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Triple Helix model: leveraging endogenous innovation systems for economic transformation in Africa

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Abstract: Economic transformation in Africa has been largely undermined by the lack of endogenous innovation models and development paths. Different governments in Africa have had to juggle several foreign development plans and policies, albeit with little success. The Triple Helix model, however, offers great opportunities for development, given its emphasis on the synergy among key development actors – university, industry and government. Hence, this study presents the Triple Helix model as a viable and sustainable tool for engendering economic transformation in Africa. The problems and prospects of implementing the model in Africa were extensively discussed. Findings revealed relatively weak links among the development actors in Africa owing to the dismal performance of many African countries' innovation indicators. Therefore, this study reiterates the imperatives of implementing the Triple Helix model in African countries towards the achievement of structural economic transformation, sustainable development as well as the transition from resource-based economies to knowledge-based economies.

Keywords: Triple Helix model; development actors; innovation model; economic transformation; Africa.

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1 Introduction

Several attempts have been made to theorise the paths to sustained economic growth (Solow, 1956; Romer, 1986; Aghion and Howitt, 1992), taking cues from the experiences of developed economies. These pathways are showcased, among other reasons, to explain the reasons for cross-country income disparity and to enable emerging and developing economies leverage the existing knowledge to drive economic transformation. One of the key consensus made by growth theorists is that technological innovation plays a pivotal role in promoting economic growth (Romer, 1990), although some growth theorists treat it as exogenous while others believe it is endogenously determined. A major conclusion from the various growth theories, however, is that the growth differentials across different countries of the world are determined largely by their level of technological progress (Romer, 2012).

Growth theories identified technological innovation as a growth driver but failed to lucidly describe how interactions among economic players can foster innovation. Thus, the quest to further explain how technological innovation can be fostered by key economic actors (university, industry and government) led to the development of the Triple Helix model (Etzkowitz and Leydesdorff, 1995; Leydesdorff and Etzkowitz, 1996; Etzkowitz and Leydesdorff, 2000; Zhou and Etzkowitz, 2021). It is a normative model situated within the framework of a knowledge-based economy to explain the interactions of university, industry and government in the national innovation system (NIS). While universities and research institutions are expected to conduct research, the industries are expected to uptake the outcomes of the research and the government should make policies to foster the university-industry interaction. Succinctly, the Triple Helix model assumes mutual interlinkages among the three aforementioned development actors, each of which carries out research (university), relies on research outcomes (industry) and formulates research-enhancing policies (government).

The model assumes that the modern economy is mostly knowledge-based and innovation-driven thus, universities, industry and government have important roles to play to become and stay competitive in the ever-changing global economy (Hasche et al., 2019). The modern economy has shown that universities need to offer beyond their traditional role of training personnel for the labour market and conducting research for promotion purposes by engaging in research that meet industrial needs as well as establishing incubators in collaboration with other stakeholders to foster the local innovation environment (Nwagwu, 2008; Adeoti, 2020). Moreover, the stiff competition

among firms and the desire for product varieties by consumers suggest the need for firms to depend on universities and research institutes to develop new products and processes to meet the new demands of the contemporary labour and product markets. Government forms the third key player in building an innovation system as it has a moderating role to play in the university-industry nexus (Zhou and Etzkowitz, 2021).

The Triple Helix model has been extensively applied in various economies to explain the triadic relationship among universities, industry and government in fostering national and regional innovation systems (Etzkowitz and Dzisah, 2008; Nwagwu, 2008; Saad et al., 2008; Cai, 2014; Zhou and Etzkowitz, 2021). However, there seems to be a lack of synergy among key development actors (universities/research institutions, industry and government) in developing regions including Africa, which continues to pose a serious challenge to technology and knowledge transfer as well as hampers the development of innovation systems and economic competitiveness in the continent (Afolabi and Ogunjimi, 2020; Adeoti et al., 2021; Afolabi, 2022). The application of the Triple Helix model has been largely idealistic in Africa given the nature and state of most African universities, the first point of call in the model and the supposed initiators of innovation (Nwagwu, 2008). First, most African government-owned universities together with their research and development (R&D) activities are poorly funded, thus they lack the requisite resources to produce innovation that would serve the industrial community and achieve the government's innovation goals (Bolaji et al., 2021; Olanrewaju and Afolabi, 2022). This has led to incessant industrial actions by both academic and non-academic staff in many African public tertiary institutions.

