Innovations

Forecasting STI Indicators (Enablers) for Nigeria Using AI: Insights on Human Capital, Infrastructure, and Regulatory Frameworks towards STYIP

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Abstract: *The development of effective Science, Technology, and Innovation (STI) strategies is critical for national progress, especially in aligning with long-term development plans like Africa's Agenda 2063. This paper investigates the impact of the enabler framework of STI indicators in supporting Nigeria towards the Second Ten-Year Implementation Plan (STYIP) using Artificial Intelligence (AI) to project trends from 2019 to 2035. For the first time, AI-driven forecasts are employed to analyze the interplay between human capital (HC) and key economic indicators, including sectoral growth, economic investment, trade, infrastructure access, and regulatory frameworks. Our research identifies significant trends and relationships across these domains. We found a concerning decline in workforce capabilities, evidenced by a drop in staff training scores from 3.27 in 2019 to 2.79 by 2035. Conversely, the gross enrolment ratio in tertiary education shows a modest increase from 12.24% in 2019 to 14.48% by 2035, yet it still falls short of the STYIP target of 50% by 2033. The adult literacy rate is projected to decline from 61% to 45%, emphasizing the urgent need for educational reforms. Notably, a perfect negative Pearson correlation of -1.000 between trade and infrastructure indicators reveals a strong inverse relationship, indicating critical challenges in balancing these areas. These findings illustrate the importance of strategic investments and policy interventions in reinforcing Nigeria's STI enablers. Our results highlight the pivotal role of infrastructure development, especially in ICT, energy, and transport, in reducing transaction costs and boosting productivity. Moreover, aligning education and training (E&T) with industry demands is essential for sustaining sectoral growth and enhancing economic performance. This study*

contributes to the broader understanding of STI indicator's role in providing a direction for achieving development objectives, providing actionable insights for STI policy formulation for policymakers to drive Nigeria's progress towards the STYIP and Africa's Agenda 2063 goals.

***Keywords**: STI indicator, STYIP, Research and Development, Regulatory Framework, Human Capital, Artificial Intelligence (AI).*

1.0 Harnessing the EF of STI indicator for Development: The case of Nacetem

Globally, the role of Science, Technology, and Innovation (STI) as drivers of economic growth and social development is paramount (Igbinovia and Krupka 2019). For developing countries, fostering an environment conducive to STI is critical for overcoming challenges related to industrialisation, technology adoption, and competitiveness. This paper investigates key enablers of STI by analysing diverse indicators that contribute to the creation of a thriving STI ecosystem in Nigeria. In the quest to elevate Nigeria's economic status and achieve sustainable development, the Science, Technology, and Innovation Policy (STYIP) 2024–2033 stands as a cornerstone. As a key implementation mechanism of Africa's Agenda 2063, the STYIP aims to harness the power of STI to drive socioeconomic progress. Focusing on the 7th Moonshot, harnessing appropriate technologies and developing relevant capacities were identified as pivotal to achieving Agenda 2063 (Union 2024).

The nexus of the STYIP and STI indicators is evident in aspiration 6 and goal 2, where AU member countries agreed to focus on developing well-educated citizens and skills revolutions as key drivers of STI. For the first time, this paper deployed Perplexity AI to project the enabler component of the STI indicators. The study utilised data obtained from reputable platforms, highlighting the relevance of these enablers in supporting Nigeria's journey towards these ambitious goals.

Nigeria recognised the importance of STI indicators and the well-being of the National Innovation System (NIS) organs in 2021. This recognition was evidenced by Siyanbola (2021), who noted the development of a web-based STI indicator dashboard to track and monitor NIS activities. In a project executed by the Africa Centre for Technology Studies (ACTS), the Africa Research and Impact Network (ARIN), the AUDA-NEPAD development agency, the Science Policy Research Unit (SPRU), and OTB Africa in Kenya, Nigeria, and Zambia, over 175 indicators were considered (Williams Siyanbola 2021). These indicators include input, output,

impact, enablers, linkages framework, and general indicators for Nigeria's Scoreboard.

The National Centre for Technology Management (NACETEM) extracted 32 strategic enablers from this list to support the STYIP. The assessment of enabler indicators and the analyses presented herein were based on projections to 2035, aligning with the STYIP's end in 2033 (Union 2024). This paper benefited from the acceptable list of indicators developed by the web-based scoreboard project for Nigeria (Siyanbola 2021). For the first time, the indicators were categorised into Regulatory and Market Conditions Indicators, Infrastructure and Access Indicators, Human Capital (HC) Indicators, Sectoral Analysis, Macroeconomic Indicators, and Economic Investment and Trade Indicators, aligning with the 6th Moonshot of the STYIP.

