3390/su11133585 www.mdpi.com/journal/sustainability.

Appiah, M., Gyamfi, B.A., Adebayo, T.S., Bekun, F.V., 2023. Do financial development, foreign direct investment, and economic growth enhance industrial development? Fresh evidence from Sub-Sahara African countries. Port. Econ. J. 22 (2), 203–227.

Arellano, M., Bond, S., 1991. Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. Rev. Econ. Stud. *58* (2), 277–297.

Arellano, M., Bover, O., 1995. Another look at the instrumental variable estimation of error-components models. J. Econ. *68* (1), 29–51.

Asadi, S., Pourhashemi, S.O., Nilashi, M., Abdullah, R., Samad, S., Yadegaridehkordi, E., Aljojo, N., Razali, N.S., 2020. Investigating influence of green innovation on sustainability performance: a case on Malaysian hotel industry. J. Clean. Prod. 2020 https://doi.org/10.1016/j.jclepro.2020.120860.

Bagehot, W. (1873) Lombard Street. Richard D. Irwin, Homewood, IL (1962 Edition).

Bankole, A.S., Oladapo, M.A., 2019. The role of regional trade integration and governance in structural transformation: evidence from ECOWAS trade bloc. Gov. Struct. Transform. Afr. 277–313.

Barro, R.J., 2019. Economic Growth, Convergence, and Government Policies. In *Economic policy, financial markets, and economic growth*. Routledge, pp. 9–28.

Barro, R.J., Sala-i-Martin, X., 1992. Convergence. J. Political Econ. *100* (2), 223–251.

Beck, T., Levine, R., Loayza, N., 2000. Finance and the sources of growth. J. Financ. Econ. 58, 261–300. https://doi.org/10.1016/S0304-405X(00)00072-6.

Bell, C., Rousseau, P.L., 2001. Post-independence India: A case of finance-led industrialization? J. Dev. Econ. *65* (1), 153–175.

Bencivenga, V.R., Smith, B.D., 1991. Financial intermediation and endogenous growth. Rev. Econ. Stud. 58, 195–209. https://doi.org/10.2307/2297964.

Blundell, R., Bond, S., 1998. Initial conditions and moment restrictions in dynamic panel data models. J. Econ. *87* (1), 115–143.

Braguinsky, S., Ohyama, A., Okazaki, T., Syverson, C., 2021. Product innovation, product diversification, and firm growth: Evidence from japan's early industrialization. Am. Econ. Rev. *111* (12), 3795–3826.

Brahmbhatt, M., Haddaoui, C., Page, J., 2017. Green industrialisation and entrepreneurship in Africa. Contrib. Pap. Afr. Econ. Outlook 1–60.

Chen, H., Liu, C., Xie, F., Zhang, T., Guan, F., 2019. Green credit and company R&D level: Empirical research based on threshold effects. *Sustainability* 2019 11, 1918.

Choi, S.M., Kim, H., Ma, X., 2021. Trade, structural transformation and growth. World Econ. *44* (6), 1770–1794.

Climate Policy Initiative (2022). The State of Climate Finance in Africa: Climate Finance Needs of African Countries. Available at: ⟨https://www.climatepolicyinitiative.org/wp-content/uploads/2022/06/Climate-Finance-Needs-of-African-Countries-1.pdf⟩.

Da Rin, M., Hellmann, T., 2002. Banks as catalysts for industrialization. J. Financ. Inter. 11, 366–397. https://doi.org/10.1006/jfin.2002.0346.

Dogaru, L., 2020. Eco-innovation and the contribution of companies to the sustainable development. Procedia Manuf. 46, 294–298. https://doi.org/10.1016/j.promfg.2020.03.043.

Dong, Z., Xu, H., Zhang, Z., Lyu, Y., Lu, Y., Duan, H., 2022. Whether green finance improves green innovation of listed companies—evidence from China. *Int. J. Environ. Res. Public Health* 2022 19, 10882. https://doi.org/10.3390/ijerph191710882.

Doumbe, D.E., Zhongxiu, Z., 2017. Financial sector development and industrialization in Cameroon (1970-2014). ISSN 2155-7950, USA January 2017 J. Bus. Econ. Volume 8 (No. 1), 105–114. https://doi.org/10.15341/jbe(2155-7950)/01.08.2017/012.

Driscoll, J.C., Kraay, A.C., 1998. Consistent covariance matrix estimation with spatially dependent panel data. Rev. Econ. Stat. *80* (4), 549–560.

Fang, Y., Shao, Z., 2022. Whether green finance can effectively moderate the green technology innovation effect of heterogeneous environmental regulation. Int. J. Environ. Res. Public Health *19* (6), 3646.