Second, the few innovations by the tertiary institutions are often unusable and uneconomical for industrialists and the government as a result of their fragility, high relative cost, heavy weight and complexity, among others (Adeoti et al., 2021). This has led to limited uptake of innovation and has made African universities resort to mainly producing a national workforce rather than complementing it with being an innovation producer. Third, universities are under intense pressure from the government and industrialists to simultaneously produce the requisite manpower to meet the country's labour market needs and to conduct researches to produce useful and modern innovation for the economy (Adeoti, 2020). However, their capacity to effectively perform these dual roles is limited. The failure of universities to play their role of generating innovation has compelled industrialists to invest in R&D and depend less on the government for their operations, thus promoting informality and deterring the mutual interactions proposed by the Triple Helix model. This has been the case in the few technology and innovation hubs in Africa. Some of them sprang up and devised strategies to develop their innovation systems, a situation which made them a formidable force in the production of knowledge and innovation.

Sidelining universities and research institutions in the production of innovation could encumber the industrial sector and reduce their effectiveness in carrying out their primary roles of producing goods and services. Hence, it becomes important for each development actor to play its role effectively to engender sustained economic growth in Africa. Against this backdrop, this study contributes to the literature by exploring how the Triple Helix model can be applied to foster economic transformation in Africa, while also shedding light on the unique challenges and opportunities faced by African nations in their pursuit of innovation-led growth. The novelty of this study is its application of the Triple Helix model to economic transformation in Africa. Previous studies have focused

on the application of the model at a country-level (Peterman et al., 2001; Adamsone, 2002; Nwagwu, 2008; Ukwuoma et al., 2018; Niembro and Starobinsky, 2023) with only a few adopting the model in a cross-country study (Saad et al., 2008; Daniels et al., 2017; Fidanoski et al., 2017). Of the few studies on the multi-country study, there appears to be no evidence on the implications of applying the Triple Helix model for economic transformation in Africa. Given the observed homogeneity in African countries' innovation system (Nwagwu, 2008), it becomes important to underscore how indigenous innovation can be leveraged among key development actors within the Triple Helix model framework to power a structurally transformed and knowledge-based economy in Africa. This is novel because it will address the specific challenges and opportunities faced by African countries in fostering economic transformation through innovation. It also underscores the need for development actors to become more active contributors to innovation process to foster economic transformation in Africa.

Following this section, the rest of this study is structured as follows: Section 2 provides empirical evidence on the nexus between the Triple Helix model and economic development while Section 3 describes the innovation frameworks and key innovation indicators in Africa. Section 4 presents the problems and prospects of adapting the Triple Helix model to the African context while Section 5 concludes the study.

2 Triple Helix model and economic development

The role of development actors (universities, industry and government) in fostering economic transformation is well documented in the literature (Saad et al., 2008; Daniels et al., 2017; Fidanoski et al., 2017; Hasche et al., 2019; Zhou and Etzkowitz, 2021). Karl Compton of Massachusetts Institute of Technology (MIT), in the 1930s, pioneered the strategy of creating new tech firms that operationalise university research outputs to simultaneously drive technological advancement, industrialisation and economic transformation (Etzkowitz and Dzisah, 2008). These new firms revolutionised the thinking on universities being agents of the trio of technological development, industrialisation and economic transformation as the income of the modern firms in 1997, which stood at about US$116 billion, was equivalent to the gross domestic product (GDP) of the 24th world largest economy (Bank Boston, 1997). In addition, about 4,000 MIT-related firms not only employed roughly 1.1 million people but also amassed unprecedented annual sales of US$232 billion in 1997 (Bank Boston, 1997). Consequently, this innovation model was replicated at Stanford and it led to the creation of an innovation-driven university and the advent of Silicon Valley (a world-class technology/innovation hub). This model was also replicated in Saskatchewan, Canada, where research outputs have become important sources of regional development (Dzisah, 2005). Interestingly, a similar success story was recorded in Saskatchewan as there was an astronomical rise in the creation of university spin-offs, which, in 2001, employed roughly 1,400 people and made a contribution of approximately US$190 million to Saskatchewan's economy (Peterman et al., 2001).

Following these success stories, the roles of universities (teaching and research) were redefined globally to include capitalisation of knowledge, production of innovation and generation of innovation-driven firms (Etzkowitz and Dzisah, 2008). However, the university is only one of the three actors in the Triple Helix framework, which works by engaging the other two development actors in development imperatives. Ideally, the

industry and government are expected to approach universities with their technological needs and the universities should, in turn, leverage their resource pools to meet the needs. The synergy among these development actors is expected to generate an innovation model that would lead to economic transformation. China leveraged this triadic collaboration to develop endogenous innovation models that engendered tremendous economic advancement (Lu, 2000). This was made possible through massive investment in science and technology infrastructures, increased R&D spending, incentives for innovative firms and effective government policy implementation. A multidisciplinary approach was adopted in solving societal problems using R&D and the private sector was given a good business environment for their business operations such that public-private partnership thrived greatly in the promotion of technology and knowledge transfer (Ukwuoma et al., 2018).

