ESSAYS ON INDUSTRIALISATION, INNOVATION, AND SUSTAINABLE DEVELOPMENT IN SAFRICA

By

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ABSTRACT

Sustainable development has attracted discourses from academics and policymakers for some time now. The United Nations has instituted seventeen (17) goals to promote sustainable development, and these goals have been decomposed into 169 sub-goals to be achieved under the 2030 agenda for sustainable development. The goals are essentially grouped into economic, ecological, and social goals. Following this, the African Union (AU) has embraced the SDGs by motivating member countries to come up with programmes that are directly related to the goals. However, whereas a lot of discussions have occurred, much of the talk has been oblivious to empirical data analysis. The AU has realised the importance of industrialisation in spearheading the bridging of the poverty gap in Africa. Industrialisation is seen as the panacea for job creation, prosperity, and wealth creation. Industrialisation induces innovation by introducing new equipment, new production techniques, increasing capacities and spreading improvements across sectors of the economy. However, since the 1990s when the policymakers started talking about industrialisation, not much has been achieved on that score. Common to industrialisation and economic development is financial development. The level of financial development can stimulate positive or negative externalities on sustainable development. The drive towards the promotion of sustainable development in Africa by the African Union and other parastatal bodies, especially the UN, motivated this thesis to examine the convoluted connections between financial development, technological innovation, industrialisation, and sustainable development in Africa in three related studies.

The first study analysed the complementary role of financial development in the relationship between industrialisation and sustainable economic development in Africa. The system dynamic Generalised Method of Moments (GMM) technique was employed with a dataset covering 2010-2019 for 48 African countries. Under this analysis, this thesis found that

industrialisation is a significant positive driver of economic development. The role of financial development in the economic development agenda among African economies was also emphasised by the results. The outcome of the moderation analysis suggested that the level of financial development significantly complements industrialisation towards improving economic growth. Thus, a more developed financial sector is potent in building an industrial economy which facilitates value addition in the manufacturing sector.

The second empirical analysis examined the interactive role of technological innovation in the relationship between financial development and sustainable development in Africa after controlling for the influence of ICT infrastructure, trade openness, inflation, and population size. The results indicated significant effects of financial development on sustainable development as well as significant relationships between technological innovation and sustainable development. In terms of social sustainability, the findings suggested that financial development tends to reduce social sustainability among African economies such that increasing the quantum of broad money and increasing the amount of domestic credit to the private sector either by households or by banks would not necessarily improve the level of social development in Africa. Concerning economic sustainability, the findings divulged a positive relationship between financial development and the economic dimension of sustainable development (i.e., economic sustainability), suggesting that African countries could leverage financial development, particularly by encouraging the supply of credit to the private sector either by households or banks to enable industries to improve their operations. As regards ecological/environmental sustainability, findings from this empirical analysis indicated mixed relationships between financial development and ecological sustainability. Thus, depending on the proxy, financial development either increases or decreases energy consumption and carbon dioxide emissions in Africa. Meanwhile, the effect of technological innovation on sustainable development was positive for all dimensions of sustainability but had varied implications. This emphasised the need to analyse how sustainable development is affected by the interaction between financial development and technological innovation. The findings from the moderation effect divulged that more technological innovation lessens **SDI** but increases GDP growth per capita, carbon dioxide emissions, and energy consumption.

The last empirical chapter revealed investigated the interactive role of technological innovation in the relationship between financial development and sustainable development in Africa. The findings from such an analysis highlighted the complementary role of technological innovation in the relationship between financial development and sustainable development in Africa. In an era of an increasing need for sustainability, these findings stressed the need to further ascertain possible convolutions between sustainable development, technological innovation, and industrialisation among African economies. The impetus for this analysis partly stemmed from the fact that industrialisation has some externalities it poses to economies. Therefore, there was a need to provide empirical evidence that helps understand the true role of industrialisation in the relationship between technological innovation and sustainable development to foster policy formulation.

Upon analysing the mediating effect of industrialisation on the relationship between technological innovation and the three dimensions of sustainable development (social, economic, and ecological/environmental sustainability) in Africa, positive relationships between technological innovation and all dimensions of sustainable development, emphasise the need to analyse how sustainable development is indirectly affected by industrialisation. The findings provide evidence of a partial contribution from industrialisation toward the impact of technological innovation on sustainable development. As a result, this thesis

concluded that the level of industrialisation complementarily mediates the relationship between technological innovation and sustainable development in Africa.

The study recommends that economies within Africa should focus on industrialisation and financial development to achieve sustainable development. Policymakers should prioritise the development of a resilient financial sector to complement industrialisation, while promoting technological innovation to support all dimensions of sustainability. Also, a balanced approach to sustainable development should be promoted by managing the trade-offs between sustainability dimensions. Finally an effectively coordinated set of policies should be put in place to reduce negative externalities resulting from industrialisation, and policymakers should carefully select implementation policies and channels.

Keywords: Africa, Carbon dioxide emissions; Financial development; General method of moments; Industrialisation; Sustainable development; Technological innovation

DECLARATION

I, Patrick Kwashie Akorsu, hereby declare that this research report is my own work except as indicated in the references and acknowledgements. It is submitted in fulfilment of the requirements for the award of Doctor of Philosophy at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

Patrick Kwashie Akorsu

Signed at: **Wits Business School, Johannesburg, South Africa.**

On the 23rd day of November 2022.

DEDICATION

To my wife Angela and children Nuvava and Nubuke.

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LIST OF ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
AU	African Union
BM	Broad Money
CO2	Carbon Dioxide Emissions
ENGCO	Energy Consumption
GDPGPC	Gross Domestic Product Growth per Capita
GDPPC	Gross Domestic Product per Capita
GMM	General Method of Moments
HDI	Human Development Index
MDGs	Millennium Development Goals
MSc	Mobile Cellular Subscriptions
MVA	Manufacturing Value Added
SDGs	Sustainable Development Goals
SDI	Sustainable Development Index
SSA	Sub-Saharan Africa
TO	Trade Openness
UN	United Nations
WDI	World Development Indicators

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

The idea of sustainable development has attracted discourses from academics and policymakers for some time now. The term is associated with environmentalism (Wilkins, 2008), implying that development should not be pursued at the expense of the protection of the ecology. Due to this, the United Nations (UN) promoted the Millennium Development Goals (MDGs) in the 2000s which highlighted eight goals, including eradicating extreme poverty and hunger, achieving universal primary education, promoting gender equality, empowering women, reducing child mortality, and improving maternal health. Other MDGs were combating HIV/AIDS, malaria, and other diseases, ensuring environmental sustainability, and developing a global partnership for development. While there has been some level of achievement on these goals, developing countries are still battling poverty, HIV/AIDS and other ailments, child mortality and environmental degradation. For instance, data produced by the World Development Indicators (WDI) (2017) suggests that the disparity in per capita income between African and High-Income countries has widened from 15 times in 1960 to 29 times in 2016 (Idun, 2021). Whilst developing countries are mainly on the MDGs, the UN is also promoting 17 Sustainable Development Goals (SDGs) to be achieved by 2030.

Notwithstanding, it is instructive to note that the level of achievement of the SDGs among African economies differs from country to country (Adeoye, Nwokolo, & Igboanugo, 2020). Mainly, aside geographical barriers, this differential may result from variations in governance structure or political systems, legal systems, culture, and religious backgrounds (Asiamah et al., 2022a). At the same time, policy responses take a delayed effect since the resultant impact of implemented policies in a given year may manifest or be witnessed in the subsequent year(s) and this may account for differentials between economies (Asiamah et al., 2022b). Impliedly, the responses offered by developing economies may generally not be homogeneous, which suggest that empirical investigations into sustainability- and development-driven agenda among several economies must take a nonlinear and dynamic approach. For instance, there is the need to examine the levels of the input variables that are good or bad for sustainable development and the nonlinear autoregressive distributive lags may be of relevance. Similarly, once a delayed impact of policies is envisaged, a dynamic estimator like the two-step Generalised Methods of Moments (GMM) proposed by Roodman (2009) – which build on the estimator of Arellano and Bond (1991) – may need to be tested in this research. This thesis examines whether financial markets' credit allocation can boost both technological innovation and industrialisation towards the realisation of sustainable development in Africa.

Before the COVID-19 pandemic, the economies of some African countries were growing at more than 5 per cent on average. The African Union (AU) has earmarked industrialisation and investment in hi-tech services as the way forward for sustainable economic development. The AU has accordingly encouraged member countries to embark on industrialisation. The industrialisation agenda sweeping through the continent is touted as the way forward to sustain growth into the future. In Africa, various governments have come up with a program to support the industrial sector to continue to push the country's developmental agenda. However, there is the need to explore the externalities of industrialisation as the continent moves towards sustainable development on economic, ecological, and social grounds.

The operational activities of manufacturing industries could be detrimental to the ecological dimension of sustainability. Due to industrialisation, the emission of carbon monoxide (CO2) has become unbearable. Therefore, it is incumbent that firms in those industries embark on acts that are friendly to the environment in their operations (Abdullahi, Mohamed, Shamsudin, Sharifuddin, & Ali, 2018). The modern framework for sustainable development reflects the triple-bottom-line dimension which are economic, ecological, and social orientations (Elkington, 1977). The focus of the triple-bottom-line model extends businesses' care for profit and the planet to include care for the people in a comprehensive framework for achieving business excellence. Businesses would have to be innovative in their approach to realizing sustainable enterprise excellence, claiming that innovation can be a catalyst in realizing the goals of triple-bottom-line sustainability (Edgeman & Eskildsen, 2014). Small and medium enterprises (SMEs) can also create sustainable innovation with commensurable resource endowment for the implementation of innovations (Halme & Korpela, 2014).

The link between finance and development was proposed by Bagehot (1873) and Schumpeter (1911). In Schumpeter's proposition, finance facilitates innovations of all forms that spur economic development. Besides, much empirical literature has affirmed the contribution of finance in either capital accumulation or total factor productivity or both which induces economic growth (King & Levine, 1993; Levine, 1991; Levine, 2005, Aghion, Howitt & Mayer-Foulkes, 2005; Idun & Aboagye, 2014; Laeven, Levine, & Michalopoulos, 2015). Financial agents supply the resources needed to actualise inventions into innovations that solve societal problems and improve productivity growth. Innovation brings about improvement in technology, new markets and institutions, new production processes, and new products and services which boost the standard of living and societal welfare (Abdullahi et al., 2018). However, innovations come with commitment and costs. Innovations can boost the industrialisation agenda of nations since they aid in the development of manufacturing and industrial technology. It is, therefore, not surprising that developed nations are considered more innovative and industrialised (Romer, 1990). The cost of innovation is vast, but the issue associated with this discourse lies in the depletion of non-renewable natural resources due to industrialisation and innovation. By the same token, the degree of industrialisation determines the level of innovativeness of a nation towards its development.

Similarly, developed nations tend to industrialise. This suggests a positive relationship between innovation, industrialisation, and economic development. Although these are positive indicators, developed nations have been cited as indulging in harmful environmental practices. The suggestion is that just achieving economic development alone is not enough to make everyone happier. Economic development should not jeopardise the sustenance of the lives of the future generation. The focus of development is gradually shifting to ensuring factors which promote economic, social, and environmental development, and this guarantees the progress of the future generation.

The financial decision of a firm can have a detrimental effect on the achievement of sustainable development when managers are fixated on improving economic outcomes which in turn can stimulate negative externalities on the environment. Similarly, owners of firms may perceive investment in sustainable development as under-investment thereby refusing to commit resources to sustainability activities. The above suggests some convolution between firms' financing and firm innovation in inducing sustainable industrialisation. However, to the best of the researcher's knowledge, no empirical investigation has been conducted on the convolution between financial development, technological innovation, industrialisation, and sustainable development to ascertain the feasibility of the sustainable development goals in

Africa. Information in these regards would augment ongoing discussions on how to improve the lives of people living within the continent.

1.2 Statement of the Problem

The study is motivated by the drive towards the promotion of sustainable development in Africa by the African Union and other parastatal bodies, especially the United Nations (UN). The UN has instituted 17 goals to promote sustainable development. These 17 Sustainable Development Goals (SDGs) have been decomposed into 169 sub-goals to be achieved under the 2030 agenda for sustainable development. The goals are essentially grouped into economic, ecological, and social goals. Against this, the African Union has embraced the Sustainable Development Goals by motivating member countries to come up with programmes that are directly related to the goals. However, whereas a lot of discussions have occurred, much of the talk has been oblivious to empirical data analysis. A closer examination of the Sustainable Development Goals reveals that technological innovation, industrialisation, and financial development are the key ingredients needed to eradicate poverty and achieve most of the goals. The empirical works that testify that the above factors account for sustainable development did not examine the symbiotic convolution among financial development, technological innovation, and industrialisation in stimulating sustainable development. Also, as the population of the world keeps growing, we turn to use natural resources without replacement. Against this backdrop, industrialisation, a key to economic development, implies increases in the use of energy and emission of carbon monoxide which tend to destroy the natural environment.

Also, the African Union has realised the importance of industrialisation in spearheading the bridging of the poverty gap in Africa. Industrialisation is seen as the panacea for job creation, prosperity, and wealth creation. Industrialisation induces innovation by introducing new equipment, new production techniques, increasing capacities and spreading improvements across sectors of the economy (African Development Bank, 2019; May 20, 2020). However, since the 1990s when the policymakers started talking about industrialisation, not much has been achieved on that score. The contribution of industry to GDP declined from 12% in 1980 to 11% in 2013. Between 2000 and 2017, on average, compound growth in Africa's manufacturing sector (5.1%) still lags that of Brazil (5.3%), Asia (5.9%), India (10.1%), Bangladesh (10.9%), Vietnam (11.1%) and China (14.0%). Over the period, Africa's growth in the manufacturing sector was only higher than Latin America which is also a developing continent. The projection by the African Development Bank shows a huge market for manufacturing by 2025. The group predicted that consumption in Africa is estimated to be around US$2 trillion in 2025. This estimate will be a colossal improvement in household consumption from US$910 billion in 2005 and US$1.42 trillion in 2015. The potential for Africa to double her manufacturing contributions and triple the growth of the sector lies in innovations for the chemical and the automobile sector, regional processing (food, beverages, etc.), resource-intensive (cement, petroleum) and labour-intensive (apparel, footwear, etc.), according to the report by the African Development Bank Group.

However, developing the manufacturing sector also comes at a certain price. The first issue relates to funding the sector. According to the World Development Indicator published by World Bank (2020), domestic credit to the private sector as a ratio of GDP has reduced from 32.688% in 2009 to 27.995% in 2019. Even in the late 1990s, the financial depth situation in sub-Saharan Africa stood at 32.016% of GDP. These data show the deterioration in the level of finance in the industrial sector which can dampen the industrialisation agenda of the AU. If funding from the financial sector is deteriorating, coupled with the fact that private sector credit has a direct effect on productivity growth, it follows that inadequate support from the financial sector can harm the sustainability development of African economies. Conversely, in its Agenda 2063 document, the AU aspires to advance the global efforts to mitigate climate change that support and improves sustainable development.

In the growth literature, the concentration has been on how other resources such as human capital and physical capital (Solow, 1958; Romer, 1990; Mankiw et al., 1992), and financial development (financial innovation) (King & Levine, 1993; Aghion, Howitt & Meyer-Foulkes, 2005) lead to economic growth without much concentration on the convolution between the ecological resources, physical capital, and human capital to boost sustainable development. The quality of natural resources informs the quality of production and consumption to enhance welfare. The natural capital serves as inputs in the manufacturing process and augments human, machine, buildings, and managerial skills to bring about welfare-enhancing productivity to induce greater quality of life. In this light, proponents of sustainable development admonish that productivity growth should not be seen as only emanating from growth in GDP (GNP) but must include social and ecological development. Natural and human-made capital must be seen as working together to address economic, social, and environmental development but not as substitutes if economies are to achieve sustainable development goals (Constanza, 1992). Judging from the 17 SDGs, it appears the focus of the world is on how to achieve economic development, social development, and environmental protection to sustain the lives of not only present humanity but also the future generation.

This thesis delineates the impact of technological innovation, industrialisation, and financial development on sustainable development in Africa by covering three important areas discussed under three themes of theoretical, empirical, and practical contributions.

1.3 Background to sustainable development

The term sustainable development was first coined at the Cocoyoc Declaration on Environment and Development in the 1970s. The concept gained greater acceptability in the Stockholm Declaration on Human Environment at the United Nations Conference in 1972 and later became a household term after a seminar organised by the World Commission on Environment and Development in 1987. In its report, the Commission defined sustainable development as “development that meets the needs of the present without compromising the ability of the future generations to meet their own needs”. This definition, however, is very profound and is expressible in various ways. It implies halting poverty, finding alternatives to stop the depletion of non-renewable resources, and reducing pollution of all forms. Economically, the framers of the concept also seek to improve employment, food security, water, and sanitation, contain population growth, and integrate economic and environmental goals among others.

Since the Brundtland Report, several declarations on sustainable development have been made. Notable among them is the World Summit on Environment and Development (Earth Summit) (1992) held in the Brazilian city, Rio-de-Janeiro, which stressed the need for the whole world to achieve the goals of sustainable development; the summit in Johannesburg in 2002 which invigorates the concerted efforts to sustainable development and the recent United Nation’s 17 sustainable goals which have influenced the development policies of many nations. The new sustainable development goals have 17 goals. These include no poverty, zero hunger, good health and well-being, quality education, gender equality, clean water and sanitation, Affordable and clean energy, Decent work and economic growth, Industry innovation and infrastructure, Reduced inequalities, Sustainable cities and communities, Responsible consumption and production, Climate Action, Life below water, Life on Land, Peace, justice, and strong institutions and Partnerships for the goals. To achieve these goals, technological innovations can harness the industrialisation drives of African nations towards inclusiveness and development. For instance, most African countries are promoting financial inclusion through mobile money technology. The technology is promoting employment and lower financial transaction costs. It has also promoted access to financial services which has the potential to boost trade and commerce coupled with greater employment to reduce poverty (Surana, Singh, & Sagar, 2020).

1.3.1 Industrialisation sustainable and economic development in Africa: The role of financial development

The environment provides the natural capital used to boost manufacturing and productivity in the industries. The ecosystem supplies raw materials to support industrial activities. Non-renewable natural resources such as fossil fuels and minerals are also direct and indirect inputs for industrialisation (Costanza & Daly, 1992; Walker & Jourdan, 2003). Sustainable development, therefore, connotes the interaction between the environment, social, and economic development to bring about improvement in the welfare of society (Parris & Kate, 2003; Jabareen, 2008, Rogers, Jalal & Boyd, 2012). However, as economies industrialise, it may have undesirable consequences on the depletion of natural resources, especially the non-renewable natural capital (Dubey, Sharma, Sinha & Shukla, 2009; Shukla, Lata & Misra, 2011). It follows that we need to determine the optimal level of industrialisation that supports the protection of the environment and at the same time ensures economic and social development. For this course, industrialisation should be pursued in the interest of preservation of the natural resources to, in turn, sustain economic development in emerging economies.

Financial development has a crucial role to play in the sustainable development of African economies. The NEPAD initiative highlights the importance of financial development in addressing the financing gap in African countries. A history of financial development in Africa shows that the continent has faced significant challenges in achieving sustainable economic growth due to a lack of adequate financial systems. Similarly, African countries have prioritized industrialization and innovation in the past, as seen in the Lagos Plan of Action for the Economic Development of Africa, 1980 - 2000. However, these efforts have not always been successful. Therefore, policymakers must prioritize the development of a resilient financial sector to complement the drive towards industrialization and sustainable development in Africa (UN, 2017; Iqbal, & Ahmad 2021; G20, 2019).

The level of financial development can also stimulate positive or negative externalities on sustainable development (Adeola & Evan, 2017; Abbasi, Hussain, Haddad Salman & Ozturk, 2022; Kirikkaleli & Adebayo, 2021; Koirala & Pradhan, 2020; Samour, Baskaya & Tursoy, 2022; Odugbesan, Ike, Olowu & Adeleye, 2022). Using the ARDL cointegration process, Abbasi and Riaz (2016) show for emerging countries that financial development promotes CO_2 emissions. Similarly, Abokyi, Appiah-Konadu, Abokyi and Oteng-Abayie (2019) applied the same method and reported that financial development can promote CO_2 emissions. By the same token, Acheampong (2019) found that financial development is directly related to environmental degradation in the form of CO_2 emissions. Saud, Chen and Haseeb (2020) studied the effect of financial development on CO_2 emissions in the countries with the Belt and Road Initiative and showed that financial development could promote CO_2

emissions. Financial development can promote environmental degradation when funds are channelled from the financial sector to boost industrialisation which, in turn, contributes to the emission of CO_2. However, none of the empirical studies has explored the likelihood that industrialisation (which is a desirable end) can mitigate or stimulate the relationship between financial development and environmental degradation (which is undesirable).

On the other hand, other studies show that financial development can have positive externalities on environmental degradation. Financial development reduces CO_2 emissions (Dogan & Seker, 2016) and improves the quality of the environment (Shahbaz, Nasir & Roubaud, 2018). Other studies suggest that financial development promotes environmental degradation and vice-versa (Khan, Peng & Li, 2019). Whilst most of these studies have been conducted for individual countries, there have been no studies on the issues concerning the African continent.

There is a need for a study of this nature to be conducted in Africa because the standard of living of people in Africa needs much more uplifting than that of the developed world. An examination of the data from the World Development Indicator shows that the gap in per capita income between African and high-income countries widened from 15.9 times in 1960 to about 25 times in 2016 (Idun, 2021). Also, the African Union and its various organs and regional integrations seek to leverage industrialisation and technological innovations to promote the 17 UN Sustainable Development Goals. This study examines how the level of financial development complements the industrialisation agenda of the AU in boosting economic development without harming social and ecological sustainability.

1.3.2 Financial Development, Technological Innovation, and Sustainable Development

The increasing nature of industrialisation in developing countries can result in urbanisation which, in turn, leads to sustainable development (Kiamba, 2012). By the same token, the industrial sector can create innovative products, processes or markets that can enhance the welfare of society and therefore promote development or harness existing technologies to enhance industrial productivity and therefore sustainable development (Abbasi et al., 2022). On the negative side, industrialisation can lead to the destruction of the ecology especially when industrial waste is not properly managed which can lead to negative externalities such as pollution and destruction of the ozone layer due to the emission of carbon monoxide (CO_2). The negative outcome of industrialisation can lead to negative consequences on the welfare of members of society which can lead to reductions in the gains of sustainable development.

In all these, the financial sector plays a role in how industrialisation leads to innovations by the firm. Romer (1990) postulated that economic development is driven by firms' resolve to obtain rent from intellectual property on new product development. Through research and development (education), firms develop improved product varieties that propel economic growth. The financial sector invests in new screening technologies that can pinpoint firms that can leverage industrialisation infrastructure to innovate and aid in economic development. The finance-growth literature also suggests that countries can use their level of financial development to import technological innovation which can propel them to grow faster and catch up with the per capita income level of high-income countries (Hsu, Tian & Xu, 2014; Pan, Uddin, Han & Pan, 2019). The Schumpeterian growth theory suggests that countries that have developed their financial markets can rely on financial development to induce financial and technological innovation to promote productivity growth (Aghion &

Howitt, 1992; King & Levine, 1993; Levine, 1991; Levine, 2005, Aghion, Howitt & Mayer-Foulkes, 2005, Idun & Aboagye, 2014, Laeven, Levine & Michalopoulos, 2015, Idun, 2021).

The literature suggests that a high level of financial development is associated with the importation of technological innovation to boost the productivity of nations. (Levine, 1997; Abeka, Andoh, Gatsi & Kawor, 2021). More empirical studies attest that technological innovation leads to economic development or causes crises in the real sector to dampen growth or lead to a new wave of growth (Abeka et al., 2021; Broughel & Thierer, 2019; Freeman, 2018; Gomulka, 2006; Idun & Aboagye, 2014; Rosenberg, 2006; Scherer, 2011; Zhou, Cai, Tan, Zhang, Du & Song, 2021). However, sustainable development goes beyond economic growth. It is yet to be known how financial development induces technological innovation that is directed at promoting environmental protection even though the call for sustainable financial development is louder in recent years (Ibrahim, Al-mulali, Ozturk, Bello & Raimi, 2022; Manigandan, Alam, Alagirisamy, Pachiyappan, Murshed & Mahmood, 2023; Usman & Hammar, 2021; Wahab, Imran, Safi, Wahab & Kirikkaleli, 2022). It follows that the level of financial development is essential for economic growth, industry productivity, technological innovation, technological infusion, and sustenance of economic growth since it provides private sector credits, diversifies intermediation risks, reduces transactions, and boosts liquidity in the economy.

As stated earlier, the African Union seeks sustainable development, but the researcher is yet to come across a study that examines the role of finance in national innovation toward promoting sustainable development. The case for Africa is important because, despite the endowment of natural resources, the economies have not harnessed technological innovation into sustainable development. Existing studies examined the role of growth in debt financing in economic growth (e.g., Idun, 2021). This study analyses whether the allocation of financial resources to enterprises can boost national innovation which would in turn boost productivity growth, societal human capital capacity, and maintain ecological sustainability.

1.3.3 Technological innovation, industrialisation, and sustainable development in Africa

Technological innovation is the bedrock of industrial transformation which leads to development (Ashton, 1997; Archibugi & Iammarino, 2002; Ziman, 2003; March, 1997). Through technological innovation, new and efficient machines can be produced which augment or replaces labour to boost productivity growth. Industrialisation leads to economic development as can be explained by the disparity in economic development between industrialised and high-income countries and that of emerging economies. It is expected that industrialisation would lead to an increasing return to scale which in turn can lead countries to reach their steady-state faster. However, technological innovation brings new processes for the transformation of extractive goods into industrial goods which are used to boost productivity in the real sector. Innovation also creates disequilibrium between the backward and forward chain in the production process which propels production diversification and industrial growth (Hirschman, 1958).

Gerschekron (1962) in Dutrénit, Anyul and Teubal (2011) postulated that "looking at the economy as a whole and not only focusing on the industrial sector, the degree of backwardness of an economy shapes the potential for industrialisation." This implies that less industrialised countries can catch up with the level of industrialisation in high-income countries faster as they put in place measures to boost industrialisation. Countries that have industrialised tend to have greater technological innovation that enhances the efficiency of factors of production than countries with a lesser amount of technological innovation

(Amankwah-Amoah, 2019; Chen, Awan, Ahmad & Tan, 2021; Kaplinsky, 2019). However, industrialisation is connected to urbanisation, which can also lead to ecological problems such as energy usage, and destruction of the ozone layer due to the emission of CFO chemicals and CO2. By the same token, education is required to promote the innovation of technologies for industrialisation without sacrificing environmental sustainability.

This aspect of the thesis is related to the work of Sadorsky (2014) which suggests that urbanisation and industrialisation increase energy consumption in the long run. Their result implies that energy consumption from non-renewable sources such as fossil fuels can be detrimental to sustainable development since such a development would hamper ecological sustainability. The study implied that achieving one aspect of sustainable development (economic development through urbanisation and industrialisation) can be harmful to the achievement of other aspects (ecological development). Similarly, Kohler (2014) identified information and telecommunication technologies as drivers for the integration of developing nations into the global economy which would lead to social and economic development. This is an indication that technological innovation complements trade to bring about sustainable development.

The impact of technological innovation on growth is well-enshrined in economic literature. The earliest view on the relationship between innovation and economic development is found in the classical school of thought which stipulates that economic development is induced by technological advancement (Smith, 1776). In the neoclassical growth perspective, technological progress is seen as the main driver of productivity growth (Solow, 1956). Technological innovation improves efficiency in the input-transformation stage which lowers the cost of production and maximizes productivity growth within the shortest period.

Technological innovations in the form of ICT also improve service delivery. However, the neoclassical growth theories opine that technological progress is exogenously determined. The new growth theories spearheaded by Romer (1990), and a host of endogenous theorists, view technological innovation as individual and firm actions that can propel the productivity growth of nations that accumulate more innovation. Schumpeter (1911), from the Austrian School of thought, views technological innovation as a conduit to induce greater economic development. In the modern Schumpeterian growth perspective, Aghion, Howitt, and Meyer-Foulkes (2005) opine that technological transfer from technological leaders to laggards encourages the movement of financial resources to induce productivity growth in countries involved. Similarly, King and Levine (1993), Levine (1997), and Levine (2005) postulate that technological transfer through innovation encourages investment in viable products that improve the transfer of financial resources into growth sectors. The modern Schumpeterian view on development, therefore, suggests that financiers assist directly or indirectly in the importation of technological innovation to induce economic growth.