Regulatory Framework (RF) indicators assess the efforts of NIS components in creating a conducive environment for innovation and economic activity (Adeyeye et al. 2018). Effective regulations can lower barriers to entry, protect intellectual property (IP) (Egbetokun and Oluwatope 2019), and foster a competitive market landscape (Adeyeye et al. 2019). According to the OECD's Oslo Manual, clear and consistent enabler indicators such as regulations can stimulate economic activities by reducing uncertainties (OECD 2005), fostering an innovation-friendly environment and investor confidence (Adeyeye et al. 2018). Enhancing judicial independence, property rights, and overall regulation quality in Nigeria can significantly impact its GDP, macroeconomic indicators, and attract Foreign Direct Investment (FDI) (Igbinovia and Krupka 2019). This was also evidenced by Gault (2008), even within the context of emerging economies, where these indicators are key to infrastructural development (Nour 2012).

Infrastructure indicators are critical enablers of economic growth and trade, measuring the availability and accessibility of industries to required infrastructure. They aim to reduce transaction costs and enhance productivity (OECD 2005). The study conducted by Freeman and Soete (2003) aligned with the Oslo Manual, underscoring the direct correlation between infrastructure improvements and increased economic outputs (Egbetokun &Oluwatope, 2019). For Nigeria, investments in ICT, energy, and transportation infrastructure are pivotal in supporting trade and integrating the country into the global economy, aligning with the STYIP's objective of transitioning Nigeria to a middle-income status. This is evident from the works of George, et al (2012) and Nour (2012), which highlighted that countries like the United States, Japan, Singapore, and Malaysia leveraged Infrastructure Indicators to transition to middle- and high-income status. Chete et al. (2012) reported a correlation between infrastructure and access to HC, while

Gimranova (2021) argued that the availability of quality human resources is crucial to sustainability.

Human Capital (HC) indicators assess the level of skills and education in an economy, which are vital for developing and adopting new technologies. Studies by George, et al (2012) identified HC as the bedrock of innovation and sectoral growth and sustainability, highlighting constraints on business activity in Kenya. The Global Competitiveness Report (Schwab 2018) indicates that nations investing significantly in E&T exhibit higher levels of innovation and economic performance (Nwachukwu and Chukwudike 2019). For Nigeria, strengthening HC through targeted training programs and improving educational outcomes is crucial for bridging the skills gap. TVET is essential to supporting the growth of key economic sectors (Union 2024).

Kane (2001) reported the roles of STI indicators as tools for policy formulation and adaptation. Siyanbola (2021) identified suitable indicators for developing an STI web-based scoreboard in Kenya, Nigeria, and Zambia. Siyanbola et al. (2016) underscored the roles of STI indicators in crafting STI policies for driving development goals. Farley and Rose (2013) agreed that STI indicators must be domesticated within the African context, with enabler frameworks being key drivers for Rwanda's development plans. The review highlighted the lack of robust indicators as a hindrance to monitoring and evaluating STI policy implementation. Despite its rich resources and potential, Nigeria continues to grapple with significant challenges in its socioeconomic development (Siyanbola et al. 2016). Adeyeye et al. (2019) explored the determinants and complementarities of organisational innovation practices in Nigeria using innovation survey data from 2008 and 2011. However, the paper cautioned that the lack of robust infrastructure, ineffective RF (Adeyeye et al. 2019), and insufficient alignment between HC and industry needs hinder the nation's ability to fully leverage STI for growth and competitiveness (Kane 2001). Addressing these gaps is critical to transforming Nigeria into a middle-income economy and achieving the milestones set out in the STYIP and Africa's Agenda 2063. This is particularly important given Nigeria's leading role within the African STI ecosystem through the FMIST, as implemented by NACETEM.