China created technology incubators and science parks, which led to a high proliferation of technology firms, which generated millions of jobs for the teeming labour force in the country. Some of these firms, in the course of time, got listed on the Chinese and New York stock exchange markets, positioning China as a prototype of a world-class knowledge-based economy from which developing economies can learn the art of knowledge and technology transfer (McCuaig-Johnston and Zhang, 2015). The role of the science and technology application as well as R&D in regional development was further brought to the fore when the recent spate of the COVID-19 pandemic, which started in China, struck the global economy (Bolaji et al., 2021; Afolabi and Oji, 2021). Cai (2014) noted that the Triple Helix model was developed from the experiences of countries in the Global South thus, a dearth of theoretical and empirical evidences of its application in developing countries exists. Cai (2014), therefore, identified institutional factors as the key difference between China and the West. The study differentiated between the institutions in the West and China with a view to demystifying how Chinese institutions applied the Triple Helix model for innovative and sustainable development. Findings revealed that China modified its institutional environment to foster interactions among innovation actors and innovatively develop its Triple Helix model to take cognisance of the peculiar nature and structure of the Chinese economy.

In the same vein, Daniels et al. (2017) assessed the role of innovation in inclusive development and its influence on public policy in BRICS (Brazil, Russia, India, China and South Africa) countries. The study explained the roles of development actors in a Triple Helix framework and emphasised the importance of the NIS. Findings revealed a dearth of studies promoting innovation for inclusive development and a paucity of empirical evidence explaining the roles of Triple Helix actors in building innovation models in BRICS countries. It was also found that BRICS countries pay little attention to innovation for inclusive growth, which could be attributed to the little knowledge about innovation being a mechanism for inclusive development. Consequently, there is no specific public policy that focuses on innovation for inclusive growth in BRICS countries, indicating the need to develop the Triple Helix model and innovation systems that actively engage all economic actors in development activities.

Aubert (2004) presented a conceptual framework for the generation and diffusion of technological innovation in developing economies, showing the need to provide the necessary support system and empowering relevant agencies to promote technological interactions among various economic actors. Ukwuoma et al. (2018) argued that one of the key strategies for deploying technological innovation for economic transformation is

the development of a NIS. The NIS is a complex set of interactions among economic actors to generate, modify, deploy and diffuse new technologies in a bid to meet various societal needs including industrial, economic, technological and environmental needs. However, the level of interaction and linkages among the various economic actors in African countries have been adjudged weak given the failure of the actors to effectively synergise in carrying out innovation activities (Adelowo et al., 2017; Adeoti, 2020; Adeyinka, 2022).

In an attempt to boost the innovative capacity of firms and engender economic growth in Northern Netherlands, Ranga et al. (2008) adopted the Triple Helix model to investigate the weak link among firms, academic/vocational institutions, and government. Findings revealed that the weak link is caused by information asymmetry among development actors, the government's oblivion of small firms' problems, cultural and linguistic diversity, duplications of duties among government agencies, bureaucratic bottlenecks and poor publicity on government programmes. The study, thus, emphasised the need for effective collaboration of development actors in a Triple Helix framework. Similarly, Saad et al. (2008) advocated for the active involvement of universities in developing countries in their quest for innovation and technological progress. Using Algeria and Malaysia as case studies, the study reiterated the importance of the university in the Triple Helix model as it could play active roles in fostering innovation and sustainable development of the countries.

Zhou and Etskowitz (2021) complemented the initial Triple Helix of university-industry-government with a new Triple Helix of university-public-government in a bid to showcase the important role of the public in fostering innovation. The study showed that twinning the triple helices at the global level will tremendously help in achieving some sustainable development goals (SDGs) through collaborative efforts beyond national borders. The study emphasised that if the SDGs would be achieved by 2030, it is imperative to foster collaboration among individuals, educational institutions, government and non-governmental organisations in deploying triple helices to harmonise innovative and sustainable development. On the other hand, Hasche et al. (2019) extended the Triple Helix model to accommodate civil society and used the quadruple helix framework in the context of the Swedish innovation system. The study showed that the fourth strand of the helix (civil society) should be perceived as an avenue through which the Triple Helix actors take on different value-addition roles for the overall societal good. However, the fourth helix is seen as complex and could mean different things at different times. Thus, Zhou and Etskowitz (2021) argued that extending the Triple Helix could improve/distort the triadic model and stimulate/hamper innovative and sustainable development. Notwithstanding, both the Triple Helix and quadruple helix models emphasise the need for active interactions among innovation actors to foster sustainable economic development.