Empirically, Omri (2020) shows that technological innovation in high-income countries stimulates sustainable production by encouraging investors to use innovative technologies for a friendlier environment. The concept of sustainable development has received considerable discussion in the literature due to its impact on human lives. However, most of the discussions have concentrated on the conceptual issue with little discussions on the empirical fronts, especially in Africa. Empirical assessments of the interrelations between technological innovation, industrialisation, and sustainable economic growth in the African context could champion the effectiveness of the policy measures employed by governments as well as practitioners and respective policymakers in their quest to promote the attainment of the MDGs and SDGs. Despite the corroborative evidence that might have been established in developed markets, the case of developing markets stands to differ amid geographical and political system differences. Besides, the approach taken by technological frontiers may be way different from technological laggards.

According to Bruyn and Sander (1997), technological innovation can reduce environmental degradation using more energy-efficient production technologies, changes in the fuel mix, and the installation of end-of-pipe technology. Bruyn and Sander show that technological innovation stimulates the three pillars of sustainable development in only developed countries. In their study, factors peculiar to developing countries such as politics, geography, the legal system, culture, religion, etc. was not used as instruments. These factors are likely to affect the relationship between technological innovation and sustainable development.

In a study conducted over the period 1995 to 2015, Bekhet and Abdul Latif (2018) analysed the role of institutions' quality in technological innovation and sustainable growth transmission. They found that the interaction between governance and technological innovation positively contributes to the sustainable growth of Malaysia. Elsewhere, Omri (2020) examined the ability of technological innovation to simultaneously promote economic progress and advance social and environmental conditions in the case of 75 low-, middle-, and high-income countries by demonstrating how this impact differs across the stages of economic development. From both long-run estimates and causality analysis, his findings reveal that technological innovation contributes simultaneously to the three pillars of sustainable development only in the case of rich countries; however, it only affects the economic and environmental dimensions in middle-income countries, and no impact is found in the case of low-income countries.

Similarly, Umar, Kirikkaleli, and Xu (2020) investigated the long-run and causal effects of innovation, financial development, and transportation infrastructure on CO_2 emissions using the combined cointegration and wavelet coherence approaches over the period from 1971 to 2018, while using economic growth as a control variable in the model. They show that there is an important cointegration relationship between CO_2 emissions, innovation, financial development, transportation infrastructure, and real GDP. Moreover, the findings from a wavelet power spectrum reveal that there is a significant vulnerability in innovation, financial development, transportation infrastructure, and CO_2 emissions at different time frames and frequencies. Furthermore, the outcomes of the wavelet coherence approach reveal that (i) Innovation is observed as a significant predictor of CO_2 emissions over the period from 2007 to 2013; (ii) In the long run, there are negative correlations between CO_2 emissions and financial development; (iii) Over the periods from 2000 to 2015, and from 1985 to 1989, transportation significantly causes CO_2 emissions. These findings have substantial policy implications that suggest there is a need to strengthen innovation and transportation infrastructure to achieve environmental sustainability targets. On the other hand, Mensah, Long, Boamah, Bediako, Dauda and Salman (2018) also found in Organisation for Economic Co-operation and Development (OECD) countries that technological innovation can promote CO_2 emissions in these countries.

However, the empirical literature does not contain information about how the level of industrialisation in the economic communities under the Africa Union can promote economic, social, and ecological sustainability without compromising on each aspect of sustainable development. The empirical literature does not also contain information on how African countries and the economic communities under the AU can leverage technological innovation to boost industrialisation without compromising on environmental sustainability.

This thesis will examine the level of innovations and technological innovation that would propel sustainable development i.e., that would allow African countries to promote economic development without risking social and ecological development. To the best of the researcher's knowledge, we do not have studies in this regard that concentrate on the African continent after the reorganisation of the Organisation of African Unity into the African Union.

In terms of methodological uniqueness, the study employed Baron and Kenny's tests (Baron & Kenny, 1986), which have been modified by Hayes (2009) and Zhao, Lynch and Chen (2010), to analyse the mediating effect of industrialisation on the nexus between technological innovation and sustainable development in Africa. The recent literature terms this approach as the ANOVA technique (Civelek, Uca, & Çemberci, 2015; D'Aleo, 2015; Sergi, D'Aleo, Konecka, Szopik-Depczyńska, Dembińska, & Ioppolo, 2021). Specifically, these tests can help to identify whether industrialization acts as a mediator, or intermediate variable, in the relationship between technological innovation and sustainable development, and to what extent this relationship is direct or indirect. This approach can provide valuable insights into the complex interactions between these factors, which can help to inform policy decisions and interventions aimed at promoting sustainable development in the region. Additionally, the use of standardized tests and procedures can help to ensure that the results are reliable and robust, enhancing the validity of the findings.

Thus, these tests provide a standardized and widely accepted approach to analyzing mediating effects, which helps to ensure that the results are comparable across different studies and contexts (Sergi, D'Aleo, Konecka, Szopik-Depczyńska, Dembińska, & Ioppolo, 2021). This enhances the reliability and validity of the findings and can help to build a more robust evidence base for policy decisions. Also, Baron and Kenny's tests provide a clear and straightforward framework for analyzing mediating effects, which can be easily understood and applied by researchers and policymakers without requiring specialized statistical knowledge or expertise (D'Aleo, 2015). This makes it a practical and accessible approach for conducting analyses in real-world settings. Finally, Baron and Kenny's tests can help to identify the specific pathways through which the mediating variable operates, which can provide valuable insights into the mechanisms underlying the relationship between the independent and dependent variables (Civelek, Uca, & Çemberci, 2015). This information can help to inform the design of interventions and policies aimed at promoting sustainable development, by highlighting the specific areas where interventions are most likely to have an impact.

1.4 Research Objectives

To examine whether the level of financial development complements the industrialisation agenda of the AU in boosting economic development without harming social and ecological sustainability.

Specifically, I

1. examined how the level of financial development in Africa and her economic communities induce technological innovations which in turn lead to sustainable development.

2. analysed the role of financial development in the relationship between technological innovation and economic, social, and ecological sustainability.

3. analyse whether African countries can leverage technological innovation to boost industrialisation without compromising on economic, social, and environmental sustainability.

1.5 Research Questions

1. How does financial development induce technological innovations which in influencing sustainable development in Africa?

2. What is the role of financial development in the relationship between technological innovation and economic, social, and ecological sustainability?

3. Can African countries leverage technological innovation to boost industrialisation without compromising on economic, social, and environmental sustainability?

1.6 Theoretical Framework

The neoclassical model (exogenous growth model) postulates that economic growth is a function of technological progress in the long run (Solow, 1956). With this assertion, the exogenous growth literature gives no room for other factors that may influence growth, for example, financial development. Specifically, the neoclassical perspective stipulated that in the absence of transaction costs, financial development, technological innovation, and industrialisation do not influence economic growth and development. However, the assertion in the neoclassical framework that productivity growth is only determined by exogenous technological progress lacks empirical acceptance. Romer (1990) and Mankiw et al. (1992) believe that education and human capital development can augment physical capital to induce investment that would propel nations to grow faster to the growth path of the technological leader. Mankiw et al. (1992) therefore developed an augmented Solow's model that implies that human capital accumulation is instrumental in achieving per capita growth convergence and therefore is important in achieving greater welfare.

In line with this study, technological innovation can lead to the development of new renewable sources of energy for industrialisation since non-renewable sources of energy are detrimental to environmental sustainability (Umar et al., 2020). Similarly, financial development can lead to greater consumption of non-renewal energy or fossil energy which can be harmful to the environment (Wang, Mirza, Vasbieva, Abbas, & Xiong, 2020; Khan, Khan, & Binh, 2020). By the same token, financial development promotes economic activities which can boost the income level of a nation. An increase in a nation's income can provide the opportunity for the development of new technology for industrial development that leverages renewable energy consumption. Technological innovations can also influence the emission of CO2 (Mensah, et al., 2018) since innovation leads to the consumption of fossil fuels.

1.7 Theoretical support for hypothesised relationships

Notably, the research objectives and hypotheses emanate from the theoretical position of Romer (1990) and Mankiw (1992). Contrary to the neoclassic economists' view that the long-run growth of an economy is hinged on its long-term technological progress regardless of the level of financial development, Romer and Mankiw theoretically contend the suitability, operability and practicality of the position of the neoclassical theorists. The premise is that it is intuitive to accept that the impetus for any given level of technological progress is human capital development or education. Without these elements, the long-term advancements in technology for any given economy may be compromised. Suffice to say, therefore, that with any level of physical capital, investment can be induced with the availability of human capital development. Meanwhile, the level of financial development is most likely a driver of human capital development and implies that the augmented Solow's model produced by Mankiw (1992) presents a theory to rightly explicate the relationship between the growth of economies, human capital accumulation, and financial development.

Furthermore, the mechanisms employed towards financial development may not be in isolation to technological innovations, which have a ripple impact on sustainability. The rampant consumption of non-renewable energy impacts sustainable development (Khan, Khan, & Binh, 2020; Wang, Mirza, Vasbieva, Abbas, & Xiong, 2020). As African economies integrate the attainment of the MDGs and SDGs, it is empirically demanding to ascertain the extent to which a given level of development drives technological innovations and the resultant impact on sustainability. The indirect relationship of technological innovation on the relationship between financial development and sustainable development among African economies needs to be empirically ascertained to influence policy decisions.

Empirically, the plausible role of technological innovation in stimulating sustainable growth has been long established among advanced economies, which are largely technological leaders (Bruyn & Sander, 1997; Omri, 2018). However, in the case of developing markets, no such evidence is available. Notwithstanding, the tendency for technological innovation to have a detrimental impact on the ecological environment cannot be side-lined and this might be prevalent among developing economies in their attempt to tap technological knowledge from their developed counterparts. Therefore, in the wake of championing the achievement of MDGs and SDGs between African economies, ascertaining how these economies could capitalise on technological innovation to improve industrialisation whilst ensuring sustainable economic growth is not trivial.

1.8 Theoretical, practical, and empirical contributions

1.8.1 Theoretical contributions

Empirical studies attest that technological innovation drives economic development or results in crises within the real sector to either diminish or heighten growth. It is instructive to note that, sustainable development extends beyond the growth of economies. Yet, it is not empirically known how financial development induces technological innovation that is directed at promoting environmental protection although the campaign for sustainable financial development is intense in recent periods. Through this study, plausible advancements in the theorised relationships (finance-growth and the Schumpeterian growth theory) between financial development, technological innovation, and sustainable development could be made. The findings from the study – in the African context – could be a means of confirming or driving new implications from a group of developed markets. This is again necessary to unravel the plausible differences that may exist between the operability of the growth theories in the developed market and developing market contexts. Given the regional, geographical, political, and cultural differences, the theoretical contribution of this study cannot be overlooked.

1.8.2 Practical contributions

This study aims to determine the optimal level of industrialisation that supports the protection of the environment and at the same time ensures economic and social development. The intuition is that industrialisation should be pursued in the interest of preservation of the natural resources to, in turn, sustain economic development in emerging economies.

Industrialisation is directly linked with urbanisation, which could lead to ecological problems in the likes of energy consumption, and ozone layer depletion due to the emission of CFO chemicals and CO2. Whilst education may be direly required to promote the innovation of technologies for industrialisation without sacrificing environmental sustainability, policy guidelines need to follow from empirical investigations. Hence, this drives the impetus of the study to examine the linkages between technological innovation, industrialisation, and sustainable development in Africa.

1.8.3 Empirical contributions

Given that industrialisation, which results from financial development, could result in positive and/or negative externalities (e.g., see, Abbasi & Riaz, 2016; Abokyi, Appiah-Konadu, Abokyi, & Oteng-Abayie, 2019; Acheampong, 2019; etc.), it is essential to empirically examine the potential role of industrialisation to influence the magnitude, strength, and direction of the relationship between financial development and environmental degradation. Per the extant literature thus far, no empirical study has explored the likelihood that industrialisation (which is a desirable end) can mitigate or stimulate the relationship between financial development and environmental degradation (which is undesirable) in the arena of developing economies. This knowledge gap would be abridged by this study. In the African context, this study investigates whether the level of financial development complements the industrialisation agenda of the AU in boosting economic development without harming social and ecological sustainability.

1.9 Structure of the thesis

The thesis is organised into five chapters. Chapter One introduces the study by providing the background of the study, statement of the problem, objectives of the study, significance of the study, theoretical supports, and contributions to the body of knowledge). Chapter Two comprises the first paper on Industrialisation and sustainable development in Africa: The role of financial development. Chapter Three comprises the second paper on financial development, technological innovation, and sustainable development. Chapter Four contains the third paper on Technological innovation, industrialization, and sustainable development in Africa. Finally, Chapter Five contains the summary, conclusions, recommendations, and suggestions for further studies.

CHAPTER TWO

INDUSTRIALISATION, SUSTAINABLE AND ECONOMIC DEVELOPMENT IN AFRICA: THE ROLE OF FINANCIAL DEVELOPMENT

2.1 Introduction

This chapter examines whether the level of financial development complements the industrialisation agenda of the AU in boosting economic development without harming social and ecological sustainability. The level of financial development in stimulating positive or negative externalities on sustainable development has been established in the literature (see e.g., Abbasi & Riaz, 2016; Abokyi, Appiah-Konadu, Abokyi & Oteng-Abayie, 2019; Acheampong, 2019; Saud Chen, & Haseeb, 2020). Yet, none of the empirical studies has explored the likelihood of industrialisation mitigating or stimulating the relationship between financial development and environmental degradation. To facilitate empirical investigations into this theme, there is the need to first examine the effect of industrialisation and financial development on the overall development of Africa. This is the focus of the chapter.

The natural capital that the environment supplies, is used to increase production and productivity in many sectors. To support industrial activity, the environment provides raw materials. Minerals and fossil fuels are two examples of non-renewable natural resources that are both direct and indirect sources of industrialisation (Costanza & Daly, 1992). Therefore, sustainable development refers to the combination of environmental, social, and economic development to enhance societal wellbeing. However, as economies become more industrialised, it may negatively affect the loss of natural resources, particularly non-renewable natural capital. Therefore, we must establish the ideal amount of industrialisation to assist environmental preservation while also ensuring social and economic advancement. In effect, to maintain economic growth in rising economies, industrialisation should be pushed in the interest of protecting the environment.

The extent of financial development can also encourage either favourable or unfavourable externalities in long-term development. Abbasi and Riaz (2016) demonstrate for developing nations that financial development encourages CO2 emissions using the ARDL cointegration approach. A similar methodology was used by Abokyi, Appiah-Konadu, Abokyi, and Oteng-Abayie (2019), who reported that financial development can encourage CO2 emissions. In the same vein, Acheampong (2019) discovered a clear link between financial development and CO2 emissions, a kind of environmental damage. In their study on the impact of financial development on CO2 emissions in the countries participating in the Belt and Road Initiative, Saud, Chen, and Haseeb (2020) demonstrated that financial development might encourage CO2 emissions. When financial resources are used to support industrialisation, which in turn increases CO2 emissions, financial development can contribute to environmental deterioration. The chance that industrialisation, which is a desirable objective, might lessen or promote the link between financial development and environmental deterioration (an undesirable outcome) has not been examined in any empirical studies.

Meanwhile, other research demonstrates that financial growth may have beneficial externalities on environmental deterioration (Dogan & Seker, 2016). Shahbaz, Nasir and Roubaud (2018) contend that financial development benefits the environment by lowering CO2 emissions. According to other research, environmental deterioration encourages financial development, and the opposite is also true (Khan, Peng & Li, 2019). There has not been any research on the problems affecting the African continent, even if the majority of these studies have been done for specific nations.

Research of this kind must be performed in Africa since there is a far greater need to raise the level of living there than there is in the industrialised world. According to data from the World Development Indicators, the disparity between the per capita incomes of high-income and African nations increased from 15.9 to nearly 25 times from 1960 to 2016 (Idun, 2021). Additionally, the 17 UN Sustainable Development Goals are being promoted by the African Union, as well as through its different organisations and regional integrations. The goal of this research is to determine if the AU's industrialisation ambition can be furthered without compromising social or environmental sustainability by looking at how far finance has advanced.

It is worth noting that the amount of economic growth varies greatly among African economies (Adeoye, Nwokolo, & Igboanugo, 2020). Aside from physical limitations, differences in governance structure or political systems, legal systems, culture, and religious backgrounds may all contribute to this disparity. At the same time, policy responses have a delayed effect since the impact of policies introduced in one year may materialise or be seen in the next year(s), which may account for economic differences (Khan, Peng & Li, 2019; Khan, Khan, & Binh, 2020). Implicitly, emerging nations' answers may not be uniform, implying that empirical inquiries into the industrialisation- and development-driven agenda of various economies must take a non-linear and dynamic approach. Once a delayed impact of policies is normally envisaged, a dynamic estimator such as Roodman's (2009) two-step Generalised Methods of Moments (GMM), which builds on Arellano and Bond's (1991) estimator, is utilised by the researcher.

The goal of this chapter is to assess how industrialisation promotes environmental preservation while also ensuring social and economic advancement. According to conventional wisdom, industrialisation should be undertaken to protect natural resources and, in turn, support economic growth in rising economies. Urbanisation is inextricably tied to industrialisation, which might result in ecological issues such as energy consumption, ozone layer depletion from CFO chemical emissions, and CO2 emissions. While there may be a pressing need for education to support the development of technology for industrialisation without compromising environmental sustainability, policy directives must be based on empirical research. This highlights the significance of the empirical analysis in this chapter.

It is pivotal to empirically examine the potential role of industrialisation to influence the magnitude, strength, and direction of the relationship between financial development and environmental degradation because industrialisation, which results from financial development, may have both positive and negative externalities. From the extant literature, no empirical study has looked at the possibility that industrialisation, which is a desirable end, can reduce or enhance the relationship between financial development and environmental degradation, which is undesirable, in the context of developing economies. The empirical investigation in this chapter would close this knowledge gap. This chapter examines whether the degree of financial development in Africa supports the AU’s industrialisation objective by fostering economic growth without jeopardising social and ecological sustainability.

2.2 Methodology

The systems dynamic panel GMM technique is employed in analysing the complementary role of financial development in the industrialisation agenda of the AU in boosting economic development without harming social and ecological sustainability. The system GMM technique makes use of a large number of data points, increasing degrees of freedom and reducing collinearity among explanatory variables, improving the efficiency of econometric estimates and allowing analysis of a variety of economic questions that are not detectable through cross-sectional or time-series data analysis (Agyei et al., 2021; Hsiao, 2003). These features make the method appealing to this research.

Under the GMM, the following basic estimation models are specified for the relationships between industrialisation and economic development along with financial development were based on empirical literature and theories (Aghion & Howitt, 1992; King & Levine, 1993; Levine, 1991; Levine, 2005, Aghion, Howitt & Mayer-Foulkes, 2005, Idun & Aboagye, 2014, Laeven, Levine & Michalopoulos, 2015, Idun, 2021). Models 1, 2, and 3 express these basic relationships when broad money (BM), domestic credit to the private sector (% of GDP) (DomCrdtP), and domestic credit to the private sector by banks (% of GDP) (DomCrdtB), respectively, are the main independent variables in addition to industrialisation, which is measured as manufacturing value added (MVA).

$$\begin{aligned} lnGDPPC_{it} = {} & \beta_1 l.lnGDPPC_{it} + \beta_2 lnMAV_{it} + \beta_3 BM_{it} + \beta_4 Inflation_{it} + \beta_5 TO_{it} \\ & + \beta_6 MSc_{it} + \beta_7 lnPopulation_{it} + \varepsilon_{it} \end{aligned} \tag{2.1}$$

$$\begin{aligned} lnGDPPC_{it} = {} & \beta_1 l.lnGDPPC_{it} + \beta_2 lnMAV_{it} + \beta_3 DomCrdtP_{it} + \beta_4 Inflation_{it} \\ & + \beta_5 TO_{it} + \beta_6 MSc_{it} + \beta_7 lnPopulation_{it} + \varepsilon_{it} \end{aligned} \tag{2.2}$$

$$lnGDPPC_{it} = \beta_1 l.lnGDPPC_{it} + \beta_2 lnMAV_{it} + \beta_3 DomCrdtB_{it} + \beta_4 Inflation_{it} + \beta_5 TO_{it} + \beta_6 MSc_{it} + \beta_7 lnPopulation_{it} + \varepsilon_{it} \quad (2.3)$$

To test the complementary role of financial development in the basic relationships between industrialisation and economic development, the interaction terms – between industrialisation (MVA) and the various proxies of financial development (broad money, domestic credit to the private sector, and domestic credit to the private sector by banks) – are introduced and specified as follows:

$$lnGDPPC_{it} = \beta_1 l.lnGDPPC_{it} + \beta_2 lnMAV_{it} + \beta_3 BM_{it} + \beta_4 (lnMAV \times BM)_{it} + \beta_5 Inflation_{it} + \beta_6 TO_{it} + \beta_7 MSc_{it} + \beta_8 lnPopulation_{it} + \varepsilon_{it} \quad (2.4)$$

$$lnGDPPC_{it} = \beta_1 l.lnGDPPC_{it} + \beta_2 lnMAV_{it} + \beta_3 DomCrdtP_{it} + \beta_4 (lnMAV \times DomCrdtP)_{it} + \beta_5 Inflation_{it} + \beta_6 TO_{it} + \beta_7 MSc_{it} + \beta_8 lnPopulation_{it} + \varepsilon_{it} \quad (2.5)$$

$$lnGDPPC_{it} = \beta_1 l.lnGDPPC_{it} + \beta_2 lnMAV_{it} + \beta_3 DomCrdtB_{it} + \beta_4 (lnMAV \times DomCrdtB)_{it} + \beta_5 Inflation_{it} + \beta_6 TO_{it} + \beta_7 MSc_{it} + \beta_8 lnPopulation_{it} + \varepsilon_{it} \quad (2.6)$$

where the full names of the variables, their measure, and data sources are detailed in Table 2.1.

Table 2.1: Meaning, measure, and data sources of variables

Variable	Full name and measure	Source
$lnGDPPC_{it}$	Proxy of economic development, measured as the natural logarithm transformation of GPD growth per capita for country i at time t. it provides a useful measure of changes in a country's economic output adjusted for population growth, and can be	WDI (2020)

	compared across countries and time periods to assess changes in standard of living.	
$lnMAV_{it}$	Proxy for industrialisation, measured as the natural logarithm transformation of manufacturing, value added (current US$) for country i at time t. it provides a measure of the contribution of the manufacturing sector to a country's economy, reflecting the level of economic development and technological sophistication of a country, as well as its ability to diversify its economy beyond agriculture and extractive industries.	WDI (2020)
BM_{it}	First proxy of financial development, measured as the share of broad money to GDP for country i at time t. It provides insights into the depth and efficiency of a country's financial system, as it captures the extent to which financial intermediaries are able to mobilize savings and allocate credit to productive sectors of the economy.	WDI (2020)
$DomCrdtP_{it}$	The second proxy of financial development – is measured as the domestic credit to the private sector (% of GDP) for country i at period t . It provides insight into the level of financial intermediation and access to credit within a country's economy, which can be important factors for promoting economic growth and development. This measure reflects the amount of credit extended by financial institutions to private borrowers, which can be indicative of the level of financial sector development and its ability to support investment and entrepreneurship.	WDI (2020)
$DomCrdtB_{it}$	The third proxy of financial development is measured as the	WDI

	domestic credit to the private sector by banks (% of GDP) for country i at period t. It provides a useful proxy for the level of financial intermediation and access to credit available to businesses and individuals in that country, which are key drivers of economic growth and development.	(2020)
$Inflation_{it}$	Inflation rate – measured as the consumer price index (annual %) for country i at period t. it measures the change in prices of a basket of goods and services consumed by households, reflecting changes in the cost of living over time, and allowing for comparisons of inflation rates across countries and time periods.	WDI (2020)
TO_{it}	Trade openness, measured as the sum of imports and exports as a % of GDP for country i at period t. It provides an indication of the degree to which a country is engaged in international trade, which is an important factor in economic development. This measure can help to explain the extent to which a country benefits from global markets and can be used to evaluate the impact of trade policies on economic growth.	WDI (2020)
MSc_{it}	ICT infrastructure, measured as the mobile cellular subscriptions per 100 people for country i at period t. It provides a useful measure of a country's level of access to mobile communications technology, which is an important driver of economic growth and development, enabling access to information and services, supporting business activities, and facilitating social interactions.	WDI (2020)
$lnPopulation_{it}$	The natural logarithm transformation of the total population for country i at period t.	WDI (2020)

The general form of the system GMM estimation used in specifying Equations 2.1–2.6 is given as:

$$lnGDPPC_{it} = \gamma_0 + \gamma_1 lnGDPPC_{it-\tau} + \sum_{h=1}^{n} \gamma_h W_{h,it-\tau} + \theta_i + \mu_i + \varepsilon_{it} \quad (2.7)$$

$$lnGDPPC_{it} - lnGDPPC_{it-\tau}$$
$$= \gamma_1 (lnGDPPC_{it-\tau} - lnGDPPC_{it-2\tau}) + \sum_{h=1}^{n} \gamma_h \ (W_{h,it-\tau} \quad (2.8)$$
$$- W_{h,it-2\tau}) + (\mu_t - \mu_{t-\tau}) + \varepsilon_{it-\tau}$$

where $lnGDPPC_{it}$ represents the natural logarithm transformation of GDP per capita of country i at time $t; \gamma_0$ is a constant; W represents a vector of control variables (inflation, trade openness (TO), ICT infrastructure (mobile cellular subscriptions per 100 people), and population); τ signifies the coefficient of autoregression (which is equal to 1 for the specification); μ_t signifies the time-specific constant; θ_i represents the country-specific effect; and ε_{it} is the disturbance term.

The strict exogeneity of the time-invariant variables will be supported by the results from Sargan overidentification and the Hansen J tests (Agyei et al., 2021; Adeoye et al., 2020; Boateng, Asongu, Akamavi, & Tchamyou, 2018).

Practically, economic growth – measured by the growth rate of gross per capita income for a given economy – is influenced by several macroeconomic variables or factors. The degree of effect or impact for each macroeconomic determinant of economic growth is largely economy-dependent due to inter alia, differences in governance systems, cultural diversity, and stability of the economy. The roles of technological innovation measures, industrialization, and country-specific factors, although significant to predict economic growth, such significant predictive powers may be supplemented by principal factors – such as physical capital accumulation, human capital accumulation, GDP, trade openness, inflation, and government expenditure which are common to all countries – that are common to all countries and empirically determined to be significant determining factors of economic growth. This inclusion of these variables as controls stems from the empirical literature (e.g., see, Adeoye, Nwokolo, & Igboanugo, 2020; Idun, 2021; etc.). Therefore, in the light of rightly specifying the model, there is the need for such factors to be controlled for by the study.

2.3 Data and preliminary analysis

The researcher obtained data on financial development (Domestic credit to the private sector, broad money to GDP, and liquid liability to GDP), sustainable development, and industrialisation from the World Development Indicators [WDI] (2020). The study period falls from 2010 to 2019 due to the availability of data from the WDI (2020). Thus, the study period and sampled countries were based on available data. Due to data constraints, an unbalanced panel made up of 48 countries over the period 2010-2019 was used in the data processing and estimation of results. The list of countries involved in the sample included sub-Saharan African countries with available data as reported in the WDI. As of 2020, the list of 48 African countries captured in the WDI report is presented in Appendix.

2.3.1 Descriptive statistics

Table 2.2 describes the statistical properties of the data, detailing the number of observations, average (mean) values, the minimum and maximum observations, and the standard deviation of the mean values over the period 2010 to 2019. Note that due to missing values, countries with insufficient data are eliminated in the estimations in Stata and, hence, the reason why the number of countries reported in the various models in the empirical results section is less than 48.