This study aims to provide novel information through an in-depth analysis of strategic enablers, a subset of STI indicators framework in Nigeria, emphasising the critical enablers that can drive the nation towards its developmental goals, supporting the aspirations outlined in the STYIP. Specifically, the objectives are: to analyse the correlation of regulatory indicators on macroeconomic indicators; to explore the relationship between infrastructure indicators and trade, highlighting their role as catalysts for economic transition to middle-income status; and to

establish the correlation between HC and sectoral growth, illustrating how skilled labour can propel various economic sectors. This is targeted at providing useful information that can guide in creating awareness on how STI indicators can support the implementation of Agenda 2063 through incorporating scientific evidence in the developing country context, learning from the Nigerian experience. The study embraced a mixed research methodology of qualitative and quantitative approaches. Secondary data were obtained from academic literature, Internet-based information, including websites and official documents on the subject matter, and their contents were rigorously analysed as presented in Figure 1.

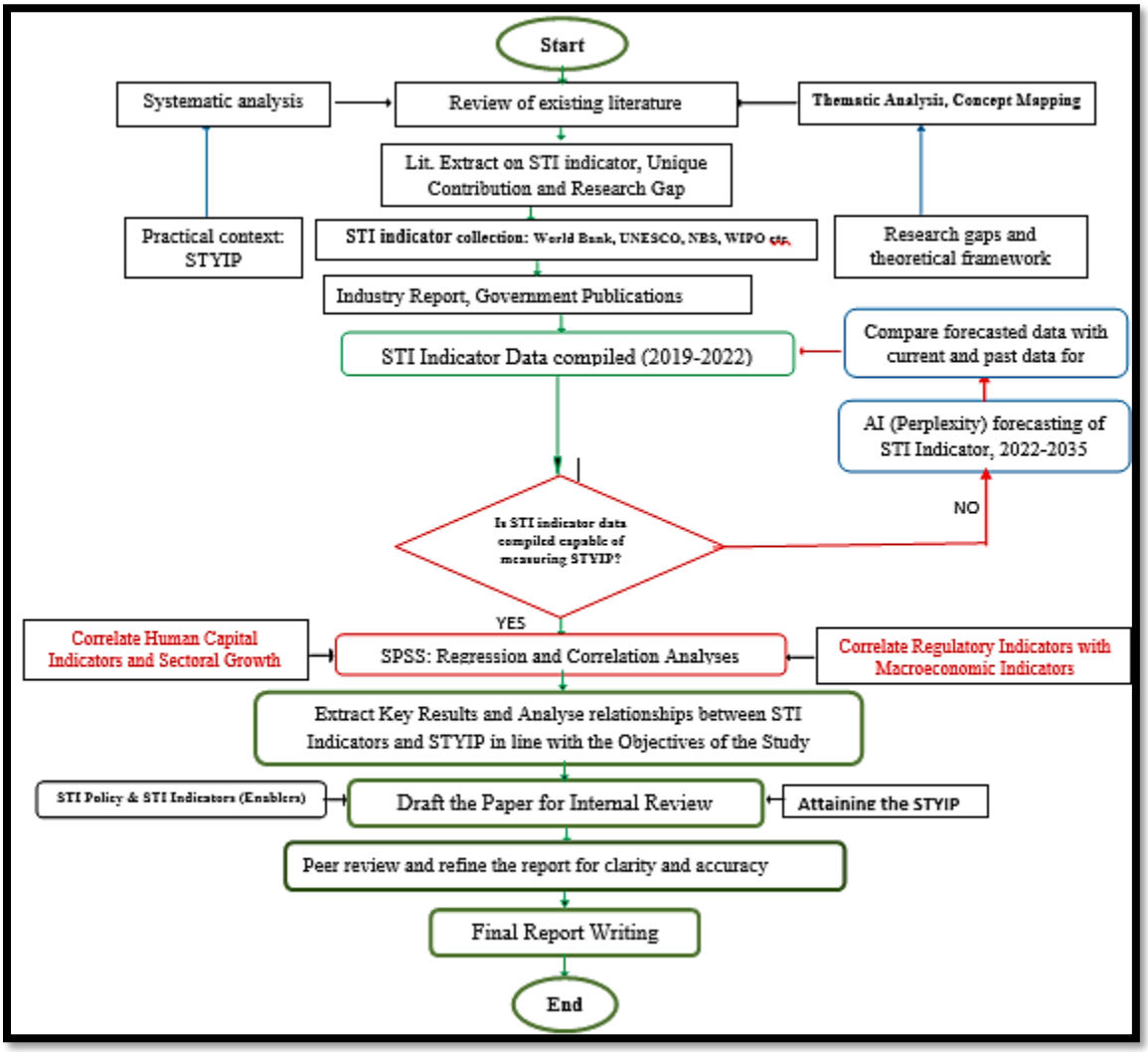

Figure 1: Research Methodology Flowchart

Consequently, the article is organised into four parts. First, it offers a relationship between the enablers of STI and development, and the roles enablers can play in

supporting the STYIP. Secondly, it examines the Nigerian experience in using artificial intelligence (AI) to project the STI indicator. Thirdly, it presents and discusses the results of analyses using SPSS. Finally, the paper concludes with policy recommendations.