3 Innovation frameworks and indicators in Africa

3.1 Innovation frameworks: systems of innovation vs. Triple Helix models

Innovation frameworks are structured approaches or models that provide guidance and structure for organisations, governments, and individuals to foster and manage innovation effectively. They help in understanding, organising, and implementing innovation

processes, strategies, and practices. There are several innovation frameworks, and the choice of which one to use depends on the specific goals, context, and needs of the organisation or entity (Leydesdorff and Zawdie, 2010). In this subsection, the systems of innovation and Triple Helix models, two distinct innovation frameworks, are discussed to gain further insights into analysis of innovation processes. These two frameworks have key differences and can complement each other in understanding the complex dynamics of innovation ecosystems. Three key differences are identified in this subsection. First, while the Triple Helix model emphasises the interactions and collaborations among three primary actors in the innovation process: government, industry (businesses), and academia (universities), the systems of innovations model takes a more comprehensive view of innovation processes by considering a wide range of factors and actors beyond the triple helix, including research institutes, financial institutions, civil society, and international organisations (Etzkowitz and Leydesdorff, 2000). Second, the Triple Helix model highlights the importance of institutional arrangements and policies that encourage collaboration among the three helices while the Systems of Innovations model focuses on the evolutionary nature of innovation systems, emphasising that they develop and change over time in response to various internal and external factors. Lastly, the Triple Helix model often looks at innovation ecosystems from a regional perspective with particular emphasis on the role of regional innovation systems in economic development. However, Systems of Innovations model is often used to analyse national and sectoral innovation systems. It considers how innovation occurs within specific industries or sectors and how it contributes to economic growth (Adamsone, 2002).

Nevertheless, these innovation frameworks play complementary, rather than substitutionary roles, in fostering economic transformation. For example, both the Triple Helix and systems of Innovations models can be integrated to provide a more holistic understanding of innovation ecosystems (Leydesdorff et al., 2017). The combination of the actor-focused perspective of the Triple Helix with the broader and evolutionary view of the systems of innovation can provide deeper insights into the complexity of innovation processes and align them for structural transformation. In addition, while the Triple Helix approach may be more suitable for examining specific collaborations and interactions among key actors, the systems of innovation approach can help contextualise these interactions within the broader innovation system, allowing for the analysis of how innovations diffuse and impact various parts of the system. Also, the combination of these models can lead to more effective innovation policy formulation (Adamsone, 2002). Understanding the interplay among actors, institutions, and the larger innovation ecosystem will be helpful in designing policies that promote collaboration, knowledge transfer, and innovation diffusion more strategically. In sum, the Triple Helix and systems of innovation models offer different perspectives on innovation processes but they can complement each other to provide a richer understanding of innovation dynamics and inform more effective innovation policies for economic transformation.

3.2 Innovation indicators in Africa

Several indicators describe the level of innovation in a country. The World Intellectual Property Organization (WIPO) is renowned for computing various innovation indicators and ranking countries based on their performance. WIPO computes the global innovation

index (GII) annually for 132 countries using aggregate input and output variables such as institutions, human capital and research, infrastructure, market sophistication, business sophistication, knowledge and technology outputs and creative outputs. These variables have different components that are computed together to form the variable index. Some of the innovation indicators that are most related to the Triple Helix analysis are presented in Table 1 for selected African countries. Two countries are selected from the five regions in the continent except Central Africa, which has only one country ranked by WIPO – Central Africa (Cameroon), East Africa (Kenya and Tanzania), North Africa (Egypt and Morocco), Southern Africa (Botswana and South Africa) and West Africa (Ghana and Nigeria). These countries are selected based on their economic viability, innovation ecosystem performance and potential to leverage the Triple Helix framework for building a NIS geared towards economic transformation and enhanced competitiveness.

Table 1 shows moderate university-industry research collaboration in South Africa, Ghana, Kenya and Tanzania, whose ranks fall among the top 50 countries. However, a very weak link is observed in university-industry research collaboration in Morocco and Nigeria as depicted by their unimpressive ranking. Overall, the university-industry research collaboration in Africa is relatively weak, depicting a lack of synergy between these development actors thus, stifling the possibility of implementing the Triple Helix model in most African countries. With regards to scientific and technical articles, all the selected African countries except Nigeria are in the top 100 countries, with South Africa topping the ranking in Africa but was ranked 40th globally. Research outputs and innovative ideas that could be useful for industry and public policy are often communicated through scientific and technical articles written by researchers, most of which are published. The ranking of each African country on this scale shows that researchers in African universities and research institutions contribute slightly to the global knowledge base, thus exerting negligible influence on science and public policy in the domestic and global economy. However, the relatively high performance of Egypt and South Africa in terms of scientific and technical articles is attributed to the high ranking of their universities, which often dominate the best ten ranking of African universities by various world-renowned university ranking institutions (see https://www.4icu.org/top-universities-africa/).