Table 2.2: Descriptive statistics

Variable	Observations	Mean	Std. Dev.	Min	Max
GDPPC	432	2282.291	2949.427	208.0747	18254.1
MVA	431	3.86e+09	9.39e+09	1.67e+07	5.89e+10
BM	455	34.88232	23.70984	9.020461	176.7889
DomCrdtP	445	22.23964	22.35156	.4976014	128.8498
DomCrdtB	458	20.57777	17.02659	.4976022	106.2603
Inflation	459	8.395313	24.4044	-4.294873	379.9996
TO	434	.0629443	.0546393	.0004889	.3714269
MSc	467	74.87085	37.60329	5.843835	198.1522
Population	472	2.05e+07	3.12e+07	87441	2.01e+08

Notes: GDPPC is GDP per capita; MVA is manufacturing value-added; BM is broad money; DomCrdtP is domestic credit to the private sector; DomCrdtB is domestic credit to the private sector by banks; TO is trade openness; and MSc is the mobile-cellular subscription per 100 people. Variables with scientific notations indicate that figures are in tens of millions (e+07), hundreds of millions (e+08), and trillions (e+10).

The average GDP per capita (GDPPC) over the sample period amounted to US$2282.291 with a huge standard deviation of US$2949.427, suggesting a high level of disparity in the levels of income distribution in Africa. This is evidenced by the minimum and maximum GDPPC of approximately US$208 and US$18,254.1 respectively. Among the sampled African countries, the average value-added from the manufacturing sector (MVA) from 2010 to 2019 was recorded at around US$3.86 billion. The huge disparity between the industrialisation levels of African economies is depicted by the high deviation from the average in terms of MVA. Concerning financial development, the ratio of broad money to GDP averaged 34.88. The proportion of GDP representing domestic credit to the private sector averaged 22.24 while that of domestic credit to the private sector by banks averaged 20.58 with a moderate standard deviation. Inflation rates among the sampled African countries averaged 8.4% with minimum and maximum values approximating -4.3% and 380%, respectively. The openness of trade (TO) measured around an average of 0.06, confirming that African countries are less open to international markets (Aderomou & Sall, 2019).

The total population of the sampled countries over the period averaged approximately 20.5 million. ICT infrastructure, proxied by mobile cellular subscriptions (MSc) (per 100 people) averaged approximately 75 over the studied period. This communicates a satisfactory and promising level of ICT infrastructure among African countries. Khan, Peng and Li (2019) contend that infrastructure is a significant predictor of economic and financial development among countries.

2.3.2 Pairwise correlations

As part of the statistical properties of the dataset, the correlation statistics are presented in Table 2.3 This is needed to examine the extent and significance of the unconditional correlations between the explanatory variables. Besides, the degree of multicollinearity among the studied variables, if any, could be assessed through correlation statistics.

Table 2.3: Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) L.lnGDPPC	1.000									

(2) lnGDPPC	0.999	1.000								
	(0.000)									
(3) lnMVA	0.350	0.361	1.000							
	(0.000)	(0.000)								
(4) BM	0.356	0.362	-0.160	1.000						
	(0.000)	(0.000)	(0.001)							
(5) DomCrdtP	0.496	0.501	0.205	0.664	1.000					
	(0.000)	(0.000)	(0.000)	(0.000)						
(6) DomCrdtB	0.495	0.504	0.063	0.724	0.921	1.000				
	(0.000)	(0.000)	(0.197)	(0.000)	(0.000)					
(7) Inflation	-0.035	-0.036	0.060	-0.028	-0.121	-0.147	1.000			
	(0.492)	(0.461)	(0.212)	(0.562)	(0.012)	(0.002)				
(8) TO	-0.526	-0.513	-0.417	-0.133	-0.256	-0.251	-0.045	1.000		
	(0.000)	(0.000)	(0.000)	(0.006)	(0.000)	(0.000)	(0.353)			
(9) MSc	0.615	0.617	0.109	0.279	0.468	0.480	-0.149	-0.345	1.000	
	(0.000)	(0.000)	(0.025)	(0.000)	(0.000)	(0.000)	(0.002)	(0.000)		
(10) lnPopulation	-0.381	-0.373	0.705	-0.414	-0.125	-0.272	0.104	0.038	-0.272	1.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.008)	(0.000)	(0.026)	(0.431)	(0.000)	

Notes: L.lnGDPPC is the lag of the natural logarithm transformation of GDP per capita; lnGDPPC is the natural logarithm transformation of GDP per capita; MVA is manufacturing value-added; BM is broad money; DomCrdtP is domestic credit to the private sector; DomCrdtB is domestic credit to the private sector by banks; TO is trade openness; and MSc is the mobile-cellular subscription per 100 people.

The pairwise correlations between the explanatory variables are in low to moderate magnitudes with high statistical significance. This largely suggests that the estimation models could be specified without any issue of multicollinearity. With a rule of thumb of 0.7 (Agyei et al., 2021), the issue of multicollinearity could be dismissed in this case. Thus, the inclusion of these regressors in the various specified models is appropriate.

2.4. Empirical Results

This chapter examines whether the level of financial development complements the industrialisation agenda of the AU in boosting economic development. The main results under the system GMM paradigm are presented in this section in two parts. First, the relationship between industrialisation and economic development is examined followed by an analysis of how financial development complements the relationship between industrialisation and economic development.

2.4.1. Effect of industrialisation and financial development on economic development

The effect of industrialisation and financial development on economic development is presented in 3 models in Table 2.4. Models M1 (column 1), M2 (column 2), and M3 (column 3) are distinct proxies of financial development, respectively for broad money (BM), domestic credit to the private sector (DomCrdtP), and domestic credit to the private sector by banks (DomCrdtB). Note that for robust estimations in Stata, countries with insufficient data are eliminated and, hence, explains why 38 countries were reported in all the models.

Table 2.4: Effect of industrialisation and financial development on economic development

Variables	M1 GDPPC	M2 GDPPC	M3 GDPPC
L.lnGDPPC	0.863***	0.854***	0.876***
	(0.0385)	(0.0425)	(0.0189)
lnMVA	0.132***	0.110***	0.0771***
	(0.0203)	(0.0353)	(0.0180)
BM	9.21e-05		
	(0.00129)		
DomCrdtP		0.00145**	
		(0.000621)	
DomCrdtB			0.00192***
			(0.000350)
Inflation	-0.000523***	-0.000440***	-0.000439***
	(9.23e-05)	(8.76e-05)	(4.70e-05)
TO	2.140***	0.220	0.0190
	(0.642)	(0.484)	(0.564)
MSc	0.000554**	0.000407	0.000139
	(0.000237)	(0.000244)	(0.000141)
lnPopulation	-0.119***	-0.107***	-0.0583***

	(0.0176)	(0.0352)	(0.0134)
Constant	-0.0429	0.407	0.171
	(0.405)	(0.251)	(0.399)
AR(1) [p-value]	0.184	0.144	0.154
AR(2) [p-value]	0.550	0.108	0.148
Sargan OIR	0.107	0.114	0.108
Hansen OIR	0.708	0.513	0.551
DHT for Instruments			
(a)GMM Instruments for levels			
H excluding group	0.456	0.452	0.840
Diff(null, H=exogenous)	0.718	0.485	0.337
(b) IV(years, eq(diff))			
H excluding group	0.643	0.448	0.488
Diff(null, H=exogenous)	0.744	0.665	0.654
Fisher	389602.10***	323627.43***	1.81e+06***
Instruments	22	22	22
Observations	324	317	326
Number of Countries	38	38	38

Notes: L.lnGDPPC is the lag of the natural logarithm transformation of GDP per capita; lnMVA is the natural logarithm transformation of manufacturing value-added; BM is broad money; DomCrdtP is domestic credit to the private sector; DomCrdtB is domestic credit to the private sector by banks; TO is trade openness; and MSc is the mobile-cellular subscription per 100 people.

The estimated system GMM models' post-diagnostic features need to be examined. In line with the existing literature (Adeoye et al., 2020; Asiamah et al., 2022a, 2022b) the diagnostics can be summarised as follows, First, there is the need to determine if there is a serial correlation between the first-order AR(1) and second-order AR(2) processes of the estimated models. The differenced residuals are subjected to the Arellano-Bond test for autocorrelation, which hypothesises that there is no autocorrelation. As the first difference variable is linked with the error term, the test for AR(1) process in first differences frequently does not support the null hypothesis. Yet, testing for AR(2) in initial differences is necessary to discover autocorrelation in levels. As the estimated models demonstrate, the null hypothesis of "no serial correlation" is not rejected, the results show that there is no serial correlation of AR(2) connected with the results in all models (M1, M2, and M3).

The null hypothesis in the Sargan test is that the instruments are all exogenous. As a result, the greater the Sargan statistic's *p*-value, the better. From the results, the study also fails to reject the null hypothesis that the instruments employed are exogenous, implying that the whole set of instruments utilised in all the estimated models is strictly exogenous. The Hansen J statistic with the same null hypothesis is also provided in robust estimations (in Stata software). These statistics are also not rejected, based on the resultant *p*-values. The null hypothesis that there is no significant harmony related to the regression result is tested using the fisher statistics. All the *f*-statistics were likewise rejected, suggesting the resilience of the estimated models.

Indicatively, from Table 2.4, the diagnostics – in terms of autocorrelation, Sargan, and Hansen J-tests, and the number of instruments vis-à-vis the number of observations and cross-sections – suggest that exogenous instruments were employed and the models were not constrained by instrument proliferation (Adeoye et al., 2020; Agyei et al., 2021). As a result, to a large extent, there is an indication that the models were well specified.

The a priori hypothesis that economic development is a dynamic variable is confirmed by the results in Table 2.4. That is, the lag dependent variable (L.lnGDPPC), is a significant predictor of the dependent variable (lnGDPPC) in all models. Indicatively, across M1, M2, and M3, the first lag of the dependent variable predicts approximately 0.863, 0.854, and 0.876 unit changes in the dependent variable. Thus, the current levels of economic development are highly dependent on the previous levels. The implication is that, when managed efficiently, present levels of economic development in Africa could translate positively into higher levels in subsequent periods. Likewise, if poor economic management activities are undertaken by governments, there is a tendency that future year levels of economic development will be greatly impacted.

On this premise, the findings in this chapter support the hypothesis that the lag dependent variable (previous year's level of economic development) is a significant positive predictor of the dependent variable (current level of economic development). Therefore, it is not trivial to examine the effect of industrialisation and financial development on economic development under a dynamic paradigm.

From Table 2.4, I found that industrialisation, proxied by manufacturing value added (lnMVA), significantly contributes to economic development. Specifically, in models 1-3 (M1, M2, and M3), the effect of industrialisation on economic development is reported at 0.132, 0.110, and 0.0771, respectively. All estimates are significant at the 1% level (i.e., $p < 0.001$). This means that industrial development is a significant driver of economic development.

Furthermore, the relationship between financial development and economic development was found positive for all proxies of financial development. In model 1 (M1), where financial development is proxied by broad money (BM), the effect of BM on GDP per capita (GDPPC) approximates to 9.21e-05 (at $p > 0.10$); when financial development is proxied by domestic credit to the private sector (DomCrdtP), the effect of DomCrdtP on GDPPC approximates to 0.00145 (at $p < 0.05$), and given domestic credit to the private sector by banks (DomCrdtB) as a proxy of financial development, the effect of DomCrdtB on GDPPC approximates to 0.00192 (at $p < 0.001$). The findings suggest that financial development positively impacts economic development. Except for broad money, the estimates for DomCrdtP and DomCrdtB are statistically significant and imply that contained in the same model, industrialisation and financial development are both significant predictors of economic development in Africa.

Additionally, in respect of the control variables, the results reveal an inverse relationship between inflation and economic development. Specifically, a percentage change in inflation results in a 0.000523% (0.000440 for M2 and 0.000439 for M3) change in economic development among 38 African economies. All estimates bear statistical significance at the 1% level (i.e., $p < 0.001$). The results further reveal that trade openness significantly drives economic development in model M1 ($\beta = 2.140$; $p < 0.001$). Thus, a percentage change in trade openness brings about a 2.14% change in economic development (proxied by GDP per capita). Similar results are revealed for models M2 and M3, but they are statistically nonsignificant.

ICT infrastructure, proxied by mobile cellular subscriptions (per 100 persons), has a positive effect on economic development ($\beta = 0.000554$; $p < 0.05$). Suggestively, a percentage change in ICT infrastructure would lead to a 0.000554% change in economic development in 38 African countries. The effect of population on economic development is reported at negative for models M1 ($\beta = -0.119$; $p < 0.001$), M2 ($\beta = -0.107$; $p < 0.001$), and M3 ($\beta = -0.0583$; $p < 0.001$). A given percentage change in population is expected to result in a change in GDP per capita. In model M1, a percentage change in population in a given African country could cause a change in the level of economic development by 0.119; 0.107 for model M2, and 0.0583 in model M3.

2.4.2. Moderating role of financial development in the relationship between industrialisation and economic development

The observation so far paves way for the assessment of how the interaction between industrialisation and financial development affects economic development in Africa. The direction and significance of this effect are essential to facilitate policy decisions. The results for this relationship, given the three initial models (M1, M2, and M3) were further developed into interaction models (M4, M5, and M6) in Table 2.5. It is worth noting that all the necessary diagnostic tests were duly passed, suggesting that the specification of the models was right. The interaction is defined as the product between the various pairs of continuous variables for industrialisation (MVA) and financial development (BM, DomCrdtP, and DomCrdtB). These are given in models 4, 5, and 6 (i.e., M4, M5, and M6) as c.lnMVA#c.BM ($\mathrm{lnMVA} \times \mathrm{BM}$), c.lnMVA#c.DomCrdtP ($\mathrm{lnMVA} \times \mathrm{DomCrdtP}$), and ($\mathrm{lnMVA} \times \mathrm{DomCrdtB}$), respectively.

It is important to note that given the prior relationships revealed in models M1, M2, and M3, the focus is now shifted to the various interaction variables, which are presented in bold fonts, in Table 2.5. However, the diagnostics in terms of autocorrelation, Sargan, and Hansen J-tests, and the number of instruments against the number of observations and cross-sections cannot be compromised. This is to ensure that the various models are not constrained by endogeneity and instrument proliferation (Agyei et al., 2021).

Table 2.5: Industrialisation, financial development and economic development

Variables	M4 GDPPC	M5 GDPPC	M6 GDPPC
L.lnGDPPC	0.892*** (0.0459)	0.893*** (0.0110)	0.891*** (0.0118)

lnMVA	0.00269	0.0611***	0.110***
	(0.0284)	(0.00779)	(0.0108)
BM	-0.0285*		
	(0.0144)		
c.lnMVA#c.BM	**0.00145****		
	(0.000664)		
DomCrdtP		-0.00755***	
		(0.00206)	
c.lnMVA#c.DomCrdtP		**0.000340*****	
		(9.00e-05)	
domcreditprivatebanks			-0.0154***
			(0.00534)
c.lnMVA#c.DomCrdtB			**0.000793*****
			(0.000251)
Inflation	-0.000410***	-0.000576***	-0.000522***
	(0.000102)	(2.74e-05)	(3.73e-05)
TO	-0.197	-0.708***	0.531*
	(0.358)	(0.249)	(0.291)
MSc	-0.000320	0.000543***	2.67e-05
	(0.000310)	(0.000143)	(5.51e-05)
lnPopulation	-0.0551*	-0.0757***	-0.0810***
	(0.0279)	(0.00687)	(0.00782)
Constant	1.611***	0.730***	-0.281
	(0.488)	(0.118)	(0.223)
AR(1) [p-value]	0.167	0.142	0.156
AR(2) [p-value]	0.143	0.120	0.118
Sargan OIR	0.177	0.104	0.215
Hansen OIR	0.887	0.564	0.637
DHT for Instruments			
(a)GMM Instruments for levels			
H excluding group	0.120	0.613	0.819
Diff(null, H=exogenous)	0.983	0.454	0.411
(b) IV(years, eq(diff))			
H excluding group	0.825	0.658	0.575
Diff(null, H=exogenous)	0.945	0.120	0.973
Fisher	572049.05***	2.40e+06***	1.32e+06***
Instruments	18	30	30
Observations	324	317	326
Number of Countries	38	38	38

Notes: L.lnGDPPC is the lag of the natural logarithm transformation of GDP per capita; lnMVA is the natural logarithm transformation of manufacturing value-added; BM is broad money; DomCrdtP is domestic credit to the private sector; DomCrdtB is domestic credit to the private sector by banks; TO is trade openness; and MSc is the mobile-cellular subscription per 100 people. c.lnMVA#c.BM is the interaction term between manufacturing value-added and broad money; c.lnMVA#c.DomCrdtP is *the interaction term between manufacturing added value and domestic credit to the private sector; and c.lnMVA#c.DomCrdtB is the interaction term between manufacturing added value and domestic credit to the private sector by banks. Bold values indicate the moderating (interaction) effect.*

The results in Table 2.5 indicate that there are significant relationships between the interaction variables and economic development. The interaction between MVA and BM results in a significant positive effect on GDPPC (β = 0.00145; p < 0.05); the effect of the interaction between MVA and DomCrdtP on GDPPC is recorded to be significantly positive (β = 0.000340; p < 0.001), and the interaction between MVA and DomCrdtB results in a significant positive effect on GDPPC (β = 0.000793; p < 0.001). It is essential to note that the interaction variable between industrialisation and financial development (proxied by BM) is significant in model M4 although the initial relationship without an interaction lacked statistical significance. This emphasises, in part, the complementary role of financial development in the relationship between industrialisation and economic development. The results imply that given a high level of financial development, the relationship between industrialisation and economic development could be significantly boosted.

The study further estimated that the marginal effects of the interaction terms and focus on them instead of the coefficients. Estimating the marginal effect of an interaction term in helps in understanding how changes in the value of one independent variable affect the dependent variable, given different values of another independent variable. This is important because it allows for a better understanding of the relationship between variables and can provide insights into how to optimize policy interventions. Additionally, it can help in detecting nonlinearities in the relationship between variables, which can improve model accuracy.

Table 2.6 Marginal effects of industrialisation, financial development and economic development

M4	M5	M6
$\frac{\Delta \mathrm{GDPPC}_{i,t}}{\Delta \mathrm{MVA}_{i,t}} = \beta_2 + \beta_4 \overline{\mathrm{c.BM}}$	$\frac{\Delta \mathrm{GDPPC}_{i,t}}{\Delta \mathrm{MVA}_{i,t}} = \beta_2 + \beta_6 \overline{\mathrm{c.DomCrdtP}}$	$\frac{\Delta \mathrm{GDPPC}_{i,t}}{\Delta \mathrm{MVA}_{i,t}} = \beta_2 + \beta_8 \overline{\mathrm{c.DomCrdtB}}$
$\frac{\Delta \mathrm{GDPPC}_{i,t}}{\Delta \mathrm{MVA}_{i,t}} = 0 + 0.00145\overline{\mathrm{c.BM}}$	$\frac{\Delta \mathrm{GDPPC}_{i,t}}{\Delta \mathrm{MVA}_{i,t}} = 0.0611 + 0.000340\overline{\mathrm{c.DomCrdtP}}$	$\frac{\Delta \mathrm{GDPPC}_{i,t}}{\Delta \mathrm{MVA}_{i,t}} = 0.110 + 0.000793\overline{\mathrm{c.DomCrdtB}}$
$\frac{\Delta \mathrm{GDPPC}_{i,t}}{\Delta \mathrm{MVA}_{i,t}} = 0 + 0.00145(34.88232)$	$\frac{\Delta \mathrm{GDPPC}_{i,t}}{\Delta \mathrm{MVA}_{i,t}} = 0.0611 + 0.000340(22.23964)$	$\frac{\Delta \mathrm{GDPPC}_{i,t}}{\Delta \mathrm{MVA}_{i,t}} = 0.110 + 0.000793(20.57777)$
$\boldsymbol{\frac{\Delta \mathrm{GDPPC}_{i,t}}{\Delta \mathrm{MVA}_{i,t}} = 0.050579364}$	$\boldsymbol{\frac{\Delta \mathrm{GDPPC}_{i,t}}{\Delta \mathrm{MVA}_{i,t}} = 0.068661478}$	$\boldsymbol{\frac{\Delta \mathrm{GDPPC}_{i,t}}{\Delta \mathrm{MVA}_{i,t}} = 0.126318172}$
$\overline{\mathrm{c.BM}} = mean\ of\ BM$	$\overline{\mathrm{c.DomCrdtP}} = mean\ of\ \mathrm{DomCrdtP}$	$\overline{\mathrm{c.DomCrdtB}} = mean\ of\ \mathrm{DomCrdtB}$

This shows that on the average with financial development as measured by broad money, domestic credit to the private sector, and domestic credit to the private sector by banks, a percentage increase in industrialization would increase economic development by 0.0506, 0.0686, and 0.1263 percent respectively. This implies that financial development has the potential to act as a catalyst for economic growth by amplifying the impact of industrialization on the economy. These findings highlight the importance of financial development in promoting sustainable economic growth and the need for policymakers to prioritize measures aimed at improving financial development in order to complement industrialization efforts. Overall, the results suggest that a combination of financial development and industrialization strategies is needed to achieve sustainable economic growth in developing economies. Policymakers should work to create an enabling environment for the manufacturing sector and prioritize the development of a resilient financial sector to complement the drive towards industrialization. These findings have important implications for policymakers in developing economies as they seek to attain the sustainable development goals.

2.5. Discussion

The complementary role of financial development in the nexus between industrialisation and economic development in Africa is examined. The results indicate that the level of economic growth could be boosted not only through industrialisation but also with the development of the financial sector. Specifically, this chapter finds that African economies could focus on financial development to boost industrialisation toward achieving economic development. The positive effect of the interaction variable suggests that more of the moderating variable (i.e., financial development) could result in high levels of the predicted variable (economic growth). Impliedly, extended levels of financial development would complement industrialisation in boosting economic development in Africa.

It is worth noting that not only could financial development boost economic development in Africa, but it could facilitate and improve the contributions made by the manufacturing sector through value additions towards economic development. Specifically, in a given African economy, increasing the money supply in forms that promotes investments in deposit and savings accounts, and gilts and treasury bills, will most likely boost financial sector activities.

High growth and level of activity in the financial sector result in available funds for financing the industrialisation agenda of firms. Manufacturing firms could add more value to attract and meet the demands of households in the African continent.

Similarly, industrialisation could be facilitated through the provision of credit to firms that are into manufacturing. Lucrative financial sector operations boost the confidence entrusted to firms. This is envisaged from the angle where households would be attracted to invest in guilts and treasury bills or deposit surplus funds for lucrative returns. By so doing, banks and other financial institutions could manage these funds to provide credit to the manufacturing sector, which would use such funds to increase the value additions they make towards economic development. Thus, the individual effects of broad money, domestic credit to the private sector, and domestic credit to the private sector by banks on the manufacturing value-added of African economies do not emanate by chance, as revealed by the empirical results. These findings lend support to previous findings in the context of developed global economies as reported by (Khan et al., 2019; Saidi & Hammami, 2015a, 2015b; Shahbaz & Lean, 2012).

In respect of the control variables, the results reveal that ICT infrastructure and trade openness are positive drivers of economic development among African countries whereas the population size and inflation negatively drive economic development, proxied by GDP per capita in a percentage change wise. The following intuitions could be drawn from these results. First, ICT infrastructure, proxied by mobile cellular subscriptions (per 100 people), could influence economic growth because development in ICT infrastructure reduces unnecessary delays and fastens decision-making among households and firms. By so doing, it is expected that fastened decision-making and more time at the disposal of firms could be used to improve the contributions of households and firms towards economic development. It is also important to note that ICT infrastructure could further improve industrialisation from the perspective of the value additions made by the manufacturing sector. An open economy is more likely to receive several contributions through official development assistance from foreign economies, direct foreign investments, and foreign portfolio investments (Ajide & Alimi, 2018; Efobi, Asongu, Okafor, Tchamyou, & Tanankem, 2016; Olayungbo & Quadri, 2019).

Khan et al. (2019) report a mix of positive and negative relationships between population and economic growth under the one-step and two-step system GMM techniques. Thus, the negative relationship between population and GDP per capita is not far from the existing evidence in the empirical literature. This is justified from the point of view that when the level of economic growth is not increased at margins greater than those of the growth in the population, the GDP per capita at any given point is likely to fall. Besides, it could be argued that the disparities between the African continent and globally developed countries in terms of governance structure or political systems, legal systems, culture, and religious backgrounds could lead to the differences in the relationship between population and economic development (Adeoye et al., 2020).

Given high levels of inflation, economic growth may be constrained as investments and savings could be compromised in high inflationary periods. Thus, whilst African economies could boost economic development through industrialisation and financial development, the impacts of other factors like population, inflation, ICT infrastructure, and trade openness cannot be sidelined as they may partially improve or lessen the level of economic development at any point in time.

2.6. Conclusions and recommendations

This chapter analysed the complementary role of financial development in the relationship between industrialisation and economic development in Africa. In the African context, the empirical literature is yet to explore the likelihood of industrialisation mitigating or stimulating the relationship between financial development and environmental degradation. The chapter sought to provide empirical evidence that facilitates empirical investigations into this theme. Hence, it examined the effect of industrialisation and financial development on the overall development of African economies. The system dynamic GMM technique was employed with a dataset covering 2010-2019 for 48 African countries.

Having controlled for the influence of ICT infrastructure, trade openness, inflation, and population size, the analysis covered two parts. First, the fundamental effects of industrialisation and financial development were examined in three separate models – M1 (when financial development is proxied by broad money), M2 (when financial development is proxied by domestic credit to the private sector), and M3 (when financial development is proxied by domestic credit to the private sector by banks). Industrialisation was proxied by manufacturing value-added whereas economic growth was proxied by GDP per capita. In the second part of the analysis, the complementary role of financial development on the relationship between industrialisation and economic development was analysed and this was measured based on the interaction between industrialisation and financial development proxies, yielding three models, M4, M5, and M6 as the corresponding models to M1, M2, and M3.

The results suggested that industrialisation is a significant positive driver of economic development. The role of financial development in the economic development agenda among African economies was also emphasised by the results. Although the relationships for all financial development proxies with economic development were positive, the significant relationships were between the proxies domestic credit to the private sector and domestic credit to the private sector by banks, and economic development. Notwithstanding, the importance of broad money in contributing to economic development in Africa cannot be shelved, as was evident in the moderation analysis.

Results from the moderation analysis suggested that the level of financial development, for all three proxies, significantly complements industrialisation towards improving economic growth. Thus, a more developed financial sector is potent in building an industrial economy which facilitates value addition in the manufacturing sector. It is recommended that the drive towards economic development through the industrialisation of economies is complemented by a resilient financial sector. A well-developed financial sector could facilitate the efficient channelling of funds from surplus spending units to deficit spending households and firms whose activities are directed towards adding value to their operations.

Furthermore, while trade openness and ICT infrastructure are a positive boost for economic development, inflation and population size negatively drive economic growth among African economies. Essentially, it must be noted that effective management of the current levels of economic development would significantly determine future years' level of economic development. The findings imply that the levels of economic development should be managed in such a manner that yields higher margins above the margins of increments in total population. Economic and policy management in African states should therefore incorporate proactive and effective management practices hinged on infrastructural and financial development to collectively build and grow the African continent towards the attainment of sustainable and/or millennium development goals S/MDGs.

Findings from this chapter suggest that the level of economic development among African economies could be boosted through industrialisation and complemented by financial development. Given the focus and emphasis of the AU on sustainable development, the findings from this chapter pave additional means to assess the extent to which the dimensions of economic development – in the context of sustainability – are affected by industrialisation and financial development.

CHAPTER THREE

FINANCIAL DEVELOPMENT, TECHNOLOGICAL INNOVATION, AND SUSTAINABLE DEVELOPMENT

3.1 Introduction

With insights from the previous chapter, this chapter examines the interactive role of technological innovation in the relationship between financial development and sustainable development in sub-Saharan Africa. Findings from the second chapter indicated that the level of economic development among African economies could be boosted through industrialisation and complemented by financial development. This lays a good foundation for the assessment of the extent to which the dimensions of economic development – in the context of sustainability – are affected by industrialisation and financial development.