2.0 Insights into Regulatory, Infrastructure and HC Indicators

Previous studies have emphasised the multifaceted nature of STI indicators(Willie Siyanbola et al. 2016)(Schubert et al. 2013). Factors such as education, infrastructure, RF, and market dynamics play significant roles in shaping the capacity of countries to innovate and develop meaningfully. This study builds on existing literature by focusing on the EF of STI indicators as adapted by Nigeria (Williams Siyanbola 2021).

Regulatory, infrastructure and HC are key enablers of STI, within the context of developing countries. Effective RF facilitate innovation by creating a stable environment where businesses can operate efficiently and securely. As Adeyeye *et al.* (2018) highlight, clear and consistent regulations reduce uncertainties and foster investor confidence. This perspective is echoed by the OECD's Oslo Manual, which accentuates the role of regulation as economic and competitive market stimulants (OECD, 2005).

In Nigeria, enhancing judicial independence and protecting IP are crucial steps toward attracting FDIs and improving macroeconomic stability (Igbinovia & Krupka, 2019). Study by Egbetokun, and Omolayo (2019) further emphasise that strong IP rights and effective RF are essential for fostering innovation-friendly environments.

2.2 Infrastructure as an Enabler of Economic Growth and Innovation

Infrastructure development, including ICT, energy, and transportation, are critical enablers of trade and economic growth. The correlation between infrastructure improvements and increased economic output is well-documented. According to Freeman and Soete (2003), as aligned with the Oslo Manual (OECD 2005), robust infrastructure reduces transaction costs and enhances productivity, directly contributing to economic growth (Abiodun *et al.,* 2019). For Nigeria, investments in these areas are pivotal to achieving the STYIP's objectives of transitioning to a middle-income economy (Union 2024).

Studies indicate that countries like the United States, Japan, Singapore, and Malaysia leveraged infrastructure development to achieve significant economic transitions (George, McGahan, & Prabhu, 2012; Nour, 2012). Chete *et al.* (2012) also established a link between infrastructure and HC access, arguing that while infrastructure is crucial, the availability of quality human resources is fundamental to sustaining

economic growth. The collection of data on these indicators by Nigeria is therefore key to tracking the STI ecosystem for quality policy advise to the government.

2.3 HC and Sectoral Growth

Theoretically, HC, encompassing education and skills, is the bedrock of innovation and sectoral sustainability (Leeson 1979). Nations investing significantly in E&T tend to exhibit higher levels of innovation and economic performance (Schwab, 2018). The missing link in Nigeria, bridging the skills gap through targeted training programs and improving educational outcomes. The alignment of HC with industry needs and fostering sectoral growth are important (Nwachukwu & Chukwudike, 2019). In the context of Kenya, indicators such as government regulation, technology know-how, and HC were identified as significant barriers to business activity (George *et al*., 2012). Adeyeye et al. (2019) and Gimranova (2021), highlighted a potential mismatch between the skills being developed through HC initiatives in Nigeria and the specific needs of the industry. These insights underscore the importance of HC in driving innovation and economic development.Theories such as the HC Theory suggest that investments in E&T should enhance economic productivity(Gimranova 2021). Nigeria can therefore consider the modernisation theory which promotes the idea of building modern values as opposed to traditional values (Gimranova, 2021) to optimize return on investment in E&T.

2.4 The Role of STI Indicators in Policy review, the case of NACETEM

STI indicators are critical tools for policy formulation and adaptation. National Centre for Technology Management (NACETEM) on behalf of the Federal Ministry of Innovation, Science and Technology (FMIST) adopted the STI indicators as key inputs to the review of the 2012 STI policy to produce the 2022 edition of the STI policy. This highlight the importance of robust indicators in monitoring and evaluating STI policy implementation. To this extent, NACETEM participated in the pilot study for identification of suitable indicators to be deployed for developing STI web-based scoreboards in Kenya, Nigeria, and Zambia.