Similarly, the receipt and issuance of patents are generally low in Africa as no African country made it to the top 50 on this innovation indicator. This unimpressive performance could be attributed to the relatively low scientific and technological research in the continent as well as the meagre amount many African countries expend on R&D activities, even though a fair proportion of the selected African countries made the top 100 R&D investing countries in the world. Moreover, the emergence of knowledge-based economies across the world necessitates the high demand for not only high-skilled labour but also labour that meets agreed global standards. Thus, knowledge-intensive employment, an innovation indicator that applies more to the industry, has become a key indicator of labour market performance. Unfortunately, most African countries are laggards with regard to this innovation indicator as the share of knowledge-intensive employment in total employment is low in many African countries with countries like Cameroon, Ghana, Morocco and Tanzania failing to make the top 100 countries with high knowledge-intensive employment.

Table 1 Global ranking of innovation indicators among selected African countries in 2021

Country	*University/industry research collaboration*	*Scientific and technical articles*	*Patent by origin*	*High-tech export (% total trade)*	*Knowledge-intensive employment*	*Institution*	*R&D spending (% of GDP)*	*Global innovation index*
Botswana	76	69	121	100	63	59	63	89
Cameroon	75	61	85	107	108	113	NA	123
Egypt	56	54	69	90	50	114	49	94
Ghana	45	73	114	125	104	120	73	112
Kenya	49	77	58	89	NA	80	48	85
Morocco	114	60	74	56	115	74	50	77
Nigeria	122	108	110	120	52	109	NA	118
South Africa	36	40	71	54	61	55	44	61
Tanzania	46	91	99	57	124	103	65	90

Note: The ranking is done among 132 countries.

Source: WIPO (2021)

With regards to the institutional quality in Africa, many African countries lag in developing an appropriate institutional framework that would make innovation thrive. Tragically, no African country made the top 50 countries with the best institutions in the world. Institutions are instrumental in the implementation of the Triple Helix model. However, the pervasively weak institutions in Africa deter the implementation of the Triple Helix model in Africa hence, the need to develop strategic steps to foster improved institutional quality. It is noteworthy that innovation activities in South Africa fared better than in any other African country as its ranking on the GII is the best in Africa even though it ranked 61 out of 132 countries. Overall, the performance of all the sampled African countries in terms of their ranking on the GII is quite unimpressive, indicating the need to deploy various strategies to develop innovation systems across the continent. Fortunately, the Triple Helix model offers the best route to achieving this lofty goal.

4 Adapting the Triple Helix model to Africa: problems and prospects

Africa is blessed with vast natural resources, which have become the mainstay of many economies in the continent. For example, Nigeria, Algeria, Gabon, Angola, Equatorial Guinea, Libya and Congo are greatly endowed with crude oil and natural gas deposits, which qualify them to be among the 13 member nations of the Organization of Petroleum Exporting Countries (OPEC) cartel. In addition, Ghana, South Africa and Mali have the largest gold deposits in the continent and earn foreign exchange from their exports while the Democratic Republic of Congo, Botswana and South Africa are the top producers of and earners of industrial diamonds in Africa. It is interesting to note that more than 50% of mobile phone components are sourced from mineral resources and semi-processed materials derived from mineral resources (Jenness et al., 2016). Specifically, the mobile body is products of aluminium and titanium; the circuit board are from copper, silicon and tantalite; battery is made from lithium, manganese, graphite, cobalt and nickel; the glass screens are produced from potassium and silica; screen assembly components are products of bauxite and tin, and speaker and microphone are made from bastnaesite and sphalerite (Jenness et al., 2016). Some of these mineral resources are extracted in Africa, implying that Africa contributes to the global production of the raw materials needed for producing industrial outputs. According to the World Mining Congress (2021), Africa contributed 5.5% to the world's mineral production in 2019 with a total worth of US$406 billion.