Fotio, H.K., Karim, A., 2024. Unravelling the impact of political risk on industrialization: Evidence from Africa. Int. Econ., 100528

Gennaioli, N., Shleifer, A., Vishny, R., 2012. Neglected risks, financial innovation and financial fragility. J. Financ. Econ. 104, 452–468. https://doi.org/10.1016/j.jfineco.2011.05.005.

Greenwood, J., Jovanovic, B., 1990. Financial development, growth, and the distribution of income. J. Political Econ. 98, 1076–1107. https://doi.org/10.1086/261720.

Gui-Diby, S.L., Renard, M.F., 2015. Foreign direct investment inflows and the industrialization of African countries. World Dev. *74*, 43–57.

Habanabakize, T., 2020. The effect of economic growth and exchange rate on imports and exports: the South African post-2008 financial crisis case. Int. J. Econ. Financ. Stud. 12 (1), 223–238. https://doi.org/10.34109/ijefs.202012114.

He, L., Wu, C., Zhong, Z., Zhu, J., 2018. Green credit, internal and external policies and commercial banks' competitiveness—An empirical study based on nine listed commercial banks. Financ. Econ. Res. 33, 91–103, 2018.

Holmstrom, B., Tirole, J., 1997. Financial Intermediation, Loanable Funds, and the Real Sector. Q. J. Econ. 112, 663–691. https://doi.org/10.1162/003355397555316.