Table 1: Studies on STI indicator, Unique Contribution and Research Gap

Reference	**Summary & Findings**	**Research Gap & Critique**	**Unique Contribution & Relevance**
Abiodun E, Omolayo O, David A & Maruf S.,2019	Investigated how industry-specific and economic contexts shape open innovation	The study was short of deep analysis of how STI enablers, particularly in the Nigerian context,	This current study can bridge this gap by focusing on how specific STI enablers (such as infrastructure,

	practices. It emphasises the need for contextual customisation of open innovation strategies.	can be systematically integrated to foster innovation across diverse economic sectors. The linkage between STI indicators enabler framework and regulatory tools in Nigeria needs more examination.	policies, and HC) can be aligned to support innovation, tailored to Nigeria's economic and industrial contexts, particularly in achieving Agenda 2063 goals.
Adeyeye, David et al. 2018.	The paper highlights the barriers firms face in Nigeria in their search for knowledge and how these affect their innovation performance. Key barriers include limited access to information and insufficient institutional support.	While barriers are identified, the paper falls short of proposing how specific enabler components of the STI indicators could mitigate these barriers. There's a lack of focus on the dynamic role of STI enablers in overcoming these barriers.	Our paper provides useful analysis of how STI enablers such as infrastructure, policy frameworks, and enhanced HC can effectively reduce barriers and boost innovative performance in Nigerian firms.
Chete, L N, J O Adeoti, F M Adeyinka, and O Ogundele. 2012.	Discusses the evolution and challenges of industrial development in Nigeria, focusing on policy, economic, and infrastructural factors.	The focus on infrastructure limits that area of application of the study. The gap in linking STI indicators to practical strategies for industrial advancement was unattended to by the study.	This study add value by analyzing the relationship between the enablers such as infrastructure and skilled workforce development and effect on economic growth aligned with Agenda 2063.

Farley, Sara E, and Amanda L Rose. 2013.	Evaluates Rwanda's STI policy, offering recommendations for enhancing national innovation systems and aligning them with development goals.	Although it provides valuable insights, the report doesn't explore the specific applicability of its recommendations to the Nigerian STI context or the broader goals of Agenda 2063.	This current paper could extrapolate these findings to the Nigerian context, demonstrating how STI enablers can be customized to fit Nigeria's unique challenges and opportunities.
Freeman, C., & Soete, L. L. G. 2003.	Discusses the historical development of STI indicators and their relevance in guiding policy decisions and innovation practices.	The historical focus limits its application to contemporary and future-oriented STI strategies, particularly in the Nigerian context. There's a gap in addressing how these lessons can inform current STI enabler frameworks.	Our paper leveraged on historical data to project to the future, proposing how evolving STI enabler frameworks can be aligned with Nigeria's development goals under Agenda 2063.
Gimranova, M.C & Ikboljon Q & Dilbar, 2021.	Discusses the role of higher education in driving local, national, and global development, highlighting the importance of aligning educational outputs with development needs.	The paper was incapable to specifically address how relevant is higher education as STI enablers to support national innovation systems and achieve Agenda 2063 targets.	We attempt to justify the role of higher education as key players in the STI ecosystem by using the enabler components such as skilled HC and research capabilities, crucial for achieving STYIP.
Igbinovia, FO, and Jiri K. 2019.	Reviews Nigeria's STI policy, focusing on its role	The review is broad but failed to recognize the role of	Our work delved into how specific STI enablers, such as

	in driving manufacturing-led economic and social transformation.	STI indicators as key inputs in the STI policy design. No mention was made of specific enablers within the STI framework that can support the manufacturing sector's growth and align with Agenda 2063.	technology adoption and innovation incentives, can be harnessed to boost manufacturing-led transformation in Nigeria.
Nwachukwu, S. T, and Chukwudike. 2019.	Examines the prospects and challenges of STI policy in Nigeria, focusing on its role in driving technological development.	The analysis was silent on specific enabler components that can address the challenges identified. The policy was not aligned with the broader Agenda 2063 goals.	We identified the relevance of enablers in STI policy implementation and need for strengthening specific STI enablers that can overcome the challenges highlighted in alignment with Agenda 2063.
Kane, Aidan. 2001.	Provides a background on the development and use of STI indicators for evaluating scientific and technological activities.	The paper is useful in demonstrating the role of indicators, but fell short in providing a detailed analysis of how these indicators can be practically applied in specific country contexts like Nigeria, particularly in achieving strategic development plans like Agenda 2063.	This current paper can contribute to review process and design of STI policy/implementation plan through practical framework for applying STI indicators in Nigeria, showing how these enablers can be aligned with the country's strategic development goals and Agenda 2063.
Adeyeye, D., Abiodun, E.,	Investigates the factors that drive	The paper could not explore how	This current paper can contribute by