However, considering the non-renewable nature of most of these natural resources and their gradual depletion, it becomes imperative for African countries to devise strategies for economic transformation and competitiveness as was the case in the United Arab Emirates, Singapore, Malaysia, China and South Korea, among other industrialised and industrialising economies. Massive investment needs to be made in R&D activities to help African economies have a strong footing in the global economy by transiting from resource-dependent economies to knowledge-based and innovation-driven economies. Evidence has shown that R&D and innovation activities are not just growth drivers but also accelerators of global competitiveness (Ukuwoma et al., 2018; Adeoti et al., 2021). This further reiterates the importance of developing a NIS rooted in the Triple Helix framework. While universities and research institutions focus on developing useful and relevant innovation, the industry needs to uptake the technological innovations while the

government formulates and implements science, technology and innovation (STI) policies as well as provides adequate funding for R&D activities to strengthen the triadic university-industry-government relationship. The links among development actors (universities/research institutions, industry and government) need to be identified, enforced and reinforced to aid the transition from resource-dependence to knowledge-based and innovation-driven economies in Africa. This would not only accelerate technological innovation in Africa but also foster economic competitiveness across the continent.

The adoption of the Triple Helix model to bridge the wide innovation gap in the African continent can have several practical implications for fostering innovation, structural economic transformation, and sustainable growth on the continent. A few of the practical implications include the strengthening of the continent's R&D ecosystems, promoting entrepreneurship, fostering innovation-driven economies and promoting regional and international collaborations. The investment of African governments in R&D activities, through the funding universities and research institutions, can promote collaboration between academia and industry, provide incentives for R&D activities, lead to the establishment of innovartion parks and further strengthen the continent's R&D ecosystems (Adelowo et al., 2017). More so, facilitating partnerships between universities and entrepreneurs can help translate academic research into practical applications and commercial ventures. It can as well enable African countries to collaborate regionally and internationally, a practice which can facilitate knowledge exchange and improved access to global markets. It can also position African countries as competitive players in the global innovation landscape. More importantly, embracing the Triple Helix model can help African countries transition from resource-based economies to innovation-driven economies, which involves diversifying economic activities and reducing dependence on commodities common in many African countries (Afolabi, 2023a, 2023b).

4.1 Problems of adapting the Triple Helix model to Africa

Given that universities/research institutions are the first point of call in the Triple Helix framework, it is important to start with the problems these institutions pose to the implementation of the Triple Helix framework in Africa. Historically, most African universities have gone through different phases of development after independence from their colonial masters. The erstwhile structure and curriculum of the universities pre-independence are strategically developed to serve the purpose of the colonial masters and not necessarily to induce economic transformation (Nwagwu, 2008). A large proportion of the R&D activities in African colonies pre-independence were restrictive, replicated the academic structure of the colonial masters' home country and promoted colonial policies (Galliard, 1996). Nonetheless, these activities left lasting footprints in Africa in terms of the creation of research institutions, training and employment of research staffs, and creation of detailed inventory of research outputs, among others.

Successive governments, post-independence, have made numerous attempts to nationalise and redefine the roles, structure and curriculum of the universities/research institutions in line with domestic realities. Some of these efforts include the indigenisation of universities' and research institutions' staffs, institutional expansion and proliferation, and the creation of regulatory bodies to implement, monitor and evaluate

national policies. During the 1965–1985 era, many African countries leveraged the support from joint schemes to develop national research systems in which the government played an active role in enhancing scientific development (Galliard, 1996). This era marked the beginning of an increased academic population and research scientists, who were sponsored through grants and aids from international organisations. Consequently, scientific publications from Africa soared on the global stage, notable scientists emerged from the continent, and domestic innovation was greatly enhanced (Nwagwu, 2008). However, external funding nosedived in the 1970s due to mismanagement of funds and the embrace of militarisation in many African countries, which subsequently led to a deterioration in science and technology activities across the continent.

Tragically, infrastructural deficits and dilapidated laboratories became pervasive in the then-modern laboratories in universities and most of the university buildings were ill-managed due to lack/mismanagement of funds. In addition, the salaries of university and research staffs were not commensurate with their labour and their counterparts in politics and other spheres earn more than they do. Consequently, university and research staffs incessantly embark on a series of industrial actions in a bid to negotiate with the government on the need to properly fund university and research and also to improve their welfare. For example, Nwajioha et al. (2021) showed that Nigerian public universities have lost more than five academic sessions to industrial actions between 1991 and 2022 due to the unresponsiveness of the government to the demands of university staff. Moreover, the regulatory bodies of African scientific research communities have gradually lost their influence, making reform implementation an uphill task.