The financial sector plays a role in how industrialisation leads to company innovation in all of these cases. According to Romer (1990), firms' determination to receive rent from an intellectual property on new product creation drives economic progress. Firms generate improved product types that fuel economic expansion via research and development. The financial sector invests in new screening technologies that can identify companies that can use industrialisation infrastructure to innovate and grow their businesses. Evidence from empirical research on the financial sector and economic growth also implies that nations can leverage their level of financial development to import technical innovation, allowing them to expand quicker and catch up to high-income countries in terms of per capita income. In the spirit of the Schumpeterian growth theory, countries with established financial markets may rely on financial development to stimulate financial and technical innovation, resulting in increased productivity (Aghion & Howitt, 1992; King & Levine, 1993; Levine, 1991; Levine, 2005, Aghion, Howitt & Mayer-Foulkes, 2005, Idun & Aboagye, 2014, Laeven, Levine & Michalopoulos, 2015, Idun, 2021).

According to the literature, a high degree of financial growth is linked to the importation of technical innovation to enhance a country's output. More empirical works show that technological innovation promotes economic development or generates crises in the real economy that stifle growth or usher in a new era of progress. Sustainable development, on the other hand, extends beyond economic growth. Even if the need for sustainable financial growth has become stronger in recent years, it is still unknown how financial development promotes technology innovation aimed at enhancing environmental preservation. As a result, because it provides private sector credits, diversifies intermediation risks, reduces transactions, and boosts liquidity in the economy, financial development is critical for economic growth, industry productivity, technological innovation, technological infusion, and sustainable economic growth.

As previously mentioned, the African Union strives for sustainable development, but in the African context, the researcher has yet to find a study that examines the role of finance in national innovation in the pursuit of sustainable development. The argument for Africa is significant because, despite abundant natural resources, the continent's economies have failed to incorporate technical innovation into long-term prosperity. Existing research focused on the effect of debt finance on economic growth (see, for example, Idun, 2021). The goal of this chapter is to investigate whether allocating financial resources to businesses can help boost national innovation, which in turn can help boost productivity, societal human capital capacity, and environmental sustainability.

Given that industrialisation, which results from financial development, could result in positive and/or negative externalities (see, for example, Abbasi & Riaz, 2016; Abokyi, Appiah-Konadu, Abokyi, & Oteng-Abayie, 2019; Acheampong, 2019), it is essential to empirically examine the potential role of industrialisation to influence the magnitude, strength, and direction of the relationship between financial development and sustainable development. Per the extant literature thus far, no empirical study has explored the likelihood that industrialisation (which is a desirable end) can mitigate or stimulate the relationship between financial development and sustainable development (which is undesirable) in the arena of developing economies. This knowledge gap is abridged by the empirical investigations in this chapter. In the African context, this chapter investigates whether the level of financial development complements the industrialisation agenda of the AU in boosting economic development without harming social and ecological sustainability.

3.2. Methodology

This chapter employs the systems dynamic panel general methods of moments (GMM) technique to analyse the interactive effect of technological innovation in the nexus between financial development and sustainable development. The system GMM technique has several advantages that make its usage preferred to other estimation techniques such as the Ordinary Least Squares (OLS) or pooled OLS, fixed and random effect models. Indicatively, the GMM approach uses a large number of data points, increasing degrees of freedom and reducing collinearity among explanatory variables, improving the efficiency of econometric estimates and allowing analysis of a variety of economic questions that are not detectable through cross-sectional or time-series data analysis (Agyei & Idan, 2022; Agyei et al., 2021; Hsiao, 2022; 2007). These features make the method appealing to this research.

Under the GMM, the following basic estimation models are specified for the relationships between financial development and sustainable development taken intuition form previous studies and theories guiding the study (Aghion & Howitt, 1992; King & Levine, 1993; Levine, 1991; Levine, 2005, Aghion, Howitt & Mayer-Foulkes, 2005, Idun & Aboagye, 2014, Laeven, Levine & Michalopoulos, 2015, Idun, 2021). To cover all dimensions of sustainability (viz. ecological, economic, and social), the estimation models are specified in line with the sustainability dimensions. Using broad money (BM) as a proxy for financial development, Models M1 and M2 (social sustainability), M3 (economic sustainability), and M4 and M5 (environmental/ecological sustainability) are specified. M1 and M2 express the basic relationships between financial development and social sustainability when the sustainable development index (SDI) and human development index (HDI) are proxies for social sustainability, respectively. M3 expresses the basic relationships between financial development and economic sustainability and M4 and M5 express the basic relationships between financial development and ecological or environmental sustainability when CO2 emissions and energy consumption, respectively are used as proxies for environmental or ecological sustainability. These models are summarised below.

$$SDI_{it} = \beta_1 l.SDI_{it} + \beta_2 BM_{it} + \beta_3 TFP_{it} + \beta_4 Inflation_{it} + \beta_5 TO_{it} + \beta_6 MSc_{it} + \beta_7 lnPopulation_{it} + \varepsilon_{it} \quad (3.1)$$

$$HDI_{it} = \beta_1 l.HDI_{it} + \beta_2 BM_{it} + \beta_3 TFP_{it} + \beta_4 Inflation_{it} + \beta_5 TO_{it} + \beta_6 MSc_{it} + \beta_7 lnPopulation_{it} + \varepsilon_{it} \quad (3.2)$$

$$GDPGPC_{it} = \beta_1 l.GDPGPC_{it} + \beta_2 BM_{it} + \beta_3 TFP_{it} + \beta_4 Inflation_{it} + \beta_5 TO_{it} + \beta_6 MSc_{it} + \beta_7 lnPopulation_{it} + \varepsilon_{it} \quad (3.3)$$

$$CO2_{it} = \beta_1 l.CO2_{it} + \beta_2 BM_{it} + \beta_3 TFP_{it} + \beta_4 Inflation_{it} + \beta_5 TO_{it} + \beta_6 MSc_{it} + \beta_7 lnPopulation_{it} + \varepsilon_{it} \quad (3.4)$$

$$ENGCO_{it} = \beta_1 l.lnENGCO_{it} + \beta_2 BM_{it} + \beta_3 TFP_{it} + \beta_4 Inflation_{it} + \beta_5 TO_{it} + \beta_6 MSc_{it} + \beta_7 lnPopulation_{it} + \varepsilon_{it} \tag{3.5}$$

where the full names of the variables, their measure, and data sources are detailed in Table 3.1.

To test the interactive effect of technological innovation (proxied with total factor productivity (TFP)) in the basic relationships between financial development and sustainable development, the interaction terms – between total factor productivity (TFP) and the broad money (BM) as a proxy of financial development – are introduced and specified in models M6 to M10 correspondingly for M1 to M5 as follows:

$$SDI_{it} = \beta_1 l.SDI_{it} + \beta_2 BM_{it} + \beta_3 TFP_{it} + \beta_4 (BM \times TFP)_{it} + \beta_5 Inflation_{it} + \beta_6 TO_{it} + \beta_7 MSc_{it} + \beta_8 lnPopulation_{it} + \varepsilon_{it} \tag{3.6}$$

$$HDI_{it} = \beta_1 l.HDI_{it} + \beta_2 BM_{it} + \beta_3 TFP_{it} + \beta_4 (BM \times TFP)_{it} + \beta_5 Inflation_{it} + \beta_6 TO_{it} + \beta_7 MSc_{it} + \beta_8 lnPopulation_{it} + \varepsilon_{it} \tag{3.7}$$

$$GDPGPC_{it} = \beta_1 l.GDPGPC_{it} + \beta_2 BM_{it} + \beta_3 TFP_{it} + \beta_4 (BM \times TFP)_{it} + \beta_5 Inflation_{it} + \beta_6 TO_{it} + \beta_7 MSc_{it} + \beta_8 lnPopulation_{it} + \varepsilon_{it} \tag{3.8}$$

$$CO2_{it} = \beta_1 l.CO2_{it} + \beta_2 BM_{it} + \beta_3 TFP_{it} + \beta_4 (BM \times TFP)_{it} + \beta_5 Inflation_{it} + \beta_6 TO_{it} + \beta_7 MSc_{it} + \beta_8 lnPopulation_{it} + \varepsilon_{it} \tag{3.9}$$

$$ENGCO_{it} = \beta_1 l.lnENGCO_{it} + \beta_2 BM_{it} + \beta_3 TFP_{it} + \beta_4 (BM \times TFP)_{it} + \beta_5 Inflation_{it} + \beta_6 TO_{it} + \beta_7 MSc_{it} + \beta_8 lnPopulation_{it} + \varepsilon_{it} \tag{3.10}$$

where the full names of the variables, their measure, and data sources are detailed in Table 3.1.

Using domestic credit to private sector and domestic credit to private sector by banks as proxies for financial development, the following additional basic models were specified. Models M11 to M15 test the relationship between financial development and sustainable development when domestic credit to the private sector (DomCrdtP) is used as a proxy for financial development.

$$SDI_{it} = \beta_1 l.SDI_{it} + \beta_2 DomCrdtP_{it} + \beta_3 TFP_{it} + \beta_4 Inflation_{it} + \beta_5 TO_{it} + \beta_6 MSc_{it} + \beta_7 lnPopulation_{it} + \varepsilon_{it} \tag{3.11}$$

$$HDI_{it} = \beta_1 l.HDI_{it} + \beta_2 DomCrdtP_{it} + \beta_3 TFP_{it} + \beta_4 Inflation_{it} + \beta_5 TO_{it} + \beta_6 MSc_{it} + \beta_7 lnPopulation_{it} + \varepsilon_{it} \tag{3.12}$$

$$GDPGPC_{it} = \beta_1 l.GDPGPC_{it} + \beta_2 DomCrdtP_{it} + \beta_3 TFP_{it} + \beta_4 Inflation_{it} + \beta_5 TO_{it} + \beta_6 MSc_{it} + \beta_7 lnPopulation_{it} + \varepsilon_{it} \tag{3.13}$$

$$CO2_{it} = \beta_1 l.CO2_{it} + \beta_2 DomCrdtP_{it} + \beta_3 TFP_{it} + \beta_4 Inflation_{it} + \beta_5 TO_{it} + \beta_6 MSc_{it} + \beta_7 lnPopulation_{it} + \varepsilon_{it} \tag{3.14}$$

$$ENGCO_{it} = \beta_1 l.lnENGCO_{it} + \beta_2 DomCrdtP_{it} + \beta_3 TFP_{it} + \beta_4 Inflation_{it} + \beta_5 TO_{it} + \beta_6 MSc_{it} + \beta_7 lnPopulation_{it} + \varepsilon_{it} \tag{3.15}$$

where the full names of the variables, their measure, and data sources are detailed in Table 3.1.

For these models (i.e., M11-M15), the respective interaction terms between financial development and technological development are specified in models M16 to M20.

$$SDI_{it} = \beta_1 l.SDI_{it} + \beta_2 DomCrdtP_{it} + \beta_3 TFP_{it} + \beta_4 (DomCrdtP \times TFP)_{it} + \beta_5 Inflation_{it} + \beta_6 TO_{it} + \beta_7 MSc_{it} + \beta_8 lnPopulation_{it} + \varepsilon_{it} \tag{3.16}$$

$$HDI_{it} = \beta_1 l.HDI_{it} + \beta_2 DomCrdtP_{it} + \beta_3 TFP_{it} + \beta_4 (DomCrdtP \times TFP)_{it} + \beta_5 Inflation_{it} + \beta_6 TO_{it} + \beta_7 MSc_{it} + \beta_8 lnPopulation_{it} + \varepsilon_{it} \quad (3.17)$$

$$GDPGPC_{it} = \beta_1 l.GDPGPC_{it} + \beta_2 DomCrdtP_{it} + \beta_3 TFP_{it} + \beta_4 (DomCrdtP \times TFP)_{it} + \beta_5 Inflation_{it} + \beta_6 TO_{it} + \beta_7 MSc_{it} + \beta_8 lnPopulation_{it} + \varepsilon_{it} \quad (3.18)$$

$$CO2_{it} = \beta_1 l.CO2_{it} + \beta_2 DomCrdtP_{it} + \beta_3 TFP_{it} + \beta_4 (DomCrdtP \times TFP)_{it} + \beta_5 Inflation_{it} + \beta_6 TO_{it} + \beta_7 MSc_{it} + \beta_8 lnPopulation_{it} + \varepsilon_{it} \quad (3.19)$$

$$ENGCO_{it} = \beta_1 l.lnENGCO_{it} + \beta_2 DomCrdtP_{it} + \beta_3 TFP_{it} + \beta_4 (DomCrdtP \times TFP)_{it} + \beta_5 Inflation_{it} + \beta_6 TO_{it} + \beta_7 MSc_{it} + \beta_8 lnPopulation_{it} + \varepsilon_{it} \quad (3.20)$$

where the full names of the variables, their measure, and data sources are detailed in Table 3.1.

Similarly, Models M21 to M25 test the relationship between financial development and sustainable development when domestic credit to the private sector by banks (DomCrdtB) is used as a proxy for financial development.

$$SDI_{it} = \beta_1 l.SDI_{it} + \beta_2 DomCrdtB_{it} + \beta_3 TFP_{it} + \beta_4 Inflation_{it} + \beta_5 TO_{it} + \beta_6 MSc_{it} + \beta_7 lnPopulation_{it} + \varepsilon_{it} \quad (3.21)$$

$$HDI_{it} = \beta_1 l.HDI_{it} + \beta_2 DomCrdtB_{it} + \beta_3 TFP_{it} + \beta_4 Inflation_{it} + \beta_5 TO_{it} + \beta_6 MSc_{it} + \beta_7 lnPopulation_{it} + \varepsilon_{it} \quad (3.22)$$

$$GDPGPC_{it} = \beta_1 l.GDPGPC_{it} + \beta_2 DomCrdtB_{it} + \beta_3 TFP_{it} + \beta_4 Inflation_{it} + \beta_5 TO_{it} + \beta_6 MSc_{it} + \beta_7 lnPopulation_{it} + \varepsilon_{it} \quad (3.23)$$

$$CO2_{it} = \beta_1 l.CO2_{it} + \beta_2 DomCrdtB_{it} + \beta_3 TFP_{it} + \beta_4 Inflation_{it} + \beta_5 TO_{it} + \beta_6 MSc_{it} + \beta_7 lnPopulation_{it} + \varepsilon_{it} \tag{3.24}$$

$$ENGCO_{it} = \beta_1 l.lnENGCO_{it} + \beta_2 DomCrdtB_{it} + \beta_3 TFP_{it} + \beta_4 Inflation_{it} + \beta_5 TO_{it} + \beta_6 MSc_{it} + \beta_7 lnPopulation_{it} + \varepsilon_{it} \tag{3.25}$$

where the full names of the variables, their measure, and data sources are detailed in Table 3.1.

For these models (i.e., M21-M25), the respective interaction terms between financial development and technological development are specified in models M26 to M30.

$$SDI_{it} = \beta_1 l.SDI_{it} + \beta_2 DomCrdtB_{it} + \beta_3 TFP_{it} + \beta_4 (DomCrdtB \times TFP)_{it} + \beta_5 Inflation_{it} + \beta_6 TO_{it} + \beta_7 MSc_{it} + \beta_8 lnPopulation_{it} + \varepsilon_{it} \tag{3.26}$$

$$HDI_{it} = \beta_1 l.HDI_{it} + \beta_2 DomCrdtB_{it} + \beta_3 TFP_{it} + \beta_4 (DomCrdtB \times TFP)_{it} + \beta_5 Inflation_{it} + \beta_6 TO_{it} + \beta_7 MSc_{it} + \beta_8 lnPopulation_{it} + \varepsilon_{it} \tag{3.27}$$

$$GDPGPC_{it} = \beta_1 l.GDPGPC_{it} + \beta_2 DomCrdtB_{it} + \beta_3 TFP_{it} + \beta_4 (DomCrdtB \times TFP)_{it} + \beta_5 Inflation_{it} + \beta_6 TO_{it} + \beta_7 MSc_{it} + \beta_8 lnPopulation_{it} + \varepsilon_{it} \tag{3.28}$$

$$CO2_{it} = \beta_1 l.CO2_{it} + \beta_2 DomCrdtB_{it} + \beta_3 TFP_{it} + \beta_4 (DomCrdtB \times TFP)_{it} + \beta_5 Inflation_{it} + \beta_6 TO_{it} + \beta_7 MSc_{it} + \beta_8 lnPopulation_{it} + \varepsilon_{it} \tag{3.29}$$

$$ENGCO_{it} = \beta_1 l.lnENGCO_{it} + \beta_2 DomCrdtB_{it} + \beta_3 TFP_{it} + \beta_4 (DomCrdtB \times TFP)_{it} + \beta_5 Inflation_{it} + \beta_6 TO_{it} + \beta_7 MSc_{it} + \beta_8 lnPopulation_{it} + \varepsilon_{it} \tag{3.30}$$

where the full names of the variables, their measure, and data sources are detailed in Table 3.1.

Table 3.1: Meaning, measure, and data sources of variables

Variable	Full name and measure	Source
SDI_{it}	Sustainable development index for country i at time t.	UNCTAD (2020)
HDI_{it}	Human development index for country i at time t.	UNDP
$lnGDPGPC_{it}$	Proxy of economic sustainability, measured as the natural logarithm transformation of GPD growth per capita for country i at time t.	WDI (2020)
$CO2_{it}$	CO_2 emissions, measured as the CO2 emissions in metric tons per capita for country i at time t.	WDI (2020)
$lnENGCO_{it}$	Energy consumption, measured as the natural logarithm of energy consumption per 100 people for country i at time t.	
BM_{it}	First proxy of financial development, measured as the share of broad money to GDP for country i at time t. It provides insights into the depth and efficiency of a country's financial system, as it captures the extent to which financial intermediaries are able to mobilize savings and allocate credit to productive sectors of the economy.	WDI (2020)
$DomCrdtP_{it}$	The second proxy of financial development – is measured as the domestic credit to the private sector (% of GDP) for country i at period t. It provides insight into the level of financial intermediation and access to credit within a country's economy, which can be important factors for promoting economic growth and development. This measure reflects the amount of credit extended by financial	WDI (2020)

	institutions to private borrowers, which can be indicative of the level of financial sector development and its ability to support investment and entrepreneurship.	
$DomCrdtB_{it}$	The third proxy of financial development is measured as the domestic credit to the private sector by banks (% of GDP) for country i at period t. It provides a useful proxy for the level of financial intermediation and access to credit available to businesses and individuals in that country, which are key drivers of economic growth and development.	WDI (2020)
$Inflation_{it}$	Inflation rate – measured as the consumer price index (annual %) for country i at period t. it measures the change in prices of a basket of goods and services consumed by households, reflecting changes in the cost of living over time, and allowing for comparisons of inflation rates across countries and time periods.	WDI (2020)
TO_{it}	Trade openness, measured as the sum of imports and exports as a % of GDP for country i at period t. It provides an indication of the degree to which a country is engaged in international trade, which is an important factor in economic development. This measure can help to explain the extent to which a country benefits from global markets and can be used to evaluate the impact of trade policies on economic growth.	WDI (2020)
MSc_{it}	ICT infrastructure, measured as the mobile cellular subscriptions per 100 people for country i at period t. It	WDI (2020)

	provides a useful measure of a country's level of access to mobile communications technology, which is an important driver of economic growth and development, enabling access to information and services, supporting business activities, and facilitating social interactions.	
$lnPopulation_{it}$	The natural logarithm transformation of the total population for country i at period t.	WDI (2020)

The general form of the system GMM estimation used in specifying Equations 3.1–3.30 is given as:

$$SDI_{it} = \gamma_0 + \gamma_1 SDI_{it-\tau} + \sum_{h=1}^{n} \gamma_h W_{h,it-\tau} + \theta_i + \mu_i + \varepsilon_{it} \tag{3.31}$$

$$SDI_{it} - SDI_{it-\tau} = \gamma_1(SDI_{it-\tau} - SDI_{it-2\tau}) + \sum_{h=1}^{n} \gamma_h \left(W_{h,it-\tau} - W_{h,it-2\tau}\right) + (\mu_t - \mu_{t-\tau}) + \varepsilon_{it-\tau} \tag{3.32}$$

where SDI_{it} represents the sustainable development index (or other sustainability dimensions – HDI, GDPGPC, CO2 and ENGCO) of country i at time $t; \gamma_0$ is a constant; W represents a vector of control variables (inflation, trade openness (TO), ICT infrastructure (mobile cellular subscriptions per 100 people), and population); τ signifies the coefficient of autoregression (which is equal to 1 for the specification); μ_t signifies the time-specific constant; θ_i represents the country-specific effect; and ε_{it} is the disturbance term.

The strict exogeneity of the time-invariant variables is supported by the results from Sargan overidentification and the Hansen J tests (Agyei et al., 2021; Adeoye et al., 2020; Boateng, Asongu, Akamavi, & Tchamyou, 2018).

3.3. Data and preliminary analysis

The researcher obtained data on financial development (Domestic credit to the private sector, broad money to GPD, and liquid liability to GDP), sustainable development (ecological/ environmental sustainability – CO2 emissions and energy consumption; social sustainability – sustainability development index and human development index; economic sustainability – GDP growth per capita), and technological innovation from the World Development Indicators [WDI] (2020). The study period falls from 2010 to 2019 due to the availability of data from the database of the WDI (2020). Thus, the study period and sampled countries were based on available data. Due to data constraints, an unbalanced panel made up of 48 countries over the period 2010-2019 was used in the data processing and estimation of results.

The list of countries involved in the sample included sub-Saharan African countries with available data and are reported on by the WDI. As of 2020, the list of SSA countries on which the WDI report data contained 48 countries. The list can be found in the Appendix section. These countries formed the cross-sections for the panel estimations carried out in this chapter.

3.3.1. Descriptive statistics

Table 3.2 describes the statistical properties of the data, detailing the number of observations, average (mean) values, the lowest (minimum) and highest (maximum) observations, and the standard deviation of the mean values over the sample period 2010 to 2019. Note that due to missing values, countries with insufficient data are eliminated in the estimations in Stata and, hence, the reason why the number of countries reported in the various models in the chapter's empirical results section is less than 48.

Table 3.2: Descriptive Statistics

Variable	Observations	Average	Std. Dev.	Min.	Max.
SDI	422	5.153483	6.49923	.61	36.31
HDI	480	.5234333	.0960687	.331	.804
GDPGPC	438	1.737594	4.238664	-36.55682	18.06597
CO2	432	.971532	1.733226	0	10.08859
ENGCO	121	692.203	648.8401	63.66971	3129.067
BM	455	34.88232	23.70984	9.020461	176.7889
DomCrdtP	445	22.23964	22.35156	.4976014	128.8498
DomCrdtB	458	20.57777	17.02659	.4976022	106.2603
TFP	260	.4541558	.2062977	.1643128	1.248934
Inflation	459	8.395313	24.4044	-4.294873	379.9996
TO	434	.0629443	.0546393	.0004889	.3714269
MSc	467	74.87085	37.60329	5.843835	198.1522
Population	472	2.05e+07	3.12e+07	87441	2.01e+08

Notes: SDI is sustainable development index; HDI is human development index; GDPPC is GDP per capita; ENGCO is energy consumption; BM is broad money; DomCrdtP is domestic credit to the private sector; DomCrdtB is domestic credit to the private sector by banks; TFP is total factor productivity; TO is trade openness; and MSc is the mobile-cellular subscription per 100 people.

The rated index in terms of sustainability (SDI) among the sampled sub-Saharan African countries averaged 5.15 over the period 2010-2019. The maximum and minimum rated indices of 36.31 and 0.61, respectively suggest high disparities in the level of social sustainability within the sub-region. It is not surprising that the rating on human development (HDI) was recorded at an average of 0.52 with maximum and minimum values of 0.331 and 0.804, respectively. In terms of economic sustainability, GDP growth per capita recorded an average of 1.74% which could standardly deviate around 4.24%. Some economies recorded negative growth in GDP per capita, suggesting that despite the highest positive growth rate of 18.07%, economic growth among SSA countries was hardly sustained for some countries over the period 2010-2019. Turning to ecological or environmental sustainability, CO2 emissions measured 0.97 metric tons per capita, which deviated around 1.73 metric tons per capita. Energy consumption was averagely 692 units per hundred people but could go as high as 3129 units per hundred people.

As a measure of technological innovation, the total factor productivity (TFP) of the sampled countries recorded an average of 0.45 with a standard deviation of 0.21 and maximum and minimum values of 1.25 and 1.64, respectively. Concerning financial development, the ratio of broad money to GDP averaged 34.88. The proportion of GDP representing domestic credit to the private sector averaged 22.24 while that of domestic credit to the private sector by banks averaged 20.58 with moderate standard deviations. Inflation rates among the sampled African countries averaged 8.4% with minimum and maximum values approximating -4.3% and 380%, respectively. The openness of trade (TO) measured around an average of 0.06, confirming that African countries are less open to international markets (Aderomou & Sall, 2019). The total population of the sampled countries over the period averaged approximately 20.5 million. ICT infrastructure, proxied with mobile cellular subscriptions (MSc) (per 100 people), averaged approximately 75 over the sample period 2010-2019. This evidences a satisfactory and promising level of ICT infrastructure among African countries. Khan, Peng and Li (2019) contend that infrastructure is a significant predictor of economic and financial development among countries.

3.3.2. Pairwise correlations

To supplement the statistical properties of the data, the correlation statistics are presented in Table 4.3 This is needed to examine the magnitude and significance of the unconditional correlations between the explanatory variables. Furthermore, the degree of multicollinearity among the studied variables, if any, could be assessed through correlation statistics.

It is worth noting that the pairwise correlations between the explanatory variables are in low to moderate magnitudes with high statistical significance. This largely suggests that the estimation models could be specified without any issue of multicollinearity. With a rule of thumb of 0.7 (Agyei et al., 2021; Agyei & Idan, 2022), the issue of multicollinearity could be dismissed in this case. Thus, the inclusion of these regressors in the various specified models is appropriate.

Table 3.3: Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
(1) SDI	1.000																	
(2) L.SDI	0.998	1.000																
	(0.000)																	
(3) HDI	0.671	0.675	1.000															
	(0.000)	(0.000)																
(4) L.HDI	0.669	0.671	0.999	1.000														
	(0.000)	(0.000)	(0.000)															
(5) GDPGPC	0.039	0.025	-0.026	-0.031	1.000													
	(0.438)	(0.636)	(0.580)	(0.535)														
(6) L. GDPGPC	0.050	0.044	-0.005	-0.020	0.382	1.000												
	(0.346)	(0.407)	(0.914)	(0.695)	(0.000)													
(7) CO2	0.592	0.606	0.643	0.658	-0.195	-0.166	1.000											
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)												
(8) L.CO2	0.592	0.592	0.641	0.643	-0.192	-0.195	0.995	1.000										
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)											
(9) lnENGCO	0.425	0.430	0.741	0.737	-0.012	0.024	0.735	0.726	1.000									
	(0.000)	(0.000)	(0.000)	(0.000)	(0.899)	(0.820)	(0.000)	(0.000)										
(10) L.lnENGCO	0.427	0.425	0.742	0.741	-0.098	-0.012	0.741	0.735	0.995	1.000								
	(0.000)	(0.000)	(0.000)	(0.000)	(0.302)	(0.899)	(0.000)	(0.000)	(0.000)									
(11) BM	0.459	0.466	0.441	0.458	0.084	0.079	0.272	0.290	0.126	0.157	1.000							
	(0.000)	(0.000)	(0.000)	(0.000)	(0.087)	(0.128)	(0.000)	(0.000)	(0.179)	(0.093)								
(12) DomCrdtP	0.407	0.411	0.577	0.577	0.009	0.017	0.545	0.550	0.539	0.543	0.664	1.000						
	(0.000)	(0.000)	(0.000)	(0.000)	(0.849)	(0.744)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)							
(13) DomCrdtB	0.496	0.498	0.617	0.615	0.055	0.061	0.405	0.411	0.484	0.482	0.724	0.921	1.000					
	(0.000)	(0.000)	(0.000)	(0.000)	(0.260)	(0.239)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)						

(14) TFP	0.528	0.525	0.675	0.673	0.074	0.095	0.460	0.447	0.532	0.521	0.639	0.519	0.646	1.000				
	(0.000)	(0.000)	(0.000)	(0.000)	(0.232)	(0.146)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)					
(15) Inflation	-0.063	-0.063	-0.087	-0.090	-0.134	0.010	-0.077	-0.075	-0.135	-0.155	-0.028	-0.121	-0.147	-0.012	1.000			
	(0.202)	(0.226)	(0.063)	(0.068)	(0.006)	(0.849)	(0.119)	(0.131)	(0.149)	(0.096)	(0.562)	(0.012)	(0.002)	(0.843)				
(16) TO	-0.331	-0.336	-0.594	-0.603	0.036	-0.006	-0.370	-0.376	-0.280	-0.305	-0.133	-0.256	-0.251	-0.581	-0.045	1.000		
	(0.000)	(0.000)	(0.000)	(0.000)	(0.466)	(0.914)	(0.000)	(0.000)	(0.002)	(0.001)	(0.006)	(0.000)	(0.000)	(0.000)	(0.353)			
(17) MSc	0.597	0.606	0.697	0.690	0.013	0.049	0.476	0.487	0.714	0.738	0.279	0.468	0.480	0.654	-0.149	-0.345	1.000	
	(0.000)	(0.000)	(0.000)	(0.000)	(0.793)	(0.344)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)	(0.000)		
(18) lnPopulation	-0.512	-0.513	-0.384	-0.388	0.134	0.148	-0.299	-0.300	-0.229	-0.245	-0.414	-0.125	-0.272	-0.296	0.104	0.038	-0.272	1.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.005)	(0.003)	(0.000)	(0.000)	(0.012)	(0.008)	(0.000)	(0.008)	(0.000)	(0.000)	(0.026)	(0.431)	(0.000)	

Notes: SDI is sustainable development index; L.SDI is the lag of sustainable development index; HDI is human development index; L.HDI is the lag of human development index; GDPGPC is GDP per capita; L.GDPGPC is the lag of GDP growth per capita; ENGCO is energy consumption; L.ENGCO is the lag of energy consumption; BM is broad money; DomCrdtP is domestic credit to the private sector; DomCrdtB is domestic credit to the private sector by banks; TFP is total factor productivity; TO is trade openness; and MSc is the mobile-cellular subscription per 100 people.