Huang, Y., Chen, C., Lei, L., Zhang, Y., 2022. Impacts of green finance on green innovation: a spatial and nonlinear perspective, 10 September 2022 J. Clean. Prod. Volume 365, 132548. https://doi.org/10.1016/j.jclepro.2022.132548.
Hyomnyoktan, H.K., 2012. Low. Carbon Green. Growth Roadmap Asia Pac.: Turn. Resour. constraints Clim. Crisis into Econ. Growth Oppor. ⟨www.semanticscholar.org⟩.
King, R.G., Levine, R., 1993. Finance and Growth-Schumpeter Might Be Right. Q. J. Econ. 108, 717–737. https://doi.org/10.2307/2118406.
Kothakapa, G., Bhupatiraju, S., Sirohi, A.R., 2020. Revisiting the link between financial development and industrialization: evidence from low and middle income countries. Ann. Financ. https://doi.org/10.1007/s10436-020-00376-y.
Laeven, L., Levine, R.S.M., 2011. Financial and Technological Innovation: Implications for Growth. Brown University Press, Rhode Island.
Lall, S., 2004. Industrial success and failure in a globalizing world. Int. J. Technol. Manag. Sustain. Dev. *3* (3), 189–214.
Le Roux, W.G., 2016. Optimum tilt and azimuth angles for fixed solar collectors in South Africa using measured data. Renew. Energy 96, 603–612.
Lee, C.C., Lee, C.C., 2022. How does green finance affect green total factor productivity? Evidence from China. Energy Econ. *107*, 105863.
Lee, C.-H., Wu, K.-J., Tseng, M.-L., 2018. Resource management practice through eco-innovation toward sustainable development using qualitative information and quantitative data. J. Clean. Prod. 202, 120–129. https://doi.org/10.1016/j.jclepro.2018.08.058.
Li, Z., Liao, G., Wang, Z., Huang, Z., 2018. Green loan and subsidy for promoting clean production innovation. J. Clean. Prod. 187, 421–431.
Liang, B., Zhang, J., 2018. Economic Opening, Financial Development and Manufacturing Structure Optimization. *J. Huazhong Univ. Sci. Technol.* (Soc. Sci. Ed.) 4, 89–101.
Lin, D., Chen, J., Qiu, G., 2018. Research on green financial support factors for China's environmental protection industry—Empirical analysis based on CSI environmental protection industry 50 index constituents. J. Ind. Technol. Econ. 37, 129–135, 2018.
Liu, J.Y., Xia, Y., Fan, Y., Lin, S.M., Wu, J., 2017. Assessment of a green credit policy aimed at energy-intensive industries in China based on a financial CGE model. J. Clean. Prod. 163, 293–302.
Liu, X., Wang, E., Cai, D., 2019. Green credit policy, property rights and debt financing: quasi-natural experimental evidence from China. Financ. Res. Lett. 29, 129–135.
Ma, L., Iqbal, N., Bouri, E., Zhang, Y., 2023. How good is green finance for green innovation? Evidence from the Chinese high-carbon sector. Resour. Policy *85*, 104047.
Mamba, E., Gniniguè, M., Ali, E., 2020. Effect of foreign direct investment on structural transformation in West African Economic and Monetary Union (WAEMU) countries. Cogent Econ. Financ. *8* (1), 1783910.
McCormick, D., 1999. African enterprise clusters and industrialization: theory and reality. World Dev. *27* (9), 1531–1551.
McKinnon, R.I., 1973. Money and Capital in Economic development. Brookings Institution, Washington, D. C.
Mignamissi, D., Nguekeng, B., 2022. Trade openness-industrialization nexus revisited in Africa. Econ. Change Restruct. *55* (4), 2547–2575.
Moran, T., 2012. Foreign direct investment. The Wiley-Blackwell. Encycl. Glob. 4, 1–9.
Morris, M., Fessehaie, J., 2014. The industrialisation challenge for Africa: towards a commodities based industrialisation path. J. Afr. Trade *1* (1), 25–36.
Murty, M.N., Kumar, S., 2003. Win–win opportunities and environmental regulation: testing of Porter hypothesis for Indian manufacturing industries. J. Environ. Manag. 67, 139–144, 2003.
Nchofoung, T.N., Kengdo, A.A.N., Moumie, E.M., Fonsoh, T.T., 2022. Teach me to fish instead of giving me fish: Foreign development aid and employment in Africa. World Dev. Sustain. *1*, 100032.
Neal, L., 1994. The Rise of Financial Capitalism. Cambridge Books.
Neusser, K., Kugler, M., 1998. Manufacturing Growth and Financial Development: Evidence from OECD Countries. Rev. Econ. Stat. 80, 638–646. https://doi.org/10.1162/003465398557726.
Nickell, S., 1981. Biases in dynamic models with fixed effects. Économ.: J. Econom. Soc. 1417–1426.
Nkemgha, G.Z., Nchofoung, T.N., Sundjo, F., 2023. Financial development and human capital thresholds for the infrastructure development-industrialization nexus in Africa. Cities *132*, 104108.
Nkemgha, G., Engone Mve, S., Balouki Mikala, H., Tékam, H., 2022. Linking natural resource dependence and industrialization in sub-Saharan African countries. Int. Rev. Appl. Econ. *36* (2), 245–263.
Nkoa, B.E.O., Fonguen-Kong-Ngoh, A.B., 2024. Industrialisation in Africa: the role of energy transition. Energy Policy *193*, 114271.
Noh, H.J., 2010. Financial strategy to accelerate innovation for green growth. Korea Cap. Mark. Inst. 2–3.
Rajan, R., Zingales, L., 1998. Financial dependence and growth. Am. Econ. Rev. 88 (3), 559–589.
Rajan, R., 2006. Has finance made the world riskier? Eur. Financ. Manag. 12, 499–533. https://doi.org/10.1111/j.1468-036X.2006.00330.x.
Roodman, D., 2009. How to do xtabond2: an introduction to difference and system GMM in Stata. stata J. *9* (1), 86–136.
Ross, L., 2005. Finance and Growth: Theory and Evidence. In: Aghion, P. and Durlauf, S., Eds. In: Handbook of Economic Growth, Vol. 1. Elsevier, Amsterdam, pp. 865–934. https://doi.org/10.1016/S1574-0684(05)01012-9.