Political instability has also taken its toll on the autonomy of universities and research institutions to lead a knowledge-based economy and develop innovative processes for economic development. The transition from one military regime to another as well as lack of continuity among democratic governments has compelled many research institutions, which have the mandate to carry out research for development, to become mere government parastatals that serve the government's interests. This limits the objectivity of research outputs as the government might oust the leadership of the research institutions that fail to do its bidding. This also attenuated the capacity of universities to conduct quality research for industrial development and discouraged joint research schemes between domestic and foreign universities/research institutions. Hence, innovative activities in most African universities end even before starting. Even though some African universities are not subjected to this malady, the overall performance of the universities in the continent is at a low ebb and undesirable as the contribution of China to the total world's research output (21,154) in 2021 exceeds that of the entire African continent (1,203) by a very wide margin (Nature Index, 2021).

Consequently, there has been a massive brain drain not only of staff of universities but also of potential students of African universities, most of who do not return to the continent after graduation thus, depriving Africa of the opportunity of reaping demographic dividends and human capital development (Ogunjimi and Oladipupo, 2019; Ogunjimi and Adebayo, 2019). This apparently leads to little or no linkage between African universities and the industrial sector; robbing the industry of the innovation they could have received from universities and research institutions to boost industrial performance. Moreover, the migration of skilled labour to developed countries has further been fostered by the growing rate of globalisation at the expense of developing

countries. The rate of emigration of skilled labour from Africa is inimical to both the African labour market and universities. Unfortunately, most foreign-trained Africans and skilled labours do not return to Africa but contribute to the workforce in developed countries due to the poor state of and living conditions in most African economies. This deters the adaptation of the Triple Helix model in the continent, revealing that some elements of the modern global economy contribute substantially to the weak link among development actors in Africa and put the continent in a disadvantaged position of economic deprivation.

The weak university-industry linkage in the continent continues to pose a great threat to industrial performance and economic transformation among African countries as well as limit the application of the Triple Helix model in most parts of the continent. The Triple Helix model assumes synergy among universities, industry and government, with each actor actively playing its role for economic prosperity. Each development actor is expected to be independent, align with shared visions, collaborate with others in achieving the vision and have clearly defined a goal that does not clash with the others'. The setting in most African countries differs significantly from the foregoing as most African universities have been reduced to mere government parastatals, a situation which facilitated the rise of unscholarly research vistas.

More so, African governments often fail to appropriately reward academics and researchers despite the prevailing unpleasant economic woes in most of the countries such as incessant exchange rate depreciation/devaluation, inflation and rising interest rate, which drastically reduce purchasing power. Particularly, the government of many African countries, excluding South Africa and francophone countries slashed the salaries of workers, including university staff and researchers, in their countries in the 1980s and 1990s. Consequently, some researchers relocated abroad while some engaged in vertical and horizontal labour mobility, reducing the staff strength of many universities and research institutions. These aforementioned problems are major deterrents to the application of the Triple Helix model in Africa. Notwithstanding the complex nature of these problems, they could be tackled to aid the development of NISs in each African country.

4.2 Prospects of adapting the Triple Helix model to Africa

Sustainable development has been largely elusive in Africa given the myriads of economic challenges facing the region including rising unemployment, widening income gap, and high poverty incidence, among others. Various institutional and policy efforts have been expended to transform the African economy and lift millions of Africans out of extreme poverty, albeit with minimal success. The Triple Helix model has been identified as a viable propeller of economic transformation as it aided industrialisation, fostered innovation, created jobs and improved welfare in many developed countries (Ahmad and Sole, 2017; Cai and Amaral, 2021). Given the success stories of the Triple Helix model implementation in industrialised countries, the achievement of SDGs in Africa could be facilitated by adapting the Triple Helix model as the model has great potential to position African economies on the path of sustainable development. The prospects of implementing the Triple Helix model in Africa are enormous.

The modern knowledge-based economy requires that each country makes a contribution to the global innovation stock by developing endogenous innovations that

conform to international standards. Hence, African universities/research institutions, the first strand of the Triple Helix model, have key roles to play in initiating the endogenous innovation models, which would be leveraged in the industry and public sector for improved shared economic prosperity. However, African universities must strive first to develop endogenous innovation systems that take cognisance of the structure and peculiarity of each African country with the hope of contributing to the global stock of knowledge/innovation. Ironically, not all globally relevant innovations have local relevance and vice versa. Ideally, effective innovation models and appropriation of knowledge should transit from the local level to the global stage, and not the other way round. This will enable the locals to test and verify the efficacy of the endogenous innovation model by first applying it to their personal and industrial needs.