3.4. Empirical results

This chapter examines the interactive role of technological innovation in the relationship between financial development and sustainable development in sub-Saharan Africa. The main results under the system GMM paradigm are presented in this section in two parts. First, the influence of financial development and technological innovation on sustainable development is examined followed by an analysis of how the interaction between technological innovation and financial development affects the relationship between financial development and sustainable development among sub-Saharan African economies.

The results for the influence of financial development and technological innovation are presented in five models each for the three proxies of financial development. The results for each proxy of financial development are presented in turn. Before delving into the models, it is essential to assess how robust the models are. Essential diagnostics are carried out to determine how fit the models are and whether their specifications were right. The estimated system GMM models' post-diagnostic features need to be examined.

First, there is the need to determine if there is a serial correlation between the first-order AR(1) and second-order AR(2) processes of the estimated models. The differenced residuals are subjected to the Arellano-Bond test for autocorrelation, which hypothesises that there is no autocorrelation. As the first difference variable is linked with the error term, the test for AR(1) process in first differences frequently does not support the null hypothesis. Yet, testing for AR(2) in initial differences is necessary to discover autocorrelation in levels. As the estimated models (Tables 3.4 to 3.6) demonstrate that the null hypothesis of "no serial correlation" is not rejected, the results show that there is no serial correlation of AR(2) connected with the results in all models.

The null hypothesis in the Sargan test is that the instruments are all exogenous. As a result, the greater the Sargan statistic's *p*-value, the better. From the results, the study also fails to reject the null hypothesis that the instruments employed are exogenous, implying that the whole set of instruments utilised in all the estimated models is strictly exogenous. The Hansen J statistic with the same null hypothesis is also provided in robust estimations (in Stata software). These statistics are also not rejected, based on the resultant *p*-values. The null hypothesis that there is no significant harmony related to the regression result is tested using the fisher statistics. All the *f*-statistics were likewise rejected, suggesting the resilience of the estimated models. Indicatively, from all the results, the diagnostics – in terms of autocorrelation, Sargan, and Hansen J-tests, and the number of instruments vis-à-vis the number of observations and cross-sections – suggest that exogenous instruments were employed and the models were not constrained by instrument proliferation (Adeoye et al., 2020; Agyei et al., 2021). As a result, to a large extent, there is an indication that the models were well specified.

Furthermore, the a priori hypothesis that sustainable development is a dynamic variable is confirmed by the results in Tables 3.4 to 3.6. That is, the various lag-dependent variables (L.SDI, L.HDI, L.GDPGPC, L.CO2, and L.lnENGCO), are significant predictors of their main dependent variables (SDI, HDI, GDPGPC, CO2, and lnENGCO) in all models. Indicatively, across all models, the first lag of the dependent variable predicts a significant unit change in its main dependent variable. Thus, the current levels of sustainable development (regardless of the dimension) are significantly dependent on the previous levels ($\beta < 1$; $p < 0.001$). The implication is that, when managed efficiently, present levels of sustainable development in Africa could translate positively into higher levels in subsequent periods. Likewise, if poor sustainable activities are undertaken by governments, there is a tendency for future year levels of sustainability to be greatly impacted.

On this premise, the findings in this chapter support the hypothesis that the lag dependent variable (previous year's level of sustainable development) is a significant positive predictor of the dependent variable (current level of sustainable development). Therefore, it is not trivial to examine the effects of financial development and technological innovation on sustainable development using a dynamic estimator.

3.4.1. Effects of financial development and technological innovation on sustainable development with broad money as a proxy for financial development

When financial development is proxied with broad money, models M1 and M2 test the effects of financial development and technological innovation on social sustainability (i.e., the social dimension of sustainable development); model M3 tests the effects of financial development and technological innovation on economic sustainability (i.e., the economic dimension of sustainable development), and models M4 and M5 test the effects of financial development and technological innovation on ecological/environmental sustainability (i.e., the ecological/environmental dimension of sustainable development). Table 3.4 presents the results for models M1, M2, M3, M4, and M5 under columns 1, 2, 3, 4, and 5, respectively.

Table 3.4: Effects of financial development (broad money) and technological innovation on sustainable development

Sustainability dimension	Social		Economic	Environmental/ecological	
	M1	M2	M3	M4	M5
Variables	SDI	HDI	GDPGPC	CO2	ENGCO
L.SDI	0.862***				
	(0.0379)				
L.HDI		0.863***			
		(0.0263)			
L.GDPGPC			0.204***		
			(0.0170)		
L.CO2				0.999***	
				(0.0238)	
L.lnENGCO					0.908***
					(0.0300)
BM	-0.0387***	-0.000523***	-0.296***	-0.0143***	-0.00175**
	(0.00516)	(0.000132)	(0.0699)	(0.00294)	(0.000817)
TFP	5.245***	0.0514***	4.497	0.676**	0.0970
	(0.843)	(0.00953)	(5.256)	(0.288)	(0.169)
Inflation	-0.000985	1.83e-05	-0.0674***	-0.00452*	0.00134
	(0.000904)	(5.05e-05)	(0.00473)	(0.00221)	(0.00106)
TO	2.465	0.00573	12.40	1.136*	0.338*
	(3.659)	(0.0444)	(15.52)	(0.599)	(0.187)
MSc	0.00338**	6.25e-05	0.0435***	0.00125**	0.00180***
	(0.00160)	(4.64e-05)	(0.0117)	(0.000524)	(0.000272)
lnPopulation	-0.261*	-0.00218***	-0.909**	-0.0350**	0.00219
	(0.139)	(0.000743)	(0.390)	(0.0150)	(0.00899)
Constant	3.539	0.103***	20.43**	0.634**	0.412***
	(2.585)	(0.0245)	(7.588)	(0.287)	(0.137)
AR(1) [p-value]	0.111	0.004	0.143	0.080	0.193
AR(2) [p-value]	0.559	0.747	0.565	0.350	0.300

Sargan OIR	0.109	0.115	0.131	0.393	0.971
Hansen OIR	0.965	0.524	0.289	0.681	0.952
DHT for Instruments					
(a)GMM Instruments for levels	0.906	0.234	0.239	0.338	0.637
H excluding group	0.889	0.680	0.366	0.770	0.935
Diff(null, H=exogenous)					
(b) IV(years, eq(diff))					
H excluding group	0.953	0.446	0.270	0.610	0.925
Diff(null, H=exogenous)	0.619	0.896	0.376	0.815	0.759
Fisher	18949.26***	230916.71***	8998.19***	9549.87***	1.30e+06***
Instruments	22	22	22	22	18
Observations	219	228	228	206	70
Number of Countries	25	26	26	26	18

Notes: SDI is sustainable development index; L.SDI is the lag of sustainable development index; HDI is human development index; L.HDI is the lag of human development index; GDPGPC is GDP per capita; L.GDPGPC is the lag of GDP growth per capita; lnENGCO is the natural logarithm of energy consumption; L.lnENGCO is the lag of the natural logarithm of energy consumption; BM is broad money; TFP is total factor productivity; TO is trade openness; and MSc is the mobile-cellular subscription per 100 people.

From Table 3.4, the results indicate that financial development, proxied by broad money, has a significant negative effect on all dimensions of sustainable development. In terms of social sustainability, broad money (BM) negatively impacts sustainable development index (SDI) ($\beta = -0.0387$; $p < 0.001$) and human development index (HDI) ($\beta = -0.000523$; $p < 0.001$). For economic sustainability, BM significantly reduces GDP growth per capita (GDPGPC) ($\beta = -0.296$; $p < 0.001$). Similarly, in terms of environmental/ecological sustainability, BM negatively affects CO2 ($\beta = -0.0143$; $p < 0.001$) and ENGCO ($\beta = -0.00175$; $p < 0.05$). Thus, a unit increase in broad money, for instance, is likely to result in a 0.0387 and 0.00523 unit reduction in SDI and HDI, respectively. A unit increase in broad money stands the chance of reducing GDP per capita by 0.000523 units. Also, raising the level of broad money by a unit is associated with a 0.0143 and 0.00175 unit reduction in CO2 emissions and energy consumption, respectively.

Concerning technological innovation, the results indicate that total factor productivity (TFP) is positively associated with all dimensions of sustainability but the relationship is significant for social sustainability (SDI and HDI) and ecological/environmental sustainability (CO2). Indicatively, in terms of social sustainability, TFP positively influences sustainable development index (SDI) ($\beta = 5.245$; $p < 0.001$) and human development index (HDI) ($\beta = 0.0514$; $p < 0.001$). TFP's influence on economic sustainability (GDPGPC) is recorded at $\beta = 4.497$; $p > 0.1$. With regard to ecological/environmental sustainability, a unit change in an SSA country's TFP is found to be positively related with CO2 emissions ($\beta = 0.676$; $p < 0.001$) and ENGCO ($\beta = 0.097$; $p > 0.1$). Emphasising the significant relationships, the results suggest that a unit increase in technological innovation in SSA countries will result in 5.245, 0.0514, and 0.676 unit changes in SDI, HDI, and CO2 emissions, respectively.

On the control variables, a unit rise in the inflation rate is found to be associated with a significant unit reduction in economic sustainability (β = -0.0674; $p < 0.001$). ICT infrastructure, proxied with mobile cellular subscriptions (MSc), is also found to be positively related to all dimensions of sustainability at varying levels of statistical significance. Furthermore, population size is found to have a negative impact on sustainable development, also at varying levels of significance.

3.4.2. Effects of financial development and technological innovation on sustainable development with domestic credit to private sector as a proxy for financial development

When financial development is proxied with broad money, models M11 and M12 test the effects of financial development and technological innovation on social sustainability (i.e., the social dimension of sustainable development); model M13 tests the effects of financial development and technological innovation on economic sustainability (i.e., the economic dimension of sustainable development), and models M14 and M15 test the effects of financial development and technological innovation on ecological/environmental sustainability (i.e., the ecological/environmental dimension of sustainable development). Table 3.5 presents the results for models M11, M12, M13, M14, and M15 under columns 1, 2, 3, 4, and 5, respectively.

Table 3.5: Effects of financial development (domestic credit to private sector) and technological innovation on sustainable development

Sustainability dimension	Social		Economic	Environmental/ecological	
	M11	M12	M13	M14	M15
Variables	SDI	HDI	GDPGPC	CO2	ENGCO
L.SDI	0.844***				
	(0.0251)				
L.HDI		0.850***			
		(0.0308)			
L.GDPGPC			0.226***		
			(0.00596)		
L.CO2				0.890***	
				(0.00818)	
L.lnENGCO					0.858***
					(0.0349)
DomCrdtP	0.0106**	0.000208***	0.120***	0.00368***	0.00137*
	(0.00379)	(6.36e-05)	(0.0295)	(0.000394)	(0.000651)
TFP	1.616***	0.0316**	-18.54***	0.112**	0.0946
	(0.399)	(0.0116)	(4.364)	(0.0439)	(0.111)
Inflation	0.000137	3.62e-05***	-0.0418***	-0.000176	-0.000139
	(0.000478)	(9.97e-06)	(0.00289)	(0.000446)	(0.00161)
TO	0.505	-0.0558**	-5.243	0.0739	0.416
	(1.139)	(0.0232)	(15.25)	(0.152)	(0.463)
MSc	0.000386	2.58e-05	0.00167	0.000437***	0.00134***
	(0.00107)	(5.79e-05)	(0.00624)	(9.83e-05)	(0.000448)
lnPopulation	-0.329***	-0.00733***	-0.522	-0.00128	0.0265**
	(0.0636)	(0.00201)	(0.313)	(0.00210)	(0.0104)
Constant	5.251***	0.186***	15.24**	-0.0588	0.239
	(1.125)	(0.0386)	(6.690)	(0.0460)	(0.292)
AR(1) [p-value]	0.166	0.002	0.148	0.082	0.289
AR(2) [p-value]	0.523	0.644	0.476	0.521	0.287

Sargan OIR	0.156	0.262	0.303	0.132	0.980
Hansen OIR	0.101	0.424	0.429	0.500	0.972
DHT for Instruments					
(a)GMM Instruments for levels	0.815	0.681	0.331	0.508	-
H excluding group	0.035	0.282	0.485	0.441	-
Diff(null, H=exogenous)					
(b) IV(years, eq(diff))					
H excluding group	0.168	0.624	0.365	0.688	0.962
Diff(null, H=exogenous)	0.070	0.061	0.877	0.056	0.596
Fisher	115140.18***	365262.65***	25472.17***	226061.14***	882587.27***
Instruments	22	22	26	26	14
Observations	212	221	221	198	62
Number of Countries	25	26	26	26	16

Notes: SDI is sustainable development index; L.SDI is the lag of sustainable development index; HDI is human development index; L.HDI is the lag of human development index; GDPGPC is GDP per capita; L.GDPGPC is the lag of GDP growth per capita; lnENGCO is the natural logarithm of energy consumption; L.lnENGCO is the lag of the natural logarithm of energy consumption; DomCrdtP is domestic credit to private sector; TFP is total factor productivity; TO is trade openness; and MSc is the mobile-cellular subscription per 100 people.

From Table 3.5, the results indicate that financial development, proxied by domestic credit to private sector (DomCrdtP), has a significant positive effect on all dimensions of sustainable development. In terms of social sustainability, domestic credit to private sector (DomCrdtP) positively impacts sustainable development index (SDI) (β = 0.0106; $p < 0.05$) and human development index (HDI) (β = 0.000208; $p < 0.001$). For economic sustainability, DomCrdtP significantly improves GDP growth per capita (GDPGPC) (β = 0.12; $p < 0.001$). Similarly, in terms of environmental/ecological sustainability, DomCrdtP positively affects CO2 (β = 0.00368; $p < 0.001$) and energy consumption (ENGCO) (β = 0.00137; $p < 0.1$). Thus, a unit increase in domestic credit to private sector, for instance, is likely to result in a 0.0106 and 0.000208 unit increments in SDI and HDI, respectively. A unit increase in domestic credit to private sector stands the chance of increasing GDP per capita by 0.12 units. Also, raising the level of domestic credit to private sector by a unit is associated with a 0.000368 and 0.00137 unit appreciations in CO2 emissions and energy consumption, respectively.

Concerning technological innovation, the results indicate that total factor productivity (TFP) is positively associated with social and ecological/environmental dimensions of sustainability but with varied significance. Meanwhile, the effect of TFP on economic sustainability showed negative. Indicatively, in terms of social sustainability, TFP positively influences sustainable development index (SDI) (β = 1.616; $p < 0.001$) and human development index (HDI) (β = 0.0316; $p < 0.001$). TFP’s influence on economic sustainability (GDPGPC) is recorded at β = -18.54; $p < 0.001$. With regard to ecological/environmental sustainability, a unit change in an SSA country’s TFP is found to be positively related with CO2 emissions (β = 0.112; $p < 0.05$) and ENGCO (β = 0.0946; $p > 0.1$). Emphasising the significant relationships, the results suggest that a unit increase in technological innovation in SSA countries will result in a 1.616, 0.0316, and 0.112 unit change in SDI, HDI, and CO2 emissions, respectively.

On the control variables, a unit rise in the inflation rate is found to have mixed effects on economic sustainability. ICT infrastructure, proxied with mobile cellular subscriptions (MSc), is also found to be positively related to all dimensions of sustainability with the only differences being levels of statistical significance. Population size is found to have a negative impact on sustainable development.

3.4.3. Effects of financial development and technological innovation on sustainable development with domestic credit to private sector by banks as a proxy for financial development

When financial development is proxied with broad money, models M21 and M22 test the effects of financial development and technological innovation on social sustainability (i.e., the social dimension of sustainable development); model M23 tests the effects of financial development and technological innovation on economic sustainability (i.e., the economic dimension of sustainable development), and models M24 and M25 test the effects of financial development and technological innovation on ecological/environmental sustainability (i.e., the ecological/environmental dimension of sustainable development). Table 3.6 presents the results for models M21, M22, M23, M24, and M25 under columns 1, 2, 3, 4, and 5, respectively.

Table 3.6: Effects of financial development (domestic credit to private sector by banks) and technological innovation on sustainable development

Sustainability dimension	Social		Economic	Environmental/ecological	
	M21	M22	M23	M24	M25
Variables	SDI	HDI	GDPGPC	CO2	ENGCO
L.SDI	0.748***				
	(0.0304)				
L.HDI		0.884***			
		(0.0251)			
L.GDPGPC			0.250***		
			(0.00800)		
L.CO2				0.983***	
				(0.00560)	
L.lnENGCO					0.854***
					(0.0119)
DomCrdtB	-0.0413***	0.000112	0.134***	-0.00116***	0.000144
	(0.00963)	(8.55e-05)	(0.0322)	(0.000359)	(0.000606)
TFP	6.928***	0.0433***	-9.136***	0.112***	0.153**
	(0.954)	(0.0117)	(2.403)	(0.0203)	(0.0682)
Inflation	-0.00297***	2.26e-05**	-0.0422***	-0.000453*	3.60e-05
	(0.000592)	(8.90e-06)	(0.00269)	(0.000243)	(0.00149)
TO	-1.159	-0.0374*	-4.473	0.135	1.449***
	(2.750)	(0.0215)	(10.25)	(0.0829)	(0.455)
MSc	0.00556***	-5.41e-05	-0.00716	0.000268***	0.00188***
	(0.00163)	(5.64e-05)	(0.0107)	(6.51e-05)	(0.000450)
lnPopulation	-0.576***	-0.00420**	0.393	-0.0182***	0.0333***
	(0.0852)	(0.00185)	(0.459)	(0.00249)	(0.00704)
Constant	8.465***	0.121***	-2.904	0.274***	0.0890
	(1.526)	(0.0332)	(8.169)	(0.0455)	(0.139)
AR(1) [p-value]	0.144	0.001	0.140	0.080	0.196

AR(2) [p-value]	0.909	0.861	0.518	0.488	0.287
Sargan OIR	0.724	0.069	0.103	0.087	0.984
Hansen OIR	0.676	0.311	0.437	0.497	0.703
DHT for Instruments					
(a)GMM Instruments for levels	0.535	0.682	0.297	0.569	0.744
H excluding group	0.630	0.158	0.527	0.400	0.575
Diff(null, H=exogenous)					
(b) IV(years, eq(diff))					
H excluding group	0.773	0.403	0.400	0.561	0.917
Diff(null, H=exogenous)	0.144	0.118	0.495	0.168	0.068
Fisher	27810.90***	82582.78***	53389.14***	501892.26***	2.50e+06***
Instruments	22	22	26	26	18
Observations	221	230	230	206	70
Number of Countries	25	26	26	26	18

Notes: SDI is sustainable development index; L.SDI is the lag of sustainable development index; HDI is human development index; L.HDI is the lag of human development index; GDPGPC is GDP per capita; L.GDPGPC is the lag of GDP growth per capita; lnENGCO is the natural logarithm of energy consumption; L.lnENGCO is the lag of the natural logarithm of energy consumption; DomCrdtB is domestic credit to private sector by banks; TFP is total factor productivity; TO is trade openness; and MSc is the mobile-cellular subscription per 100 people.

From Table 3.6, the results indicate that financial development, proxied by domestic credit to private sector by banks, has mixed effects on sustainable development. In terms of social sustainability, domestic credit to private sector by banks (DomCrdtB) negatively impacts sustainable development index (SDI) (β = -0.0413; $p < 0.001$) CO2 emission (β = -0.00116; $p < 0.001$) but positively impacts GDP growth per capita (GDPGPC) (β = 0.134; $p < 0.001$). Thus, a unit increase in domestic credit to private sector by banks, for instance, is likely to result in a 0.0413 and 0.00116 unit reduction in SDI and CO2 emissions, respectively. However, a unit increase in domestic credit to private sector stands the chance of increasing GDP per capita by 0.134 units.

Concerning technological innovation, the results indicate that total factor productivity (TFP) is positively connected with social and ecological/environmental dimensions of sustainability but negatively connected with economic sustainability. Indicatively, in terms of social sustainability, TFP positively influences sustainable development index (SDI) (β = 6.928; $p <$ 0.001) and human development index (HDI) (β = 0.0433; $p < 0.001$). TFP's influence on economic sustainability (GDPGPC) is recorded at β = -9.136; $p < 0.001$. With regard to ecological/environmental sustainability, a unit change in an SSA country's TFP is found to be positively related with CO2 emissions (β = 0.112; $p < 0.001$) and ENGCO (β = 0.153; $p <$ 0.001). Emphasising the significant relationships, the results suggest that a unit increase in technological innovation in SSA countries will result in 6.928, 0.0433, 0.112, and 0.153 unit changes in SDI, HDI, CO2, and ENGCO, respectively.

On the control variables, inflation rate and population are found to be negatively connected to all dimensions of sustainability whereas ICT infrastructure, proxied with mobile cellular subscriptions (MSc), is found to be positively related to SDI, CO2, and ENGCO.

4.4.2. Moderating role of technological innovation in the relationship between financial development and sustainable development

The results from the basic models, which look at the influence of technological innovation and financial development on sustainable development, generally point to mixed effects of financial development on sustainable development and a positive effect of technological innovation on sustainable development. With some mixed relationships, especially between financial development and sustainable development, the results so far paves way for the assessment of how the interaction between financial development and technological innovation affects economic development in Africa. The direction and significance of this effect are essential to facilitate policy decisions. The results for this relationship, given the five initial models (for broad money - (M1, M2, M3, M4, and M5); for domestic credit to private sector - (M11, M12, M13, M14, and M15); for domestic credit to private sector by banks - (M21, M22, M23, M24, and M25)) were further developed into interaction models (for broad money - (M6, M7, M8, M9, and M10); for domestic credit to private sector - (M16, M17, M18, M19, and M20); for domestic credit to private sector by banks - (M26, M27, M28, M29, and M30)) in Tables 3.7, 3.8, and 3.9.

It is worth noting that all the necessary diagnostic tests were duly passed, suggesting that all the models were rightly specified. The interaction is defined as the product between the various pairs of continuous variables for financial development (i.e., broad money (BM), domestic credit to private sector (DomCrdtP), and domestic credit to private sector by banks (DomCrdtB)) and technological innovation (i.e., total factor productivity (TFP)). These are given in models M6-1M0, M16-20, and M26-30 as c.BM#c.TFP $(\mathrm{BM} \times \mathrm{TFP})$, c.DomCrdtP#c.TFP $(\mathrm{DomCrdtP} \times \mathrm{TFP})$, and c.DomCrdtB#c.TFP $(\mathrm{DomCrdtB} \times \mathrm{TFP})$, respectively.

For the models in Tables 3.7 to 3.9, the study further estimated that the marginal effects of the interaction terms and focus on them instead of the coefficients as

$$\frac{\Delta \text{Sustainability dimension}_{i,t}}{\Delta \text{c. BM}_{i,t}} = \beta_6 + \beta_8 \overline{\text{TFP}}$$

Table 3.7: Moderating role of technological innovation in the relationship between financial development (broad money) and sustainable development

Sustainability dimension	Social		Economic	Environmental/ecological	
	M6	M7	M8	M9	M10
Variables	SDI	HDI	GDPGPC	CO2	ENGCO
L.SDI	0.883***				
	(0.104)				
L.HDI		0.855***			
		(0.0336)			
L.GDPGPC			0.213***		
			(0.0171)		
L.CO2				0.920***	
				(0.0465)	
L.lnENGCO					0.955***
					(0.0317)
BM	-0.00159	-0.000319*	-0.551***	-0.00954***	-0.00731*
	(0.0156)	(0.000158)	(0.121)	(0.00245)	(0.00400)
TFP	4.851***	0.0598***	-23.66**	1.320***	-0.517
	(1.522)	(0.0118)	(8.642)	(0.423)	(0.327)
c.BM#c.TFP	**-0.0256****	**-0.000196*****	**0.434****	**-0.00665*****	**0.00911**
	(0.0115)	**(6.86e-05)**	**(0.179)**	**(0.00199)**	**(0.00677)**
Inflation	0.000177	9.16e-06	-0.0710***	-0.00652*	0.000396
	(0.00121)	(4.75e-05)	(0.00563)	(0.00354)	(0.000988)
TO	6.611**	-0.00490	0.831	1.862*	0.171
	(3.043)	(0.0430)	(21.62)	(0.998)	(0.362)
MSc	0.00457***	6.87e-05	0.0379**	0.000622	0.00200***
	(0.00134)	(5.52e-05)	(0.0146)	(0.000586)	(0.000321)
lnPopulation	-0.176	-0.00250***	-0.961	-0.0317*	0.00656
	(0.247)	(0.000834)	(0.654)	(0.0180)	(0.0139)
Constant	1.088	0.106***	35.96***	0.321	0.353*

	(4.722)	(0.0265)	(10.92)	(0.438)	(0.182)
AR(1) [p-value]	0.085	0.004	0.125	0.075	0.161
AR(2) [p-value]	0.656	0.710	0.565	0.233	0.266
Sargan OIR	0.290	0.068	0.309	0.431	0.973
Hansen OIR	0.161	0.501	0.281	0.844	0.949
DHT for Instruments					
(a)GMM Instruments for levels	0.590	0.131	0.311	0.756	0.851
H excluding group	0.121	0.753	0.295	0.743	0.913
Diff(null, H=exogenous)					
(b) IV(years, eq(diff))					
H excluding group	0.139	0.430	0.223	0.805	0.912
Diff(null, H=exogenous)	0.387	0.709	0.779	0.618	0.883
Fisher	7767.62***	163744.68***	1947.40***	11670.78***	2.48e+06***
Instruments	18	22	22	22	18
Observations	219	228	228	206	70
Number of Countries	25	26	26	26	18
	M6	M7	M8	M9	M10
Marginal effect	-0.011626388	-0.000408015	-0.353896383	-0.012560136	-0.00731

Notes: SDI is sustainable development index; L.SDI is the lag of sustainable development index; HDI is human development index; L.HDI is the lag of human development index; GDPGPC is GDP per capita; L.GDPGPC is the lag of GDP growth per capita; lnENGCO is the natural logarithm of energy consumption; L.lnENGCO is the lag of the natural logarithm of energy consumption; BM is broad money; TFP is total factor productivity; c.BM#c.TFP is the interaction term between broad money and total factor productivity; TO is trade openness, and MSc is the mobile-cellular subscription per 100 people.