Sadiq, M., Le-Dinh, T., Tran, T.K., Chien, F., Phan, H.T.T., Huy, P.Q., 2023. The role of green finance, eco-innovation, and creativity in the sustainable development goals of ASEAN countries. Econ. Res. Istraživanja 36 (2), 2175010. https://doi.org/10.1080/1331677X.2023.2175010.
Saha, T., Sinha, A., Abbas, S., 2022. Green financing of eco-innovations: is the gender inclusivity taken care of? Econ. Res. -Èkon. Istraživanja 35 (1), 5514–5535. https://doi.org/10.1080/1331677X.2022.2029715.
Sarkar, A.N., 2013. Promoting eco-innovations to leverage sustainable development of eco-industry and green growth. *Eur. J. Sustain. Dev.* (2013) 2 (1), 171–224. ISSN: 2239-5938 http://ecsdev.org.
Schumpeter, J. (1912). Theorie der Wirtschaftlichen, Entwicklung [The theory of Economic Development], Leipzag: Dunker and Humblot, 1912; translated by Redevers Opie (Cambridge, Massachusetts: Harvard University Press, 1934).
Shaw, E., 1973. Financial Deepening in Economic growth. Oxford University Press, New York.
Sohag, K., Chukavina, K., Samargandi, N., 2021. Renewable energy and total factor productivity in OECD member countries. J. Clean. Prod. *296*, 126499.
Takalo, S.K., Tooranloo, H.S., 2021. Green innovation: a systematic literature review. J. Clean. Prod. *279*, 122474.
Tchapchet Tchouto, J.E., Njoya, L., Nchofoung, T., Ketu, I., 2022. Investigating the effects of environmental tax regulations on industrialization in African countries. Environ., Dev. Sustain. 1–30.
Tolliver, C., Keeley, A., Managi, S., 2020. Policy targets behind green bonds for renewable energy: do climate commitments matter? Technol. Forecast. Soc. Change *157*, 120051.
Ukoba, K., Kunene, T.J., Harmse, P., Lukong, V.T., Chien Jen, T., 2023. The role of renewable energy sources and industry 4.0 focus for Africa: a review. Appl. Sci. 13, 1074. https://doi.org/10.3390/app13021074.
United Nations Environment Programme Finance Initiative, (2007). Green Financial Products and Services: Current Trends and Future Opportunities in North America (Geneva, 2007). Available from www.unepfi.org/fileadmin/documents/greenprods_01.pdf (Accessed 16 July 2023).
Vernon, R., 1966. The Product Life Cycle. Q. J. Econ. 80, 190–207. https://doi.org/10.2307/1880689.
Wang, K., Tsai, S., Du, X., Bi, D., 2019. Internet finance, green finance, and sustainability. Sustain. -Basel 11, 3856.
Wang, X., Wang, Q., 2021. Research on the impact of green finance on the upgrading of China's regional industrial structure from the perspective of sustainable development. December 2021 Resour. Policy Volume 74, 102436. https://doi.org/10.1016/j.resourpol.2021.102436.
Windmeijer, F., 2005. A finite sample correction for the variance of linear efficient two-step GMM estimators. J. Econ. *126* (1), 25–51.
Wirajing, M.A.K., Nchofoung, T.N., Etape, F.M., 2023. Revisiting the human capital–economic growth nexus in Africa. SN Bus. Econ. *3* (7), 1–29.
Wu, S., Wu, L., Lv, H., 2019. Research on the impact mechanism of green credit on corporate eco-innovation. Soft Sci. 33, 53–56, 2019.
Xie, Z., Wang, J., Zhao, G., 2022. Impact of green innovation on firm value: evidence from listed companies in China's heavy pollution industries. Front. Energy Res. 9, 806926 https://doi.org/10.3389/fenrg.2021.806926.
Xu, X., Li, J., 2020. Asymmetric impacts of the policy and development of green credit on the debt financing cost and maturity of different types of enterprises in China. J. Clean. Prod. 264, 121574.
Yan, Z., Zou, B., Du, K., Li, K., 2020. Do renewable energy technology innovations promote China's green productivity growth? Fresh evidence from partially linear functional-coefficient models. Energy Econ. *90*, 104842.
Yang, M.G., Hong, P., Modi, S.B., 2011. Impact of lean manufacturing and environmental management on business performance: an empirical study of manufacturing firms. Int. J. Prod. Econ. 129, 251–261, 2011.
Yang, S., Jahanger, A., Usman, M., 2024. Examining the influence of green innovations in industrial enterprises on China's smart city development. Technol. Forecast. Soc. Change *199*, 123031.
Yi, X., Liu, F., 2015. Financial development, technological innovation and industrial structure transition: analysis framework of multi-sectoral endogenous growth theory. Manag. World 10, 24–39.
Yu, C.H., Wu, X., Zhang, D., Chen, S., Zhao, J., 2021. Demand for green finance: resolving financing constraints on green innovation in China. Energy Policy 153 (2021)), 112255. https://doi.org/10.1016/j.enpol.2021.112255.
Yu, H., Zhao, J., 2024. Financial sector development and industrialization: lessons and prospects for Ethiopia. China Econ. J. *17* (2), 300–321.
Zhang, B., Yang, Y., Bi, J., 2011. Tracking the implementation of green credit policy in China: top-down perspective and bottom-up reform. J. Environ. Manag. 92 (4), 1321–1327.
Zhang, Y., Wei, J., Zhu, Y., George-Ufot, G., 2020. Untangling the relationship between corporate environmental performance and corporate financial performance: The double-edged moderating effects of environmental uncertainty. J. Clean. Prod. 263, 121584 https://doi.org/10.1016/j.jclepro.2020.121584.
Zhao, S.X.B., 2003. Spatial restructuring of financial centers in Mainland China and Hong Kong: a geography of finance perspective. Urban Aff. Rev. 38, 535–571. https://doi.org/10.1177/1078087402250364.
Zhou, X., Tang, X., Zhang, R., 2020. Impact of green finance on economic development and environmental quality: a study based on provincial panel data from China. Environ. Sci. Pollut. Res. https://doi.org/10.1007/s11356-020-08383-2.