Thus, the onus lies on the development actors in each African country to prioritise the development of innovation systems that meet local demands without comprising global standards. This calls for a strong synergy among the development actors who should meet regularly to decide on the pressing needs of the country and devise modalities for developing innovation systems that would effectively address the issues. The presence of this strategy will, to a large extent, enable latecomer nations, like many African countries, catch-up and possibly leapfrog some industrialised countries. It will also enable development actors in Africa to solve endogenous problems using endogenous knowledge that conforms to global standards. The endogenous model could be adopted or mimicked by other industrialising or developing countries, a situation which will present African countries as models of innovation and knowledge-based economies. This will not only foster improved economic competitiveness but also create decent jobs for the teeming African labour force, which will help alleviate poverty, close income gaps and improve general economic welfare.

Moreover, the implementation of the Triple Helix model in Africa is a pathway to knowledge-based development in the continent. The model presents African countries with the rare opportunity of transiting from resource-based economies to knowledge-based economies as most of the resources in Africa are non-renewable, thus their depletion is inevitable and imminent. The eventual depletion of these resources spells doom for the continent as the current macroeconomic woes will be further exacerbated. There have been several efforts geared towards economic diversification in Africa but with undesirable outcomes. Thus, the Triple Helix model is presented as a viable tool for achieving this quest. This is due to its inherent ability to identify and address local problems through the interactions among universities, industry and government. The model enhances self-generated development by looking inward to generate and proffer evidence-based solutions to domestic problems with the universities/research institutions being at the forefront but supported by industry actors and the government. This can be done by enhancing local intellectual capacity, providing adequate support to universities/research institutions and innovation hubs, and providing a conducive environment where innovation can thrive.

The transition to a knowledge-based African economy, as is the case in many industrialised economies, is made easier through the Triple Helix model, which is adjudged the ultimate source of development (Etzkowitz and Dzisah, 2008). Thus, development actors in African countries need to synergise to translate research into new products and processes that would aid economic transformation. Efforts should be geared towards creating endogenous sources of development that contextualise innovation to address domestic issues with universities/research institutions, industry and government

playing active roles in this regard. Universities/research institutions need to be reinforced and prioritised as the heart of Africa's development. The modern role of universities to create industrial spheres with the support of the government will foster institutional interrelations and instigate a knowledge-based African economy.

5 Conclusions

The quest for development in Africa has received a major boost in recent decades as evidenced by the formulation and implementation of various foreign and domestic policies as well as the creation of various institutional frameworks. However, the developmental problems of the continent linger. This made African countries remain laggards in the implementation of national and global development plans. The introduction of the Triple Helix model by Etzkowitz and Leydesdorff (1995) and Leydesdorff and Etzkowitz (1996), however, redefined the pathway to economic development, which is triggered by the interactions among university, industry and government. The model gives the university, with the support of the industry and government, an enhanced role in innovation and development, notwithstanding the weak link between African universities and the industry. Considering the age-long developmental problems of Africa, this study showcases the potentials inherent in the Triple Helix model to propel economic transformation in Africa. A robust university, vibrant industry and responsive government interacting with one another in perfect symphony are key prerequisites for implementing the Triple Helix model in Africa.

However, findings revealed relatively weak linkages among these development actors, thus frustrating efforts at implementing the model in the African context. The key bottlenecks in the implementation of the model in Africa include cancellation of external research funding, infrastructural deficits, political instability, massive brain drain, weak university-industry linkage and lack of autonomy of innovation actors. Nonetheless, the implementation of the Triple Helix model offers great potential for economic transformation in Africa including the development of endogenous innovation models, sustainable development paths, creation of decent jobs, industrialisation, poverty alleviation, bridging income gaps, improving general economic welfare and aiding the transition from a resource-based economy to a knowledge-based African economy. Thus, this study advocates for synergy among development actors (university, industry and government) in African countries to build endogenous development and innovation models that would engender economic transformation in the continent. It also suggests the need for all the development actors to actively play their role in fostering endogenous innovations that would meet societal needs and position African countries at the heart of innovation on the global stage.

Despite the novel approach of the Triple Helix model, it has a few limitations. First, it focuses on only three key development actors when, in reality, innovation ecosystems involve a wide range of actors, including research institutes, startups, civil society organisations, and international actors. Second, the model assumes a linear and sequential relationship where government funds academia, academia produces knowledge, and industry applies this knowledge. In practice, innovation is often more complex and nonlinear, with feedback loops, serendipity, and the involvement of various actors at multiple stages. Despite these limitations, the Triple Helix model remains a valuable

framework for understanding and promoting indigenous innovation that is essential for economic transformation. Given the gradual depletion of natural resources in many African countries together with its associated consequences, it becomes crucial for African economies to implement the Triple Helix model to enable their transition to knowledge-intensive economies. The path to self-generating and self-sustaining development lies in the implementation of the Triple Helix model with the university playing a central role in this regard.

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