Table 3.8: Moderating role of technological innovation in the relationship between financial development (domestic credit to private sector) and sustainable development

Sustainability dimension	Social		Economic	Environmental/ecological	
	M16	M17	M18	M19	M20
Variables	SDI	HDI	GDPGPC	CO2	ENGCO
L.SDI	0.880***				
	(0.0284)				
L.HDI		0.851***			
		(0.0246)			
L.GDPGPC			0.223***		
			(0.00947)		
L.CO2				0.954***	
				(0.00938)	
L.lnENGCO					0.883***
					(0.0643)
DomCrdtP	0.0375**	-0.000183	0.0550	-0.00465**	-0.000119
	(0.0177)	(0.000518)	(0.100)	(0.00202)	(0.00519)
TFP	4.641**	0.0212	-22.20***	-0.501***	0.0105
	(1.769)	(0.0147)	(6.460)	(0.120)	(0.342)
c.DomCrdtP#c.TFP	**-0.0631****	**0.000450**	**0.0541**	**0.0126*****	**0.00120**
	(0.0258)	**(0.000732)**	**(0.127)**	**(0.00267)**	**(0.00478)**
Inflation	0.000738	2.91e-05*	-0.0467***	0.00136**	0.000339
	(0.000914)	(1.45e-05)	(0.00570)	(0.000521)	(0.00251)
TO	0.211	-0.0595***	-15.44	-0.331***	0.641
	(2.385)	(0.0197)	(15.44)	(0.112)	(0.712)
MSc	-0.00177	2.91e-05	0.00739	0.000233	0.00165
	(0.00210)	(5.91e-05)	(0.0146)	(0.000196)	(0.00117)
lnPopulation	-0.351***	-0.00730***	-0.933	-0.0571***	0.0261*
	(0.0798)	(0.00255)	(0.802)	(0.0109)	(0.0135)

Constant	4.407***	0.192***	24.55	1.148***	0.115
	(1.557)	(0.0460)	(14.50)	(0.216)	(0.350)
AR(1) [p-value]	0.156	0.002	0.149	0.086	0.270
AR(2) [p-value]	0.562	0.827	0.451	0.520	0.275
Sargan OIR	0.490	0.390	0.265	0.121	0.968
Hansen OIR	0.182	0.496	0.321	0.300	0.939
DHT for Instruments					
(a)GMM Instruments for levels	0.785	0.776	0.183	0.163	-
H excluding group	0.091	0.336	0.480	0.477	-
Diff(null, H=exogenous)					
(b) IV(years, eq(diff))					
H excluding group	0.140	0.515	0.284	0.359	0.907
Diff(null, H=exogenous)	0.740	0.270	0.513	0.148	0.621
Fisher	20371.32***	173735.15***	35346.85***	249294.34***	1.46e+06***
Instruments	22	22	26	26	14
Observations	212	221	221	198	62
Number of Countries	25	26	26	26	16
	M16	M17	M18	M19	M20
Marginal effect	0.008842769	0	0	0.001072363	0

Notes: SDI is sustainable development index; L.SDI is the lag of sustainable development index; HDI is human development index; L.HDI is the lag of human development index; GDPGPC is GDP per capita; L.GDPGPC is the lag of GDP growth per capita; lnENGCO is the natural logarithm of energy consumption; L.lnENGCO is the lag of the natural logarithm of energy consumption; DomCrdtP is domestic credit to private sector; TFP is total factor productivity; c.DomCrdtP#c.TFP is the interaction term between domestic credit to private sector and total factor productivity; TO is trade openness, and MSc is the mobile-cellular subscription per 100 people.

Table 3.9: Moderating role of technological innovation in the relationship between financial development (domestic credit to private sector) and sustainable development

Sustainability dimension	Social		Economic	Environmental/ecological	
	M26	M27	M28	M29	M30
Variables	SDI	HDI	GDPGPC	CO2	ENGCO
L.SDI	0.952***				
	(0.0204)				
L.HDI		0.823***			
		(0.0318)			
L.GDPGPC			0.252***		
			(0.0114)		
L.CO2				0.974***	
				(0.00718)	
L.lnENGCO					0.878***
					(0.0198)
DomCrdtB	0.0265**	-0.000200	-0.0272	-0.00581**	-0.0115**
	(0.0124)	(0.000175)	(0.0390)	(0.00250)	(0.00425)
TFP	3.666***	0.0177	-26.84***	-0.181	-0.635**
	(0.860)	(0.0165)	(5.616)	(0.134)	(0.251)
c.DomCrdtB#c.TFP	**-0.0439*** **	**0.000557*** **	**0.306*** **	**0.00708** **	**0.0161** **
	(0.0129)	**(0.000198)**	**(0.0573)**	**(0.00333)**	**(0.00618)**
Inflation	0.00153***	2.64e-05**	-0.0472***	-0.000369	-0.000436
	(0.000535)	(1.28e-05)	(0.00269)	(0.000260)	(0.00158)
TO	3.767	0.0937**	-21.32*	0.0884	-0.823
	(2.231)	(0.0420)	(10.79)	(0.162)	(0.518)
MSc	-0.00320***	8.75e-05	-0.0104	0.000547***	0.00211***
	(0.00110)	(5.18e-05)	(0.0115)	(0.000131)	(0.000513)
lnPopulation	-0.130**	0.00392*	0.402*	-0.0192*	0.00748
	(0.0487)	(0.00201)	(0.233)	(0.00935)	(0.0139)
Constant	0.730	0.0143	5.939	0.426***	0.900***

	(0.946)	(0.0436)	(6.055)	(0.111)	(0.295)
AR(1) [p-value]	0.116	0.004	0.133	0.079	0.229
AR(2) [p-value]	0.700	0.556	0.520	0.514	0.264
Sargan OIR	0.602	0.011	0.145	0.090	0.995
Hansen OIR	0.181	0.799	0.450	0.369	0.773
DHT for Instruments					
(a)GMM Instruments for levels	0.904	0.132	0.195	0.585	0.674
H excluding group	0.078	0.980	0.642	0.266	0.704
Diff(null, H=exogenous)					
(b) IV(years, eq(diff))					
H excluding group	0.135	0.897	0.398	0.309	0.948
Diff(null, H=exogenous)	0.969	0.130	0.618	0.809	0.089
Fisher	32720.54***	89848.04***	17785.52***	321309.96***	116027.20***
Instruments	22	22	26	26	18
Observations	221	230	230	206	70
Number of Countries	25	26	26	26	18
	M26	M27	M28	M29	M30
Marginal effect	0.00656256	0.000252965	0.138971675	-0.002594577	-0.004188092

Notes: SDI is sustainable development index; L.SDI is the lag of sustainable development index; HDI is human development index; L.HDI is the lag of human development index; GDPGPC is GDP per capita; L.GDPGPC is the lag of GDP growth per capita; lnENGCO is the natural logarithm of energy consumption; L.lnENGCO is the lag of the natural logarithm of energy consumption; DomCrdtB is domestic credit to private sector by banks; TFP is total factor productivity; c.DomCrdtB#c.TFP is the interaction term between domestic credit to private sector by banks and total factor productivity; TO is trade openness, and MSc is the mobile-cellular subscription per 100 people.

It is important to note that given the prior relationships revealed in models M1-M5, M11-M15, and M21-M25, the focus is now shifted to the various interaction variables, which are presented in bold fonts in Tables 3.7 to 3.9. However, the diagnostics in terms of autocorrelation, Sargan, and Hansen J-tests, and the number of instruments against the number of observations and cross-sections cannot be compromised. This is to ensure that the various models are not constrained by endogeneity and instrument proliferation (Agyei et al., 2021). All of these diagnostics were met, as shown in Tables 3.7 to 3.9.

The results in Tables 3.7 to 3.9 indicate that there are significant relationships between the interaction variables and sustainable development. From Table 3.7, the interaction between BM and TFP results in a significant positive effect on GDPGPC ($\beta = 0.434$; $p < 0.05$) and significant negative effects on SDI ($\beta = -0.0256$; $p < 0.05$), HDI ($\beta = -0.000196$; $p < 0.001$), and CO2 ($\beta = -0.00665$; $p < 0.001$). The relationship between the interaction variable and the various dimensions of sustainable development in Table 3.8 indicates a negative relationship for SDI and positive for all other dimensions' proxies but at varying levels of significance. Specifically, the positive effect of the interaction between DomCrdtP and TFP is significant for CO2 ($\beta = 0.0126$; $p < 0.001$). From Table 3.9, the interaction between DomCrdtB and TFP exhibits a negative relationship with SDI ($\beta = -0.0439$; $p < 0.001$) but positive for all other proxies and dimensions of sustainable development. The interaction between DomCrdtB and TFP positively causes HDI ($\beta = 0.000557$; $p < 0.001$), GDPGPC ($\beta = 0.306$; $p < 0.001$), CO2 ($\beta = 0.00708$; $p < 0.05$), and ENGCO ($\beta = 0.0161$; $p < 0.05$).

A general observation from the results on the effect of the interaction variables on sustainable development is that the direction of the effect is proxy-dependent. Notwithstanding, a careful examination of these relationships leads to some common generalisations as follows.

Specifically, the interaction between financial development and technological innovation mostly has a negative impact on sustainability dimensions when broad money is used to proxy financial development. Meanwhile, the impact of the interaction between financial development and technological innovation is mostly positive for sustainability dimensions when financial development is proxy by domestic credit to private sector by banks and finally the results shows that TFP marginally affect SDI, CO2 and ENGCO only when domestic credit to private sector by private sector. It is clear that a trade-off between the various dimensions of sustainability may prevail given the interaction between financial development and technological innovation.

3.5. Discussion

This chapter assessed the extent to which the dimensions of economic development – in the context of sustainability (social, environmental/ecological, and economic) – are affected by industrialisation and financial development. The results from the empirical analysis indicate intriguing findings that are discussed in this section. The discussion is presented in two parts – first, on the results concerning the fundamental effects of financial development and technological innovation and, second, on the moderation effect of technological innovation on the relationship between financial development and sustainable development in Africa.

3.5.1. Effect of financial development on sustainable development

In terms of social sustainability, the empirical results suggest that financial development tends to reduce social sustainability among African economies. The implication of this finding suggests that increasing the quantum of broad money and increasing the amount of domestic credit to the private sector either by households or by banks would not improve the level of social development in Africa. Education, income, and life expectancy of the citizenry or labour force of African economies are hardly improved through the increment of credit to the private sector for industrialisation. Thus, financial development may rather boost other dimensions of sustainability rather than social sustainability, as Umar, Ji, Kirikkaleli and Xu (2020) advocated. In the context of a developing region like Africa, it could be explained that the lack of a proper long-term development plan among economies within the region retards the growth in individuals' income, life expectancy, and educational levels. Attributing high funds to the private sector with no clear and well-defined routine for credit utilisation would not result in improved income, educational levels, and life expectancy of citizens. The resulting impact is seen in the lower ratings or indices for the human development index (HDI) and sustainable development index (SDI).

It may be noted that given combined pressures from the AU and the UN concerning the achievement of millennium development goals and sustainable development goals, respectively, some African countries and other developing economies may rush into spending surplus funds on industrialisation and technological innovation. However, given the relative inexperience and lack of adequate mechanisms to innovate in Africa (Khan et al., 2019), such funds may go waste as the desired outcome may not be achieved. It is worthily noting that social sustainability hinges on the educational levels, life expectancy, and income of individuals relative to some ecological factors, as Hickel (2020) contends. Therefore, increasing the amount of funds or credit to the private sector must be strategically planned.

Turning to economic sustainability, the results generally revealed that financial development is positively related to the economic dimension of sustainable development (i.e., economic sustainability). This finding suggests that African countries could leverage financial development, particularly by encouraging the supply of credit to private sector either by households or banks to enable industries to improve their operations. As Adeoye et al. (2020) noted, the benefits associated with developing the financial sector serve as a boost for development practitioners from Africa to continuously experiment with other sources of funds (other than foreign direct investment and foreign portfolio investment) for development. This is consistent with the conclusion of Acheampong (2019) that economic development could complement financial development in improving sustainability.

Concerning ecological/environmental sustainability, the results indicate mixed relationships between financial development and ecological sustainability. Thus, depending on the proxy, financial development either increases or decreases energy consumption and CO2 emissions in Africa. Thus, it could be noted that when available credits or funds are used in boosting industrialisation, developing the financial sector through increasing the supply of money or credit to the private sector would most likely increase energy consumption and the emission of CO2. This is because industrialisation could increase the extent to which manufacturing firms emit CO2 so the more economies spend available funds on industrial activities, the more CO2 emissions are recorded. This finding supports the observation of Abokyi, Appiah-Konadu, Abokyi and Oteng-Abayie (2019) and Acheampong (2019) that the major drawbacks to achieving sustainable development include rising concerns and the associated effects of environmental degradation and climate change, which is evidenced by rises in CO2 emissions. Abbasi and Riaz (2016) explain that for economies in their early stages of structural transformation of their financial sector, CO2 emissions are hardly diminished. Thus, CO2 emissions are largely increased by financial development in economies that are in the early stages of transforming their financial sector. This is no different from economies of Africa, as could be inferred from the empirical findings. Conversely, when available funds are directed towards other activities like investment in innovative ways of production, the quantum of energy consumed and the emission of CO_2 could be reduced.

3.5.2. Effect of technological innovation on sustainable development

Unlike financial development's effect on sustainable development, the findings indicate that the effect of technological innovation on sustainable development is more consistent. The effect of technological innovation, measured by total factor productivity, on social and ecological/environmental sustainability dimensions, is found to be positive but negative for economic sustainability.

It is natural to expect that increases in technological innovation will result in high social sustainability. Human capital could be developed through the application of technological processes. When an economy improves upon its technology, it is expected that the human capital is developed to the level where it can easily apply the invented technology. This leads to improvement in educational levels, income, and life expectancy of individuals which, in turn, leads to higher ratings in respect of the human development index and sustainable development index. This finding is commensurate with Kiamba's (2012) observation that increasing the nature of industrialisation through technological innovation in developing countries can result in urbanisation which, in turn, leads to sustainable development.

Whereas it is hardly disputable that an economy will train its human capital to meet the demands of new technological inventions, the quality of structures and governance procedures are instrumental in ensuring that the innovated technology is effectively utilised. Thus, amid weak structures and poor governance structures, technological innovation results in reduced economic growth (Castellacci & Natera, 2013; Law & Azman-Saini, 2012). This finding lends additional support to the work of Bekhet and Abdul Latif (2018) in which the authors found that technological innovation may hardly contribute to sustainable development if it is not supported by quality institutions and governance mechanisms.

Moreover, as economies think of innovative ways of producing goods and services, the resulting externalities from innovative technology cannot be overlooked. High energy consumption and the emission of CO2 increase as economies increase their use of innovative technology and this highlights why the link between technological innovation and ecological/environmental sustainability could be negative. This finding supports the observation of Umar, Ji, Kirikkaleli and Xu (2020) that technological innovation significantly increases CO2 emissions but contradicts that of Shahbaz, Raghutla, Song, Zameer and Jiao (2020) who provide evidence that technological innovation significantly reduces CO2 emissions in China. As both studies were situated in China, it signals that the effect of technological innovation could be mixed in other contexts. In the case of a technological frontier region – Africa, which entails countries that are mainly technological laggers, failure to apply high standard technological procedures constrains the ability of member economies to effectively carry out production in such a manner that minimises their level of CO2 emissions.

3.5.3. Moderating role of technological innovation on the relationship between financial development and sustainable development

Having found significant relationships between (i) financial development and sustainable development and (ii) technological innovation and sustainable development, the motivation to probe further into the effect of the interaction between financial development and technological innovation on sustainable development is underscored by the convoluted relationships between technological innovation and sustainable growth.

From the results, the interaction between financial development and technological innovation mostly has a negative impact on social sustainability measures or indicators (i.e., SDI and HDI). The implication to be drawn from this observation is that firstly, financial development and technological innovation may lead to income inequality. That is, access to finance and technology can be concentrated among certain groups or regions, leading to unequal distribution of benefits. This can exacerbate existing social and economic disparities, and result in lower levels of social sustainability. Also, rapid technological change and financial development can lead to job displacement and labour market disruptions. New technologies may automate or replace certain jobs, while financial innovations may change the nature of work or create new risks for workers. This can result in higher unemployment, lower wages, and reduced job security, all of which can negatively impact social sustainability indicators.

Thirdly, financial development and technological innovation may create new forms of environmental degradation or social dislocation which are also important concerns in many African countries, particularly those that are resource-rich and experiencing rapid urbanization and industrialization. As such, rapid urbanization and industrialization can lead to increased pollution and loss of natural habitats, while financial innovations may encourage speculative investment or exacerbate resource extraction. Finally, the benefits of financial development and technological innovation may be short-term or volatile, leading to unsustainable growth patterns or economic instability. For example, financial bubbles or technology-driven booms may create short-term gains, but also increase the risk of financial crises or economic downturns in Africa given the region's vulnerability to external shocks and its limited capacity to absorb economic and financial risks. Hence, some dimensions of sustainable development may be compromised in the quest to achieve overall sustainable growth and development (Abbasi & Riaz 2016).

The results further indicate a positive impact of the interaction between financial development and technological innovation on economic sustainability (i.e., GDPGPC) and environmental/ecological sustainability (i.e., CO2 and ENGCO). Thus, more technological innovation increases GDPGPC, CO2 emissions, and energy consumption. It is clear that a trade-off between the economic and ecological/environmental dimensions of sustainability may prevail given the interaction between financial development and technological innovation. Hence, it may not be prudent to discuss their implications in solitude. The convoluted moderating effect of technological innovation on the relationship between financial development and technological innovation could be explained as follows.

As Abokyi et al. (2019) indicated, the achievement of sustainable development is hugely impacted by notable drawbacks such as the rising concerns about and the potential effects of environmental degradation and climate change, which is evidenced by rises in CO2 emissions. Hence, in their attempt to increase economic sustainability (in terms of national outputs), externalities from technological innovations – which are facilitated by a well-developed financial sector – affect economies' achievement of ecological/environmental sustainability. This lends support to Abbasi and Riaz's (2016) documentation that CO2 emissions move in line with growth in per capita GDP. Conclusions from the work of Acheampong (2019) also support this observation.

It is worth noting that other factors may induce the negative effect of the interaction between financial development and technological innovation. The empirical work of Shahbaz et al. (2020) noted that environmental sustainability is impeded by high levels of foreign direct investment. That is, CO2 emissions are stimulated by FDI. Given African countries' large dependence on foreign direct investments for possible economic development (Adeoye et al., 2020), it is unsurprising that CO2 emissions are high at high levels of technological innovation. The findings do not mean that financial development and technological innovation should not be pursued together. It is instructive to note that Umar et al.'s (2020) empirical findings indicated that although technological innovation significantly causes CO2 emissions, technological innovation in the long term can reduce CO2 emissions. Hence it could be inferred that when strengthened, technological innovation can significantly and favourably support sustainable development, particularly ecological or environmental sustainability.

3.6. Conclusions, and recommendations

Having drawn insights from the second chapter's findings which indicated that the level of economic development among African economies could be boosted through industrialisation and complemented by financial development, this chapter examined the interactive role of technological innovation in the relationship between financial development and sustainable development in Africa. Having controlled for the influence of ICT infrastructure, trade openness, inflation, and population size, the system dynamic general methods of moments (GMM) technique was employed with a panel dataset covering 2010-2019 for 48 African countries.

The analysis covered two parts. First, the fundamental effects of financial development and technological innovation and, second, the moderation effect of technological innovation on the relationship between financial development and sustainable development in Africa. In the first part, the fundamental relationships, by proxying technological innovation with total factor productivity, all analyses were carried out in three separate sets of models – M1-M5 (when financial development is proxied by broad money), M11-M15 (when financial development is proxied by domestic credit to the private sector), and M21-25 (when financial development is proxied by domestic credit to the private sector by banks). In the second part of the analysis, the moderating effect of technological innovation on the relationship between financial development and sustainable development was analysed. The moderating variable was measured as the interaction between technological innovation and the various financial development proxies, yielding three additional sets of models, M6-M10, M16-M20, and M26-M30 as the corresponding models to M1-M5, M11-M15, and M21-M25.

The results indicate significant effects of financial development on sustainable development as well as significant relationships between technological innovation and sustainable development. Indicatively, in terms of social sustainability, the findings suggest that financial development tends to reduce social sustainability among African economies such that increasing the quantum of broad money and increasing the amount of domestic credit to the private sector either by households or by banks would not necessarily improve the level of social development in Africa. Turning to economic sustainability, the findings divulged a positive relationship between financial development and the economic dimension of sustainable development (i.e., economic sustainability), suggesting that African countries could leverage financial development, particularly by encouraging the supply of credit to private sector either by households or banks to enable industries to improve their operations.

Concerning ecological/environmental sustainability, findings from this chapter indicated mixed relationships between financial development and ecological sustainability. Thus, depending on the proxy, financial development either increases or decreases energy consumption and CO_2 emissions in Africa. Meanwhile, the effect of technological innovation on sustainable development was positive for all dimensions of sustainability but had varied implications. This emphasised the need to analyse how sustainable development is affected by the interaction between financial development and technological innovation.

The findings from the moderating effect of technological innovation on the fundamental relationship between financial development and sustainable development indicated that generally, technological innovation negatively moderates the relationship between financial development and social sustainability indicators (i.e., SDI and HDI). However, the interaction between financial development and technological innovation had a positive effect on economic sustainability (i.e., GDP growth per capita) and environmental/ecological sustainability (i.e., CO_2 emission and energy consumption). Thus, findings from the moderation effect divulged that more technological innovation lessens SDI but increases GDP growth per capita, CO_2 emissions, and energy consumption. Impliedly, the trade-off between the various dimensions of sustainability that may prevail when working towards the achievement of sustainable development cannot go unnoticed.

Findings from the chapter raise several implications for which appropriate recommendations must be considered to optimise the extent to which sustainable development may be boosted and minimise externalities. The following three recommendations are critically based on the implications of the key findings from the chapter.

First, it is prudent for regional economies to streamline policies targeted at achieving sustainable development. The coming together of leading and notable developed economies to support the crafting of policies and their implementation for sustainable growth and development is key to ensuring minimal environmental degradation whilst boosting economic and social sustainability. Second, transfers – of advanced technologies – from technological leaders to technological frontiers must be encouraged to support the collective sustainable growth of the world economy through reductions in CO2 emissions and other practices that inhibit social, ecological/environmental, and economic sustainability. This collaboration between developed (technological leaders) and developing (technological frontiers) economies is essential owing to the high contributions of global world CO2 emissions from developing economies for which the effect is suffered by the world at large. Third, it must be noted that the link between technological innovation and financial development may be complicated. In effect, technological innovation must be integrated with strategically positioned policies to boost sustainable development in Africa. Hence, by way of broadening the existing evidence in the body of knowledge, the role of institutions in the relationship between technological innovation and sustainable growth could be given attention in future studies.

CHAPTER FOUR

TECHNOLOGICAL INNOVATION, INDUSTRIALISATION, AND SUSTAINABLE DEVELOPMENT IN AFRICA

4.1 Introduction

The foundation of industrial change, which results in development, is technological innovation (Zhou, Cai, Tan, Zhang, & Song, 2021). The development of new, effective machines that supplement or replace labour and increase productivity can be facilitated by technological innovation (Mensah, Long, Boamah, Bediako, Dauda, & Salman, 2018). The discrepancy in economic development between industrialised and high-income nations and that of developing economies can be attributed to the fact that industrialisation leads to economic development (Omri, 2020). It is anticipated that as economies industrialise, returns to scale would increase, allowing for a quicker transition to a steady state. To increase productivity in the real sector, however, technological innovation introduces new methods for turning extractive products into industrial goods (Wang, Luo, Sari, & Sharo, 2020). In the manufacturing process, innovation also causes an imbalance between the backward and forward value chains, which encourages production diversification and industrial development (Hirschman, 1958).

According to Gerschekron (1962), looking at the economy as a whole and not simply focusing on the industrial sector, the degree of backwardness of an economy influences the capacity for industrialisation. This suggests that less developed nations may catch up to the degree of industrialisation in high-income nations more quickly if they put policies in place to promote industrialisation (Dutrénit, Anyul, & Teubal, 2011). Compared to nations with less technological innovation, industrialised nations often have more technological advancements that improve the productivity of the means of production (Wang, Umar, Akram, & Caglar, 2021). Urbanisation, which is related to industrialisation may cause ecological issues including excessive energy use, ozone layer loss from CFO chemical emissions, and CO2 emissions, which are also linked to industrialisation (Zhou et al., 2021). In the same vein, education is necessary to support the development of industrialisation-related technologies without compromising environmental sustainability.

This part of the argument is connected to Sadorsky's (2014) study, which contends that long-term urbanisation and industrialisation increase energy consumption. Their findings imply that using energy from non-renewable resources, like fossil fuels, might be harmful to sustainable growth because doing so would jeopardise ecological sustainability. According to the study, attaining one component of sustainable development – economic growth through urbanisation and industrialisation – could be detrimental to achieving other components (ecological development). This is similar to Kohler (2014), who cited information and telecommunications technology as catalysts for developing countries' integration into the world economy and subsequent social and economic growth. This shows that commerce and technological innovation work together to promote sustainable development.

In economic literature, the effect of technological innovation on growth is widely established. The classical school of thought, which holds that technological improvement causes economic growth, contains the first theory on the connection between innovation and economic development (Smith, 1776). According to the neo-classical growth perspective, technological advancement is the primary force behind rising productivity (Solow, 1956). Technological advancement raises productivity in the input-transformation stage, lowering production costs and maximising productivity growth in the shortest amount of time. Neo-classical growth theories contend that technological advancement is exogenously determined, nonetheless. Technological innovation is viewed by the new growth theories developed by Romer (1990) and a large number of endogenous theorists as human and corporate actions that can boost the productivity development of countries that collect more inventions.

Schumpeter (1911) saw technological advancement as a way to spur further economic growth. Aghion, Howitt, and Meyer-Foulkes (2005) argue that technology transfer from technological leaders to laggards stimulates the flow of financial resources to induce productivity development of the nations engaged under the current Schumpeterian growth viewpoint. In a similar vein, King and Levine (1993), Levine (1997), and Levine (2005) contend that innovation promotes technological transfer by promoting investment in commercially viable goods, which facilitates the flow of capital into industries that are experiencing growth. Therefore, the contemporary Schumpeterian theory of development proposes that financiers support the importation of technological innovation to spur economic expansion either directly or indirectly through industrialisation.

Empirically, Omri (2018) demonstrates how the employment of new technology by investors promotes sustainable manufacturing (industrialisation) in high-income nations by making the environment friendlier. Due to its effects on people's lives, the idea of sustainable development has been extensively discussed in the literature. The conceptual issue has, however, received the most of the attention, with little examination of the empirical fronts, particularly in Africa. To support the implementation of the millennium development goals (MDGs) and sustainable development goals (SDGs), governments, practitioners, and respective policy-makers may use a variety of policy measures. Empirical analyses of the interactions between technological innovation, industrialisation, and sustainable economic growth in the African context may support the effectiveness of these measures. Despite any supporting data that may have been created in developed markets, the situation in developing markets is likely to be different due to disparities in geographical and political systems (Adeoye, Nwokolo, & Igboanugo, 2020). Additionally, technology frontiers may have a very different strategy than technological laggards.

By using end-of-pipe technology, altering the fuel mix, and implementing more energy-efficient industrial techniques, technological innovation can lessen environmental damage (Bruyn & Sander, 1997). Evidence from developed and/or highly industrialised economies demonstrates that only industrialised nations experience the three pillars of sustainable development being stimulated by technological innovation (Wang, Umar, Akram, & Caglar, 2021; Zhou et al., 2021). The existing works did not employ tools in their study that are specific to emerging nations, such as political and geographical conditions, legal systems, cultural background, religious orientation, etc. These elements might have an impact on how technological innovation, industrialisation, and sustainable development interact.

Bekhet and Abdul Latif (2018) examined the effect of institutional quality on the transfer of technological innovation and sustainable growth in a study that covered the years 1995 to 2015. They discovered that the connection between technological innovation and government positively contributes to Malaysia's sustainable growth. The ability of technological innovation to advance social and environmental conditions while simultaneously promoting economic progress was also examined by Omri (2020) in the context of 75 low-, middle-, and high-income countries by highlighting how this impact varies depending on the stage of economic development. His findings show that technological innovation only simultaneously contributes to the three pillars of sustainable development in the case of rich (industrialised) countries, only affects the economic and environmental dimensions in the case of middle-income countries, and has no impact in the case of low-income countries, according to both long-run estimates and causality analysis.

Similarly, Umar, Kirikkaleli, and Xu (2020) used the combined cointegration and wavelet coherence approaches to examine the long-run and causal effects of innovation, financial development, and transportation infrastructure on CO2 emissions over the period from 1971 to 2018, using economic growth as a control variable in the model. They demonstrate that there is a significant cointegration link between real GDP, innovation, financial development, and CO2 emissions. Additionally, the results of a wavelet power spectrum show that CO2 emissions, financial development, transportation infrastructure, and innovation are all very vulnerable at various time scales and frequencies. The results of the wavelet coherence approach also show that: (i) innovation is seen as a significant predictor of CO2 emissions over the period from 2007 to 2013; (ii) over the long term, there are negative correlations between CO2 emissions and financial development; and (iii) over the periods from 2000 to 2015 and from 1985 to 1989, transportation is seen as a significant contributor to CO2 emissions. To meet environmental sustainability goals, it is suggested by these findings that innovation and transportation infrastructure need to be strengthened. Conversely, Mensah et al. (2018) discovered that technological innovation can increase CO2 emissions in OECD nations as they industrialise.

The empirical research, however, lacks information on how the degree of industrialisation in the economies governed by the African Union might advance economic, social, and environmental sustainability without sacrificing any of its constituent components. Information on how African nations and the economic communities governed by the AU may use technological innovation to accelerate industrialisation without compromising environmental sustainability is not also included in the empirical literature.

For African countries to encourage economic growth without jeopardising social and ecological development, this chapter investigates the amount of creativity and technological innovation that would support sustainable development. As far as the researcher is aware, there are no studies in this area that specifically focus on the African continent. Policy-makers will be able to choose the actions to conduct within the time horizon to support sustainable development depending on the input variables if they are aware of the direct and indirect relationships between these economic variables. Industrialisation is directly linked with urbanisation, which could lead to ecological problems in the likes of energy consumption, and ozone layer depletion due to the emission of CFO chemicals and CO2. Whilst education may be direly required to promote the innovation of technologies for industrialisation without sacrificing environmental sustainability, policy guidelines need to follow from empirical investigations. Hence, this drives the impetus of the study to examine the linkages between technological innovation, industrialisation, and sustainable development in Africa.

This contribution of this chapter to the body of knowledge cannot be belittled. Novel to the empirical literature on African economies, this research determines how industrialisation supports the protection of the environment and at the same time ensures economic and social development. By so doing, rather than using an aggregated measure of sustainability, the analysis outlined in this chapter is segregated into the three dimensions of sustainability, namely economic; social, and ecological/environmental. The intuition is that industrialisation should be pursued in the interest of preservation of the natural resources to, in turn, sustain economic development in emerging economies. Through this empirical analysis, the study provides evidence of how policy actions would be crafted to enhance the attainment of sustainability.

4.2 Methodology

This chapter employs Baron and Kenny's tests (Baron & Kenny, 1986), which have been modified by Hayes (2009) and Zhao, Lynch and Chen (2010), to analyse the mediating effect of industrialisation on the nexus between technological innovation and sustainable development in Africa. The recent literature terms this approach as the ANOVA technique (Civelek, Uca, & Çemberci, 2015; D'Aleo, 2015; Sergi, D'Aleo, Konecka, Szopik-Depczyńska, Dembińska, & Ioppolo, 2021). It has gained popularity due to its robustness in modelling mediated relationships under no strict assumptions as may have been applied in classical panel regression models (Sergi et al., 2021). As indicated in Figure 1, three tests are advised to demonstrate that a predictor variable (X) (i.e., technological innovation (TIN)) influences a distal dependent variable (Y) (i.e., sustainable development (SD)) via a mediating variable (M) (i.e., industrialisation (IND)).

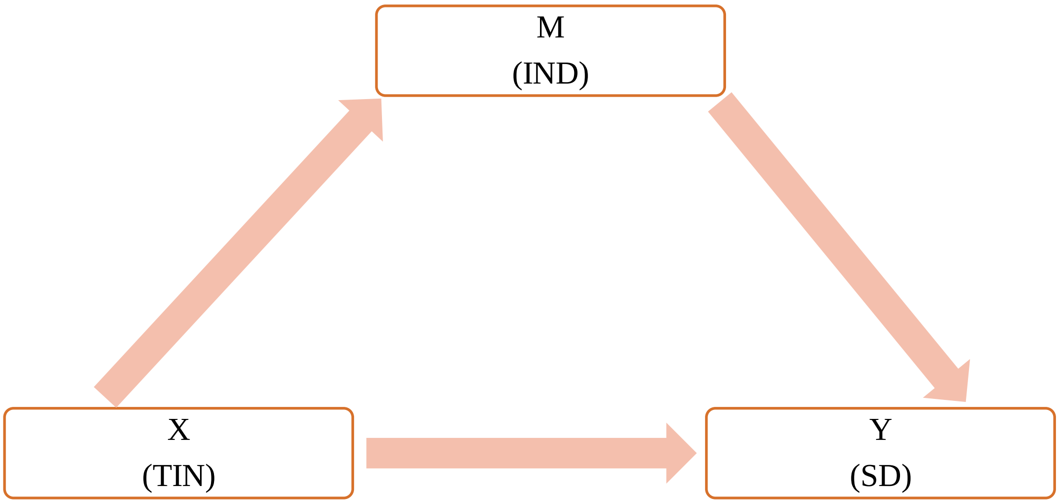

Figure 1: Mediating Effect Model

Notes: the directional arrow from (X) to (M) (X→M) depicts path a; the directional arrow from (M) to (Y) (M→Y) depicts path b; the directional arrow from (X) to (Y) (X→Y) in the presence of M depicts path c'. X, M, and Y are the independent, mediating, and dependent variables, respectively.

When a variable meets all three of the following criteria, it is said to be acting as a mediator:

(a) changes in the independent variable's levels significantly explain the changes in the supposed mediator (i.e., path a);

(b) changes in the mediator significantly explain the changes in the dependent variable (i.e., path b); and

(c) a previously significant relationship between the dependent and independent variables is no longer significant when paths 'a' and 'b' are controlled, with path c' being zero, providing the greatest evidence of mediation.

Note that the total effect of (X) on (Y) is denoted as path c while with the introduction of a mediating variable, the effect of (X) on (Y) becomes the direct effect, labelled as path c'. Although Hayes (2009) and Zhao et al. (2010) contend the precondition for (X) to have a significant relationship with (Y) (i.e., path c), their approaches to mediation are comparable and all conditions are met in this research. All the approaches agree that for the third condition (c') to hold in a mediating model, a test of significance for path c' is necessary. The estimation tests for the various paths a, b, and c' are simplified in equations (4.1), (4.2), and (4.3), respectively as follows.

$$M = i_1 + aX + e_1. \tag{4.1}$$

$$Y = i_2 + c'X + e_2. \tag{4.2}$$

$$Y = i_3 + cX + bM + e_1. \tag{4.3}$$

Baron and Kenny (1986, p. 1177) state as follows:

> "To test mediation, one should estimate the three following regression equations: first, regressing the mediator on the independent variable; second, regressing the dependent variable on the independent variable; and third, regressing the dependent variable on both the independent variable and on the mediator. ... To establish mediation, the following conditions must hold: First, the independent variable must affect the mediator in the first equation; second, the independent variable must be shown to affect the dependent variable in the second equation; and third, the mediator must affect the dependent variable in the third equation."

Based on the above, and to aid effective comparison, this research deduced the following hypotheses from the research model:

H_1: industrialisation (IND) is positively influenced by technological innovation (TIN)

H_2: sustainable development (SD) is positively influenced by industrialisation (IND)

H_3: sustainable development (SD) is positively influenced by technological innovation (TIN)

H_4: industrialisation (IND) exercises a mediating effect on the relationship between technological innovation (TIN) and sustainable development (SD)

In deciding on the significance of mediation, the coefficient of the direct effect (i.e., path c', which can be deduced from H_4) should be less than the total effect (i.e., path c, which can be deduced from H_2). That is, in this research, path c is envisaged from H_2 while path c' is envisaged from H_4. To test the above-hypothesised relationships, hierarchical regression models based on the recommended steps by Baron and Kenny (1986), Hayes (2009), and Zhao et al. (2010) can be specified as follows:

$$IND = \beta_0 + \beta_1 TIN + \varepsilon. \quad (4.4)$$

$$SD = \beta_0 + \beta_1 IND + \varepsilon. \quad (4.5)$$

$$SD = \beta_0 + \beta_1 TIN + \varepsilon. \quad (4.6)$$

$$SD = \beta_0 + \beta_1 TIN + IND + \varepsilon. \quad (4.7)$$

Note that equations 4.4-4.7 are the basic models and depending on the dimension and its proxies, the following equations are deduced for social sustainability given that SDI is sustainable development index (i.e., equations 4.8-4.11) and HDI is human development index (i.e., equations 4.12-4.15):

$$IND = \beta_0 + \beta_1 TIN + \varepsilon. \quad (4.8)$$

$$SDI = \beta_0 + \beta_1 IND + \varepsilon. \quad (4.9)$$

$$SDI = \beta_0 + \beta_1 TIN + \varepsilon. \quad (4.10)$$

$$SDI = \beta_0 + \beta_1 TIN + IND + \varepsilon. \quad (4.11)$$

$$IND = \beta_0 + \beta_1 TIN + \varepsilon. \quad (4.12)$$

$$HDI = \beta_0 + \beta_1 IND + \varepsilon. \quad (4.13)$$

$$HDI = \beta_0 + \beta_1 TIN + \varepsilon. \quad (4.14)$$

$$HDI = \beta_0 + \beta_1 TIN + IND + \varepsilon. \qquad (4.15)$$

Similarly, for economic sustainability, which is proxied by GDP growth per capita (GDPGPC), the following equations are specified:

$$IND = \beta_0 + \beta_1 TIN + \varepsilon. \qquad (4.16)$$

$$GDPGPC = \beta_0 + \beta_1 IND + \varepsilon. \qquad (4.17)$$

$$GDPGPC = \beta_0 + \beta_1 TIN + \varepsilon. \qquad (4.18)$$

$$GDPGPC = \beta_0 + \beta_1 TIN + IND + \varepsilon. \qquad (4.19)$$

Furthermore, given CO2 emissions (CO2) and energy consumption (ENGCO), for environmental/ecological sustainability, the following equations (4.20-4.23 and 4.24-4.27, respectively) are specified.

$$CO2 = \beta_0 + \beta_1 TIN + \varepsilon. \qquad (4.20)$$

$$CO2 = \beta_0 + \beta_1 IND + \varepsilon. \qquad (4.21)$$

$$CO2 = \beta_0 + \beta_1 TIN + \varepsilon. \qquad (4.22)$$

$$CO2 = \beta_0 + \beta_1 TIN + IND + \varepsilon. \qquad (4.23)$$

$$ENGCO = \beta_0 + \beta_1 TIN + \varepsilon. \qquad (4.24)$$

$$ENGCO = \beta_0 + \beta_1 IND + \varepsilon. \qquad (4.25)$$

$$ENGCO = \beta_0 + \beta_1 TIN + \varepsilon. \qquad (4.26)$$

$$ENGCO = \beta_0 + \beta_1 TIN + IND + \varepsilon. \qquad (4.27)$$

4.3 Data description and preliminary analysis

Data were obtained on technological innovation (total factor productivity), sustainable development (ecological/environmental sustainability – CO2 emissions and energy consumption; social sustainability – sustainability development index and human development index; economic sustainability – GDP growth per capita), and industrialisation (manufacturing value added) from the World Development Indicators [WDI] (2020). These specific variables were selected based on the empirical reviews and theories guiding the study (Aghion & Howitt, 1992; King & Levine, 1993; Levine, 1991; Levine, 2005, Aghion, Howitt & Mayer-Foulkes, 2005, Idun & Aboagye, 2014, Laeven, Levine & Michalopoulos, 2015, Idun, 2021). The study period falls from 2010 to 2019 due to the availability of data from the database of the WDI (2020). Thus, the study period and sampled countries were based on available data. Due to data constraints, an unbalanced panel made up of 48 countries over the period 2010-2019 was used in the data processing and estimation of results.

The list of countries involved in the sample included sub-Saharan African countries with available data and are reported on by the WDI. As of 2020, the list of SSA countries on which the WDI report data contained 48 countries. The list of the countries employed in the study can be seen in the Appendix. These countries formed the cross-sections for the panel estimations carried out in this chapter.

4.3.1. Descriptive statistics

Table 4.1 describes the statistical properties of the data, detailing the number of observations, average (mean) values, the lowest (minimum) and highest (maximum) observations, and the standard deviation of the mean values over the sample period 2010 to 2019.

Table 4.1: Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
CO2	432	0.971532	1.733226	0.000	10.08859
ENGCO	121	692.203	648.8401	63.66971	3129.067
HDI	480	0.5234333	.0960687	0.331	0.804
MVA	431	3.86e+09	9.39e+09	1.67e+07	5.89e+10

SDI	422	5.153483	6.49923	0.61	36.31
GDPGPC	438	1.737594	4.238664	-36.55682	18.06597
TFP	260	0.4541558	.2062977	0.1643128	1.248934

Notes: SDI is sustainable development index; HDI is human development index; GDPPC is GDP per capita; ENGCO is energy consumption; TFP is total factor productivity; MVA is manufacturing value added.

The rated index in terms of sustainability (SDI) among the sampled sub-Saharan African countries averaged 5.15 over the period 2010-2019. The maximum and minimum rated indices of 36.31 and 0.61, respectively suggest high disparities in the level of social sustainability within the sub-region. It is not surprising that the rating on human development (HDI) was recorded at an average of 0.52 with maximum and minimum values of 0.331 and 0.804, respectively. In terms of economic sustainability, GDP growth per capita recorded an average of 1.74% which could standardly deviate around 4.24%. Some economies recorded negative growth in GDP per capita, suggesting that despite the highest positive growth rate of 18.07%, economic growth among African countries was hardly sustained for some countries over the period 2010-2019. Turning to ecological or environmental sustainability, CO2 emissions measured 0.97 metric tons per capita, which deviated around 1.73 metric tons per capita. Energy consumption was averagely 692 units per hundred people but could go as high as 3129 units per hundred people.

As a measure of industrialisation, the total factor productivity (TFP) of the sampled countries recorded an average of 0.45 with a standard deviation of 0.21 and maximum and minimum values of 1.25 and 1.64, respectively. Among the sampled African countries, the average value-added from the manufacturing sector (MVA) from 2010 to 2019 was recorded at around US$3.86 billion. The huge disparity between the industrialisation levels of African economies is depicted by the high deviation from the average in terms of MVA.

4.3.2. Pairwise correlations

To supplement the statistical properties of the data, the correlation statistics are presented in Tables 4.2, 4.3, and 4.4 representing social sustainability, economic sustainability, and ecological/environmental sustainability, respectively. This is needed to examine the magnitude and significance of the unconditional correlations between the explanatory variables for the various sustainability dimensions. Furthermore, the degree of multicollinearity among the studied variables, if any, could be assessed through correlation statistics. It is worth noting that the pairwise correlations between the explanatory variables are in low to moderate magnitudes with high statistical significance. This largely suggests that the estimation models could be specified without any issue of multicollinearity. With a rule of thumb of 0.7 (Agyei et al., 2021; Agyei & Idan, 2022), the issue of multicollinearity could be dismissed in this case. Thus, the inclusion of these regressors in the various specified models is appropriate.

Specifically, for social sustainability, the correlation matrix in panel A of Table 4.2 indicate that the correlations between SDI and TFP (r = 0.41; $p < 0.001$), SDI and MVA (r = 0.18; $p < 0.001$), and TFP (r = 0.22; $p < 0.001$) are positive and statistically significant. Similarly, the correlation matrix in panel B of Table 5.2 indicate that the correlations between HDI and TFP (r = 0.31; $p < 0.001$), SDI and MVA (r = 0.18; $p < 0.001$), and TFP and MVA (r = 0.22; $p < 0.001$) are positive and statistically significant. All correlation estimates are statistically significant at the 1% level. Hence, the preconditions for analysing the supposed mediation effect between the variables are met for the specified models in relation to social sustainability.

Table 4.2: Correlation matrix for social sustainability models

Panel A: Sustainable Development Index				Panel B: Human Development Index			
	SDI	TFP	MVA		HDI	TFP	MVA

SDI	1.0000	0.4100	0.1800	HDI	1.0000	0.3100	0.1900
		0.0000	0.0000			0.0000	0.0000
TFP	0.4100	1.0000	0.2200	TFP	0.3100	1.0000	0.2200
	0.0000		0.0000		0.0000		0.0000
MVA	0.1800	0.2200	1.0000	MVA	0.1900	0.2200	1.0000
	0.0000	0.0000			0.0000	0.0000	

Notes: SDI is sustainable development index; HDI is human development index; TFP is total factor productivity; MVA is manufacturing value added.

For economic sustainability (Table 4.3), the correlation matrix indicate that the correlations between GDPGPC and TFP (r = 0.13; $p < 0.01$), GDPGPC and MVA (r = 0.09; $p < 0.1$), and TFP and MVA (r = 0.22; $p < 0.001$) are positive and statistically significant. The correlation between GDPGPC and TFP and that of TFP and MVA are significant at 1% while the correlation between GDPGPC and MVA is significant at 10%. Hence, it could be deduced that the preconditions for analysing the supposed mediation effect between the variables are met for the specified models concerning economic sustainability.

Table 4.3: Correlation matrix for economic sustainability model

	GDPGPC	TFP	MVA
GDPGPC	1.0000	0.1300	0.0900
		(0.0053)	(0.0570)
TFP	0.1300	1.0000	0.2200
	(0.0053)		(0.0000)
MVA	0.0900	0.2200	1.0000
	(0.0570)	(0.0000)	

Notes: GDPGPC is GDP growth per capita; TFP is total factor productivity; MVA is manufacturing value added.

For environmental/ecological sustainability (Table 4.4), the correlation matrix in panel A of Table 4.4 indicate that the correlations between ENGCO and TFP (r = 0.21; $p < 0.001$), ENGCO and MVA (r = 0.16; $p < 0.001$), and TFP (r = 0.22; $p < 0.001$) are positive and statistically significant. Similarly, the correlation matrix in panel B of Table 4.4 indicate that the correlations between CO2 and TFP (r = 0.16; $p < 0.001$), CO2 and MVA (r = 0.17; p <

0.001), and TFP and MVA (r = 0.22; $p < 0.001$) are positive and statistically significant. All correlation estimates are statistically significant at the 1% level. Hence, the preconditions for analysing the supposed mediation effect between the variables are met for the specified models in relation to environmental/ecological sustainability.

Table 4.4: Correlation matrix for environmental sustainability models

	Panel A: ENGCO				Panel B: CO2		
	ENGCO	TFP	MVA		CO2	TFP	MVA
ENGCO	1.0000	0.2100	0.1600	CO2	1.0000	0.1600	0.1700
		0.0000	0.0006			0.0004	0.0001
TFP	0.2100	1.0000	0.2200	TFP	0.1600	1.0000	0.2200
	0.0000		0.0000		0.0004		0.0000
MVA	0.1600	0.2200	1.0000	MVA	0.1700	0.2200	1.0000
	0.0006	0.0000			0.0001	0.0000	

Notes: ENGCO is energy consumption; CO2 is carbon dioxide emissions; TFP is total factor productivity; MVA is manufacturing value added.

4.4. Empirical results

This chapter examines the mediating effect of industrialisation on the relationship between technological innovation and sustainable development in Africa. The main results are presented in this section in two parts. The meaningfulness of the estimated models is first assessed followed by a presentation of the main results.

4.4.1. Model diagnostics

For each of the models under the various dimensions of sustainability, the diagnostics are presented in the form of analysis of variance (ANOVA). Tables 4.5, 4.6, and 4.7 present the ANOVA statistics for each of the models under the various sustainability dimensions, which are social sustainability, economic sustainability, and ecological/environmental sustainability, respectively. Based on the recommendation of Baron and Kenny (1986), four models were estimated for each sustainability dimension. The models, M1, M2, M3, and M4 correspond to the hypothesised relationships H_1, H_2, H_3, and H_4.

Table 4.5: ANOVA for social sustainability models

Model	Df	Sum Sq.	Mean Sq.	Fisher	*p*-value
Sustainable Development Index					
M1	1	961.60	961.57	23.96	0.00
Residuals	478	19185.30	40.14		
M2	1	617.40	617.38	15.94	0.00
Residuals	478	18519.90	38.74		
M3	1	3149.60	3149.59	94.17	
Residuals	478	15987.70	33.45		
M4	1	3149.60	3149.59	94.96	0.00
	1	166.40	166.36	5.02	0.03
Residuals	477	15821.30	33.17		
Human Development Index	Df	Sum Sq.	Mean Sq.	Fisher	*p*-value
M1	1	961.60	961.57	23.96	0.00
Residuals	478	19185.30	40.14		
M2	1	0.15	0.15	17.25	0.00
Residuals	478	4.27	0.01		
M3	1	0.43	0.43	51.12	0.00
Residuals	478	3.99	0.01		
M4	1	0.43	0.43	51.86	0.00
	1	0.07	0.07	7.95	0.01
Residuals	477	3.93	0.01		

Notes: M1 is model 1, testing the effect of the independent variable (TFP) on the mediating variable (MVA); M2 is model 2, testing the effect of the mediating variable (MVA) on the dependent variables (SDI and HDI); M3 is model 3, testing the effect of the independent variable (TFP) on the dependent variables (SDI and HDI); M4 is model 4, testing the effects of the independent and mediator variables (TFP and MVA, respectively) on the dependent variables (SDI and HDI).

Table 4.6: ANOVA for economic sustainability models

GDPGPC	Df	Sum Sq.	Mean Sq.	Fisher	*p*-value
M1	1	961.60	961.57	23.96	0.00
Residuals	478	19185.30	40.14		
M2	1	60.20	60.22	3.64	0.06
Residuals	478	7906.80	16.54		
M3	1	128.70	128.73	7.85	0.01
Residuals	478	7838.20	16.40		

M4	1	128.70	128.73	7.86	0.01
	1	29.30	29.29	1.79	0.18
Residuals	477	7808.90	16.37		

Notes: M1 is model 1, testing the effect of the independent variable (TFP) on the mediating variable (MVA); M2 is model 2, testing the effect of the mediating variable (MVA) on the dependent variable (GDPGPC); M3 is model 3, testing the effect of the independent variable (TFP) on the dependent variable (GDPGPC); M4 is model 4, testing the effects of the independent and mediator variables (TFP and MVA, respectively) on the dependent variable (GDPGPC).

Table 4.7: ANOVA for environmental sustainability models

ENGCO	Df	Sum Sq.	Mean Sq.	Fisher	*p*-value
M1	1	961.60	961.57	23.96	0.00
Residuals	478	19185.30	40.14		
M2	1	2305724.00	2305724.00	12.04	0.00
Residuals	478	91575139.00	191580.00		
M3	1	4179623.00	4179623.00	22.27	0.00
Residuals	478	89701239.00	187659.00		
M4	1	4179623.00	4179623.00	22.53	0.00
	1	1206383.00	1206383.00	6.50	0.01
Residuals	477	88494856.00	185524.00		
CO2 Emissions	Df	Sum Sq.	Mean Sq.	Fisher	*p*-value
M1	1	961.60	961.57	23.96	0.00
Residuals	478	19185.30	40.14		
M2	1	40.29	40.29	14.87	0.00
Residuals	478	1295.24	2.71		
M3	1	34.83	34.83	12.80	0.00
Residuals	478	1300.70	2.72		
M4	1	34.83	34.83	13.04	0.00
	1	26.87	26.87	10.06	0.00
Residuals	477	1273.84	2.67		

Notes: M1 is model 1, testing the effect of the independent variable (TFP) on the mediating variable (MVA); M2 is model 2, testing the effect of the mediating variable (MVA) on the dependent variables (ENGCO and CO2); M3 is model 3, testing the effect of the independent variable (TFP) on the dependent variables (ENGCO and CO2); M4 is model 4, testing the effects of the independent and mediator variables (TFP and MVA, respectively) on the dependent variables (ENGCO and CO2).

The ANOVA statistics in Tables 4.5, 4.6, and 4.7 evidence the robustness of the various models specified under each dimension of sustainability. This facilitates the analysis of the mediation effect of industrialisation on the nexus between technological innovation and sustainable development in Africa.

4.4.2. Regression results

The regression results for all models under each of the dimensions of sustainable development are presented in Tables 4.8-4.10. In each Table, the regressors are labelled: TFP for total factor productivity, which represents technological innovation, and MVA for manufacturing value added, which represents industrialisation.

The results for the four models (M1-M4) for social sustainability are presented in Table 4.8 under panel A (sustainable development index) and panel B (human development index). From panel A of Table 4.8, when the independent variable (technological innovation) is regressed on the mediator variable (industrialisation), the effect of technological innovation (i.e., total factor productivity (TFP)) on industrialisation (i.e., manufacturing value added (MVA)) is significantly positive ($\beta = 5.20$; $p < 0.05$), as seen in model M1. The effect of industrialisation (i.e., manufacturing value added (MVA)) on sustainable development index (SDI) is significantly positive ($\beta = 0.18$; $p < 0.05$), as seen in model M2.

In model M3, when the independent variable (technological innovation) is regressed on the dependent variable (sustainable development index), the direct effect of technological innovation (TFP) on SDI is significantly positive ($\beta = 9.41$; $p < 0.05$). When the mediator variable and the independent variables are modelled together in model M4, the results show a significant positive effect of the mediator variable (i.e., industrialisation (MVA)) ($\beta = 0.09$; $p < 0.05$), and the effect of the independent variable (TFP) on the dependent variable (SDI) reduces ($\beta = 8.92$; $p < 0.05$), communicating the significance of the mediating effect. Since the directions of the direct and indirect effects are the same, it suggests that there exists a complementary mediation. Hence, the results from this chapter suggest a complementary mediating role of industrialisation in the relationship between technological innovation and social sustainability, proxied by SDI.

The results for the human development index are reported under panel B of Table 4.8. When the independent variable (technological innovation) is regressed on the mediator variable (industrialisation), the effect of technological innovation (i.e., total factor productivity (TFP)) on industrialisation (i.e., manufacturing value added (MVA)) is significantly positive (β = 5.20; $p < 0.05$), as seen in model M1. The effect of industrialisation (i.e., manufacturing value added (MVA)) on human development index (HDI) is significantly positive (β = 0.003; $p < 0.05$), as seen in model M2. In model M3, when the independent variable (technological innovation) is regressed on the dependent variable (human development index), the direct effect of technological innovation (TFP) on HDI is significantly positive (β = 0.11; $p < 0.05$).

When the mediator variable and the independent variables are modelled together in model M4, the results show a significant positive effect of the mediator variable (i.e., industrialisation (MVA)) (β = 0.02; $p < 0.05$), and the effect of the independent variable (TFP) on the dependent variable (HDI) reduces (β = 0.10; $p < 0.05$), communicating the significance of the mediating effect. Since the directions of the direct and indirect effects are the same, it suggests that there exists a complementary mediation. Therefore, the results from this chapter suggest a complementary mediating role of industrialisation in the relationship between technological innovation and social sustainability, proxied by HDI.

Table 4.8: Regression coefficients for social sustainability models

Panel A: SDI		Beta	*SE*	T-stats	Sig.
M1	(Intercept)	17.38	0.39	44.60	0.00
	TFP	5.20	1.06	4.90	0.00
M2	(Intercept)	1.26	0.87	1.46	0.15
	MVA	0.18	0.04	3.99	0.00
M3	(Intercept)	2.22	0.36	6.23	0.00
	TFP	9.41	0.97	9.70	0.00
M4	(Intercept)	0.60	0.80	0.74	0.46
	TFP	8.92	0.99	9.02	0.00
	MVA	0.09	0.04	2.24	0.03
Panel B: HDI		**Beta**	***SE***	**T-stats**	**Sig.**
M1	(Intercept)	17.38	0.39	44.60	0.00
	TFP	5.20	1.06	4.90	0.00
M2	(Intercept)	0.47	0.01	35.90	0.00
	MVA	0.003	0.00	4.15	0.00
M3	(Intercept)	0.50	0.01	88.31	0.00
	TFP	0.11	0.02	7.15	0.00
M4	(Intercept)	0.46	0.01	36.62	0.00
	TFP	0.10	0.02	6.41	0.00
	MVA	0.002	0.00	2.82	0.01

Notes: SDI is sustainable development index; HDI is human development index; TFP is total factor productivity; MVA is manufacturing value added. M1 is model 1, testing the effect of the independent variable (TFP) on the mediating variable (MVA); M2 is model 2, testing the effect of the mediating variable (MVA) on the dependent variables (SDI and HDI); M3 is model 3, testing the effect of the independent variable (TFP) on the dependent variables (SDI and HDI); M4 is model 4, testing the effects of the independent and mediator variables (TFP and MVA, respectively) on the dependent variables (SDI and HDI).

The regression results in Table 4.9 are for the four models (M1-M4) of economic sustainability, proxied by GDP growth per capita (GDPGPC). The results show that when the independent variable (technological innovation) is regressed on the mediator variable (industrialisation), the effect of technological innovation (i.e., total factor productivity (TFP)) on industrialisation (i.e., manufacturing value added (MVA)) is significantly positive (β = 5.20; $p < 0.05$), as seen in model M1. The effect of industrialisation (i.e., manufacturing value added (MVA)) on GDP growth per capita (GDPGPC) is significantly positive (β = 0.05; $p < 0.05$), as seen in model M2.

In model M3, when the independent variable (technological innovation) is regressed on the dependent variable (GDP growth per capita), the direct effect of technological innovation (TFP) on GDPGPC is significantly positive ($\beta = 1.90$; $p < 0.05$). When the mediator variable and the independent variables are modelled together in model M4, the results show a significant positive effect of the mediator variable (i.e., industrialisation (MVA)) ($\beta = 0.04$; $p < 0.05$), and the effect of the independent variable (TFP) on the dependent variable (GDPGPC) reduces ($\beta = 1.70$; $p < 0.05$), communicating the significance of the mediating effect of industrialisation on the nexus between technological innovation and economic sustainability. Since the directions of the direct and indirect effects are the same, it suggests that there exists a complementary mediation. Hence, the results from this chapter suggest a complementary mediating role of industrialisation in the relationship between technological innovation and economic sustainability, proxied by GDPGPC.

Table 4.9: Regression coefficients for the economic sustainability model

GDPGPC		Beta	*SE*	T-stats	Sig.
M1	(Intercept)	17.38	0.39	44.60	0.00
	TFP	5.20	1.06	4.90	0.00
M2	(Intercept)	0.57	0.57	1.00	0.32
	MVA	0.05	0.03	1.91	0.06
M3	(Intercept)	1.12	0.25	4.49	0.00
	TFP	1.90	0.68	2.80	0.01
M4	(Intercept)	0.44	0.57	0.78	0.44
	TFP	1.70	0.69	2.44	0.01
	MVA	0.04	0.03	1.34	0.18

Notes: GDPPC is GDP per capita; ENGCO is energy consumption; TFP is total factor productivity; MVA is manufacturing value added. M1 is model 1, testing the effect of the independent variable (TFP) on the mediating variable (MVA); M2 is model 2, testing the effect of the mediating variable (MVA) on the dependent variable (GDPGPC); M3 is model 3, testing the effect of the independent variable (TFP) on the dependent variable (GDPGPC); M4 is model 4, testing the effects of the independent and mediator variables (TFP and MVA, respectively) on the dependent variable (GDPGPC).

The regression results in Table 4.10 are those of the four models (M1-M4) for ecological sustainability – energy consumption (ENGCO) in panel A and CO2 emissions (CO2) in panel B. From panel A of Table 4.10, when the independent variable (technological innovation) is regressed on the mediator variable (industrialisation), the effect of technological innovation (i.e., total factor productivity (TFP)) on industrialisation (i.e., manufacturing value added (MVA)) is significantly positive (β = 5.20; $p < 0.05$), as seen in model M1. The effect of industrialisation (i.e., manufacturing value added (MVA)) on energy consumption (ENGCO) is significantly positive (β = 10.70; $p < 0.05$), as seen in model M2.

In model M3, when the independent variable (technological innovation) is regressed on the dependent variable (energy consumption), the direct effect of technological innovation (TFP) on ENGCO is significantly positive (β = 342.64; $p < 0.05$). When the mediator variable and the independent variables are modelled together in model M4, the results show a significant positive effect of the mediator variable (i.e., industrialisation (MVA)) (β = 7.93; $p < 0.05$), and the effect of the independent variable (TFP) on the dependent variable (ENGCO) reduces (β = 301.43; $p < 0.05$), communicating the significance of the mediating effect. Since the directions of the direct and indirect effects are the same, it suggests that there exists a complementary mediation. Hence, the results from this chapter suggest a complementary mediating role of industrialisation in the relationship between technological innovation and environmental/ecological sustainability, proxied by energy consumption.

The results for CO2 emissions are reported under panel B of Table 4.10. When the independent variable (technological innovation) is regressed on the mediator variable (industrialisation), the effect of technological innovation (i.e., total factor productivity (TFP)) on industrialisation (i.e., manufacturing value added (MVA)) is significantly positive (β =

5.20; $p < 0.05$), as seen in model M1. The effect of industrialisation (i.e., manufacturing value added (MVA)) on CO2 emissions (CO2) is significantly positive ($\beta = 0.045$; $p < 0.05$), as seen in model M2. In model M3, when the independent variable (technological innovation) is regressed on the dependent variable (CO2 emissions), the direct effect of technological innovation (TFP) on HDI is significantly positive ($\beta = 0.99$; $p < 0.05$).

When the mediator variable and the independent variables are modelled together in model M4, the results show a significant positive effect of the mediator variable (i.e., industrialisation (MVA)) ($\beta = 0.037$; $p < 0.05$), and the effect of the independent variable (TFP) on the dependent variable (CO2) reduces ($\beta = 0.79$; $p < 0.05$), communicating the significance of the mediating effect. Since the directions of the direct and indirect effects are the same, it suggests that there exists a complementary mediation. Therefore, the results from this chapter suggest a complementary mediating role of industrialisation in the relationship between technological innovation and ecological/environmental sustainability, proxied by CO2 emissions.

Table 4.10: Regression coefficients for environmental sustainability models

		Panel A: ENGCO			
		Beta	*SE*	T-stats	Sig.
M1	(Intercept)	17.38	0.39	44.60	0.00
	TFP	5.20	1.06	4.90	0.00
M2	(Intercept)	-25.09	60.90	-0.41	0.68
	MVA	10.70	3.08	3.47	0.00
M3	(Intercept)	90.20	26.64	3.39	0.00
	TFP	342.64	72.60	4.72	0.00
M4	(Intercept)	-47.60	60.18	-0.79	0.43
	TFP	301.43	73.97	4.08	0.00
	MVA	7.93	3.11	2.55	0.01
		Panel B: CO2 Emission			
		Beta	*SE*	T-stats	Sig.
M1	(Intercept)	17.38	0.39	44.60	0.00

	TFP	5.20	1.06	4.90	0.00
M2	(Intercept)	0.04	0.23	0.18	0.86
	MVA	0.04	0.01	3.86	0.00
M3	(Intercept)	0.63	0.10	6.22	0.00
	TFP	0.99	0.28	3.58	0.00
M4	(Intercept)	-0.02	0.23	-0.08	0.93
	TFP	0.79	0.28	2.83	0.00
	MVA	0.04	0.01	3.17	0.00

Notes: ENGCO is energy consumption; TFP is total factor productivity; MVA is manufacturing value added. M1 is model 1, testing the effect of the independent variable (TFP) on the mediating variable (MVA); M2 is model 2, testing the effect of the mediating variable (MVA) on the dependent variables (ENGCO and CO2); M3 is model 3, testing the effect of the independent variable (TFP) on the dependent variables (ENGCO and CO2); M4 is model 4, testing the effects of the independent and mediator variables (TFP and MVA, respectively) on the dependent variables (ENGCO and CO2).

4.5. Discussion

This chapter investigated the mediating effect of industrialisation on the relationship between technological innovation and sustainable development among African countries. The results from the empirical analysis indicate intriguing findings that are discussed in this section. The discussion covers three related issues – first, on the results concerning the mediating effect of industrialisation on the relationship between technological innovation and social sustainability; second, on the mediating effect of industrialisation on the relationship between technological innovation and economic sustainability; and third, on the mediating effect of industrialisation on the relationship between technological innovation and ecological/environmental sustainability.

In terms of social sustainability, the results suggest a positive effect of both industrialisation and technological development. This relationship is consistent with both proxies of social sustainability (i.e., HDI and SDI). From the perspective of technological innovation and social sustainability, the result is reasonable. Thus, increases in activities related to technological innovation are expected to improve social sustainability standards. In practice, human capital could be developed through the application of technological processes. When an economy improves upon its technology, it is expected that the human capital is developed to the level where it can easily apply the invented technology (Wang, Luo, Sari, & Sharo, 2020). This leads to improvement in educational levels, income, and life expectancy of individuals which, in turn, leads to higher ratings in respect of the human development index and sustainable development index. This finding is commensurate with Kiamba's (2012) observation that increasing the nature of industrialisation through technological innovation in developing countries can result in urbanisation which, in turn, leads to sustainable development and was recently emphasised by Wang et al. (2020).

Drawing insights from the above discussion, it stands to reason that technological innovation 'in' and/or 'of' itself may not be able to completely explain the variations in an economy's level of economic, social, and ecological/environmental sustainability. Given any level of technological innovation, an economy's industries are required to make full and effective implementation of such innovation to enhance its influence on social sustainability (Cheng, Awan, Ahmad, & Tan, 2021). This chapter revealed that both technological innovation and industrialisation significantly positively influence social sustainability. Improvements to the contribution of the manufacturing sector of economies are facilitated by improvements in existing and the introduction of new technological processes.

Impliedly, we could deduce that the contribution of technological innovation toward economic growth and development is complemented by the level of industrialisation in the economy (Omri, 2020; Zhou, Cai, Tan, Zhang, & Song, 2021). This explains the mediated effect posed by industrialisation on the relationship between technological innovation and economic sustainability, which is proxied by GDP growth per capita. This chapter provides enough evidence in support of a complementary mediating effect of industrialisation on the relationship between technological innovation and the overall level of sustainable development in Africa.

The findings from this chapter also highlight the positive impact of both technological innovation and industrialisation on ecological sustainability. Despite the effects being in a positive direction, the implication of this result is unfavourable to sustainable development. Although it is hardly arguable that an economy will train its human capital to meet the demands of new technological inventions, the quality of structures and governance procedures are instrumental in ensuring that innovations from technology are effectively utilised by industries. Amid weak structures and poor governance structures, technological innovation results in reduced economic growth (Castellacci & Natera, 2013; Law & Azman-Saini, 2012). Since Africa has been characterised by poor and weak governance structures (Adeoye et al., 2020), it is not surprising that technological innovations rather augment the levels of CO2 emissions and energy consumption. This finding lends additional support to the work of Bekhet and Abdul Latif (2018) in which the authors found that technological innovation would hardly contribute to sustainable development if it is not supported by quality institutions and governance mechanisms. Conversely, the result contradicts the conclusion of Wang, Umar, Akram and Caglar (2021) that technological innovation contributes to ecological sustainability. The disparity in findings could be justified based on geographical differences and asymmetric levels of development among developing countries and/or regional blocs (such as Africa) and their developed counterparts.

This chapter reiterates the position of Dutrénit et al. (2011) that less developed nations may not catch up to the degree of industrialisation in high-income nations more quickly until they put policies in place to promote industrialisation. Overall, the complementary role of industrialisation can be emphasised from the increasing drive for globalisation and the advocate for more open economies. Highly industrialised economies are expected to be open to other markets. As industrialised economies increase their demand for innovative technology to boost output and trade (Bloom, Draca, Van Reenen, 2016; Lee, Sangwon, Nam, Lee, Seonmi, Son, 2016; Wang et al., 2021), the partial role contributed by both industrialisation on the relationship between technological innovation and industrialisation cannot be shelved.

4.6. Conclusions and recommendations

The foundations for the focus of this chapter had been laid in the third and fourth chapters. The third chapter of this research indicated that the level of economic development among African economies could be boosted through industrialisation and complemented by financial development. Following such findings, the fourth chapter examined the interactive role of technological innovation in the relationship between financial development and sustainable development in Africa. The findings from the chapter highlighted the complementary role of technological innovation in the relationship between financial development and sustainable development in Africa. In an era of an increasing need for sustainability, these findings stressed the need to further ascertain possible convolutions between sustainable development, technological innovation, and industrialisation among African economies. The impetus for this analysis partly stems from the fact that industrialisation has some externalities it poses to economies. Therefore, the goal of this chapter was to provide empirical evidence that helps understand the true role of industrialisation in the relationship between technological innovation and sustainable development to foster policy formulation.

This chapter analysed the mediating effect of industrialisation on the relationship between technological innovation and the three dimensions of sustainable development (social, economic, and ecological/environmental sustainability) in Africa. In this chapter, social sustainability proxies included the sustainable development index and the human development index; economic sustainability was measured as GDP growth per capita; ecological/environmental sustainability proxies included energy consumption per 100 people and CO_2 emissions per metric tonne; industrialisation was proxied with manufacturing value-added, and total factor productivity served as the proxy for technological innovation. The hierarchical regression technique originally developed by Baron and Kenny (1986) and modified by Hayes (2009) and Zhao et al. (2010) was employed with datasets covering 48 African countries over the period 2010-2019.

The findings suggest significant positive relationships between technological innovation and all dimensions of sustainable development. That is, the effects of both technological innovation and industrialisation on sustainable development were positive for all dimensions of sustainability but had varied implications. This emphasised the need to analyse how sustainable development is indirectly affected by industrialisation. The findings provide evidence of a partial contribution from industrialisation toward the impact of technological innovation on sustainable development. As a result, this chapter concluded that the level of industrialisation complementarily mediates the relationship between technological innovation and sustainable development in Africa.

Hence, it is expected that in the presence of technological innovations, the manufacturing sector of economies needs to utilise them through industrialisation because it is the surest way through which the benefits of such technological innovations may be realised. Less developed nations and regional blocs like Africa can catch up to the degree of industrialisation in high-income nations more quickly when effective policies are in place to promote optimal industrialisation. It is worth noting that the above conclusion holds for social and economic sustainability. In terms of environmental sustainability, the chapter reveals that among African economies, a rise in industrialisation activities from technological innovations rather inhibits sustainability by increasing CO2 emissions and energy consumption. The peculiar situation of African economies concerning poor structures of governance and institutions is accountable for this.

Findings from the chapter point to several implications for which appropriate recommendations must be considered to optimise the extent to which sustainable development may be boosted and minimise externalities. The following two recommendations are critically based on the implications of the key findings from the chapter.

First, an effectively coordinated set of policies are essential to reduce externalities that result from industrialisation. Regulators from Africa could devise a set of synchronised policies that govern the means through which member economies industrialise. Through this, disparities in approaches to achieving sustainability could be lessened and the partial contribution of industrialisation towards sustainable development could be fully enhanced. Second, it should be emphasised that there may be convolutions in the relationship between technological innovation and sustainable development. To support sustainable growth in Africa, technological innovation must be combined with carefully chosen policies. Wrong channels of industrialising among developing economies like Africa may result in higher levels of environmental deterioration, which harms the attainment of ecological/environmental sustainability. Hence, policymakers should not overlook the partial role of industrialisation and carefully select implementation policies and channels.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Introduction

This chapter comprises the study's summary, conclusions, and recommendations. The chapter commences by summarising the main findings, followed by highlights of the study's contributions to the body of knowledge, and policy recommendations. The final section of this chapter highlights potential directions for future research.

5.2 Summary

Motivated by the drive towards the promotion of sustainable development in Africa by the African Union and other parastatal bodies, especially the UN, this thesis examined the convoluted connections between financial development, technological innovation, industrialisation, and sustainable development in Africa. The UN has instituted 17 crucial goals to promote sustainable development. These 17 Sustainable Development Goals (SDGs) have been decomposed into 169 sub-goals to be achieved under the 2030 agenda for sustainable development. The goals are essentially grouped into economic, ecological, and social goals. Against this, the African Union has embraced the Sustainable Development Goals by motivating member countries to come up with programmes that are directly related to the goals. However, whereas a lot of discussions have occurred, much of the talk has been oblivious to empirical data analysis.

The African Union has realised the importance of industrialisation in spearheading the bridging of the poverty gap in Africa. Industrialisation is seen as the panacea for job creation, prosperity, and wealth creation. Industrialisation induces innovation by introducing new equipment, new production techniques, increasing capacities and spreading improvements across sectors of the economy (African Development Bank, 2019). However, since the 1990s when the policymakers started talking about industrialisation, not much has been achieved on that score. To this end, this thesis developed the following research hypotheses based on the outcome of a review of the existing literature:

1. Does financial development induce technological innovations in influencing sustainable development in Africa?

2. What is the role of financial development in the relationship between technological innovation and economic, social, and ecological sustainability?

3. Can African countries leverage technological innovation to boost industrialisation without compromising on economic, social, and environmental sustainability?

The methodological approaches employed in executing the various objectives were the systems dynamic generalised method of moments (GMM) technique and the analysis of variance (ANOVA) technique. The GMM approach helped in analysing whether financial development induce technological innovations in influencing sustainable development in Africa and the role of financial development in the relationship between technological innovation and economic, social, and ecological sustainability while the ANOVA approach aided in modelling the mediating effect of technological innovation in the relationship between industrialisation and economic, social, and environmental sustainability.

5.3 Conclusions and findings

5.3.1 Industrialisation and sustainable development in Africa

This thesis analysed the complementary role of financial development in the relationship between industrialisation and sustainable economic development in Africa. The system dynamic GMM technique was employed with a dataset covering 2010-2019 for 48 African countries. Having controlled for the influence of ICT infrastructure, trade openness, inflation, and population size, the analysis covered two parts. First, the fundamental effects of industrialisation and financial development were examined by proxying industrialisation by manufacturing value-added and economic growth by GDP per capita. In the second part of the analysis, the complementary role of financial development on the relationship between industrialisation and economic development was analysed and this was measured based on the interaction between industrialisation and financial development proxies.

This thesis found that industrialisation is a significant positive driver of economic development. The role of financial development in the economic development agenda among African economies was also emphasised by the results. Although the relationships for all financial development proxies with economic development were positive, the significant relationships were between the proxies domestic credit to the private sector and domestic credit to the private sector by banks, and economic development. Notwithstanding, the importance of broad money in contributing to economic development in Africa cannot be shelved, as was evident in the moderation analysis. Results from the moderation analysis suggested that the level of financial development, for all three proxies, significantly complements industrialisation towards improving economic growth. Thus, a more developed financial sector is potent in building an industrial economy which facilitates value addition in the manufacturing sector. It is recommended that the drive towards economic development through the industrialisation of economies is complemented by a resilient financial sector. A well-developed financial sector could facilitate the efficient channelling of funds from surplus spending units to deficit spending households and firms whose activities are directed towards adding value to their operations.

Furthermore, while trade openness and ICT infrastructure are a positive boost for economic development, inflation and population size negatively drive economic growth among African economies. Essentially, it must be noted that effective management of the current levels of economic development would significantly determine future years' level of economic development. The findings imply that the levels of economic development should be managed in such a manner that yields higher margins above the margins of increments in total population. Economic and policy management in African states should therefore incorporate proactive and effective management practices hinged on infrastructural and financial development to collectively build and grow the African continent towards the attainment of sustainable and/or millennium development goals S/MDGs.

5.3.2 Financial development, technological innovation, and sustainable development

Having drawn insights from the findings from the first empirical chapter which indicated that the level of economic development among African economies could be boosted through industrialisation and complemented by financial development, this thesis further examined the interactive role of technological innovation in the relationship between financial development and sustainable development in Africa. After controlling for the influence of ICT infrastructure, trade openness, inflation, and population size, the system dynamic general methods of moments (GMM) technique was employed with a panel dataset covering 2010-2019 for 48 African countries. This analysis covered two parts. First, the fundamental effects of financial development and technological innovation and, second, the moderation effect of technological innovation on the relationship between financial development and sustainable development in Africa. In the first part, the fundamental relationships, by proxying technological innovation with total factor productivity, all analyses were carried while in the second part, the moderating effect of technological innovation on the relationship between financial development and sustainable development was analysed. The moderating variable was measured as the interaction between technological innovation and the various financial development proxies.

The results indicated significant effects of financial development on sustainable development as well as significant relationships between technological innovation and sustainable development. Indicatively, in terms of social sustainability, the findings suggested that financial development tends to reduce social sustainability among Africa economies such that increasing the quantum of broad money and increasing the amount of domestic credit to the private sector either by households or by banks would not necessarily improve the level of social development in Africa. Turning to economic sustainability, the findings divulged a positive relationship between financial development and the economic dimension of sustainable development (i.e., economic sustainability), suggesting that Africa countries could leverage financial development, particularly by encouraging the supply of credit to private sector either by households or banks to enable industries to improve their operations. Concerning ecological/environmental sustainability, findings from this thesis indicated mixed relationships between financial development and ecological sustainability. Thus, depending on the proxy, financial development either increases or decreases energy consumption and CO_2 emissions in Africa. Meanwhile, the effect of technological innovation on sustainable development was positive for all dimensions of sustainability but obviously had varied implications. This emphasised the need to analyse how sustainable development is affected by the interaction between financial development and technological innovation. The findings from the moderation effect divulged that more technological innovation lessens SDI but increases GDP growth per capita, CO_2 emissions, and energy consumption. Impliedly, the trade-off between the various dimensions of sustainability that may prevail when working towards the achievement of sustainable development cannot go unnoticed.

5.3.3 Technological innovation, industrialisation, and sustainable development

This thesis revealed that the level of economic development among African economies could be boosted through industrialisation and complemented by financial development. Following such findings, the interactive role of technological innovation in the relationship between financial development and sustainable development in Africa was analysed. The findings from such an analysis highlighted the complementary role of technological innovation in the relationship between financial development and sustainable development in Africa. In an era of an increasing need for sustainability, these findings stressed the need to further ascertain possible convolutions between sustainable development, technological innovation, and industrialisation among African economies. The impetus for this analysis partly stemmed from the fact that industrialisation has some externalities it poses to economies. Therefore, there was a need to provide empirical evidence that helps understand the true role of industrialisation in the relationship between technological innovation and sustainable development to foster policy formulation.

This thesis analysed the mediating effect of industrialisation on the relationship between technological innovation and the three dimensions of sustainable development (social, economic, and ecological/environmental sustainability) in Africa. Social sustainability proxies included the sustainable development index and the human development index; economic sustainability was measured as GDP growth per capita; ecological/environmental sustainability proxies included energy consumption per 100 people and CO_2 emissions per metric tonne; industrialisation was proxied with manufacturing value-added, and total factor productivity served as the proxy for technological innovation. The hierarchical regression technique originally developed by Baron and Kenny (1986) and modified by Hayes (2009) and Zhao et al. (2010) was employed with datasets covering 48 African countries over the period 2010-2019.

The findings suggest significant positive relationships between technological innovation and all dimensions of sustainable development, emphasising the need to analyse how sustainable development is indirectly affected by industrialisation. The findings provide evidence of a partial contribution from industrialisation toward the impact of technological innovation on sustainable development. As a result, this thesis concluded that the level of industrialisation complementarily mediates the relationship between technological innovation and sustainable development in Africa. Hence, it is expected that in the presence of technological innovations, the manufacturing sector of economies needs to utilise them through industrialisation because it is the surest way through which the benefits of such technological innovations may be realised. Less developed nations and regional blocs like Africa can catch up to the degree of industrialisation in high-income nations more quickly when effective policies are in place to promote optimal industrialisation. It is worth noting that the above conclusion holds for social and economic sustainability. In terms of environmental sustainability, this thesis revealed that among African economies, a rise in industrialisation activities from technological innovations rather inhibits sustainability by increasing CO_2

emissions and energy consumption. The peculiar situation of African economies concerning poor structures of governance and institutions is accountable for this.

5.4 Recommendations

Findings from the thesis suggest that the level of economic development among African economies could be boosted through industrialisation and complemented by financial development. It is prudent for regional economies to streamline policies targeted at achieving sustainable development. The coming together of leading and notable developed economies to support the crafting of policies and their implementation for sustainable growth and development is key to ensuring minimal environmental degradation whilst boosting economic and social sustainability. Transfers – of advanced technologies – from technological leaders to technological frontiers must be encouraged to support the collective sustainable growth of the world economy through reductions in CO2 emissions and other practices that inhibit social, ecological/environmental, and economic sustainability. This collaboration between developed (technological leaders) and developing (technological frontiers) economies is essential owing to the high contributions of global world CO2 emissions from developing economies for which the effect is suffered by the world at large. It must be noted that the link between technological innovation and financial development may be complicated. In effect, technological innovation must be integrated with strategically positioned policies to boost sustainable development in Africa.

Therefore, policymakers should prioritize the development of a resilient financial sector to complement the drive towards industrialization. To achieve this, policies could focus on enhancing access to financial services and products for households and firms, promoting financial innovation and modernization, and strengthening the regulatory framework to ensure financial stability and consumer protection. Additionally, policies aimed at promoting trade openness and improving ICT infrastructure could be implemented, while efforts should also be made to address the negative impact of inflation and population size on economic growth. Overall, the policy implication is that African states should adopt a holistic and proactive approach to economic and policy management, incorporating infrastructural and financial development strategies to collectively build and grow the African continent towards the attainment of sustainable development goals.

Also, a recommendation from the findings of the analysis is to promote a balanced approach to sustainable development in Africa, by focusing on encouraging financial development to support economic sustainability, managing the social impact of financial development, promoting technological innovation to support all dimensions of sustainability, and managing the trade-offs between sustainability dimensions. Policymakers could consider implementing measures such as increasing access to credit for the private sector, investing in social safety nets, promoting financial literacy programs, investing in research and development, providing incentives for innovation, and promoting the adoption of new technologies, and balancing trade-offs between different dimensions of sustainability, such as promoting energy efficiency and renewable energy to mitigate the negative environmental impact of economic growth.

The findings suggest that policymakers in Africa should focus on promoting both technological innovation and industrialisation to achieve sustainable development. This can be achieved by creating an enabling environment for the manufacturing sector to utilise technological innovations effectively. However, an effectively coordinated set of policies are essential to reduce negative externalities that result from industrialisation. Regulators from Africa could devise a set of synchronised policies that govern the means through which member economies industrialise. Through this, disparities in approaches to achieving sustainability could be lessened and the partial contribution of industrialisation towards sustainable development could be fully enhanced. It is worth emphasising that there may be convolutions in the relationship between technological innovation and sustainable development. To support sustainable growth in Africa, technological innovation must be combined with carefully chosen policies. Wrong channels of industrialising among developing economies like Africa may result in higher levels of environmental deterioration, which harms the attainment of ecological/environmental sustainability. Hence, policymakers should not overlook the partial role of industrialisation and carefully select implementation policies and channels.

5.5 Areas for future research

By way of broadening the existing evidence in the body of knowledge, the role of institutions in the relationship between technological innovation and sustainable growth could be given attention in future studies.

Also, a contrasting study between the circumstances in Africa and other regions could be looked at in future studies.

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Appendix

List of Countries used in the study

Angola	Gabon	Niger
Burundi	Ghana	Nigeria
Benin	Guinea	Rwanda
Burkina Faso	Gambia	Sudan
Botswana	Guinea-Bissau	Senegal
Central African Republic	Equatorial Guinea	Sierra Leone
Chad	Kenya	Somalia
Côte d'Ivoire	Liberia	South Sudan
Cameroon	Lesotho	São Tomé and Principe
Congo	Madagascar	Seychelles
Democratic Republic Congo	Mali	Togo
Comoros	Mozambique	Tanzania
Cabo Verde	Mauritania	Uganda
Eritrea	Mauritius	South Africa
Eswatini	Malawi	Zambia
Ethiopia	Namibia	Zimbabwe