Omolayo, O., and Maruf, S. 2019.	organizational innovation in Nigerian firms, focusing on manufacturing and service sectors. It identifies the critical role of organizational practices and external collaboration.	comprehensive STI enablers can support and enhance organizational innovation practices. The interconnectedness of different enablers (e.g., policy support, infrastructure, education) with innovation outcomes is under-explored.	examining how a robust STI EF can synergistically support organizational innovation practices. This will provide actionable insights into achieving the innovation objectives outlined in Agenda 2063.

Source: Author's compilation from the literature (2024).

3.0 Result of Analyses and Discussion

Table 2: STI indicator obtained from relevant sources (2019-2022) and projected data (2023-2035)

Indicators/ Year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Extent of ST, 1-7	3.27	3.24	3.21	3.18	3.15	3.12	3.09	3.06	3.03	3	2.97	2.94	2.91	2.88	2.85	2.82	2.79
Gross enrolment ratio, tertiary, both sexes (%)	12.24	12.38	12.52	12.66	12.8	12.94	13.08	13.22	13.36	13.5	13.64	13.78	13.92	14.06	14.2	14.34	14.48
Literacy rate, adult total (% of people ages 15 and above)	0.61	0.6	0.59	0.58	0.57	0.56	0.55	0.54	0.53	0.52	0.51	0.5	0.49	0.48	0.47	0.46	0.45
FDI, net inflows (% of GDP)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Imports of goods and services (% of GDP)	16.9	16.3	15.7	15.1	14.5	13.9	13.3	12.7	12.1	11.5	10.9	10.3	9.7	9.1	8.5	7.9	7.3

Industry (including construction), value added (% of GDP)	25.1	24.5	23.9	23.3	22.7	22.1	21.5	20.9	20.3	19.7	19.1	18.5	17.9	17.3	16.7	16.1	15.5
Internet access tariffs (20 hours per month), in US$, and as a percentage of per capita income	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66
Mobile cellular tariffs (100 minutes of use per month), in US$, and as a percentage of per capita	92	96	100	104	108	112	116	120	124	128	132	136	140	144	148	152	156

income																	
ICT goods exports as a percentage of total exports	4.41	4.03	3.65	3.27	2.89	2.51	2.13	1.75	1.37	0.99	0.61	0.23	-0.15	-0.53	-0.91	-1.29	-1.67
Affordability: 1GB of data must be available for 2% or less of average monthly income	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Judicial independence (WEF) - 1-7 Best	3	2.9	2.8	2.7	2.6	2.5	2.4	2.3	2.2	2.1	2	1.9	1.8	1.7	1.6	1.5	1.4
Prevalence of foreign ownership - 1-7 Best	4.72	4.64	4.56	4.48	4.4	4.32	4.24	4.16	4.08	4	3.92	3.84	3.76	3.68	3.6	3.52	3.44
Property rights, 1-7	3.53	3.46	3.39	3.32	3.25	3.18	3.11	3.04	2.97	2.9	2.83	2.76	2.69	2.62	2.55	2.48	2.41

(best) - Value																	
Strength of auditing and reporting standards - 1-7 Best	4.41	4.49	4.57	4.65	4.73	4.81	4.89	4.97	5.05	5.13	5.21	5.29	5.37	5.45	5.53	5.61	5.69
(M) GDP (current US$) (Modified - Per capita)	-0.1	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
GDP growth (annual %)	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6
Government effectiveness	-1.11	-1.12	-1.13	-1.14	-1.15	-1.16	-1.17	-1.18	-1.19	-1.2	-1.21	-1.22	-1.23	-1.24	-1.25	-1.26	-1.27
Political stability non violence	4.2	3.68	3.16	2.64	2.12	1.6	1.08	0.56	0.04	-0.48	-1	-1.52	-2.04	-2.56	-3.08	-3.6	-4.12
Regulatory quality	16.35	15.87	15.39	14.91	14.43	13.95	13.47	12.99	12.51	12.03	11.55	11.07	10.59	10.11	9.63	9.15	8.67
Rule of law	-0.8	-0.7	-0.69	-0.62	-0.55	-0.48	-0.41	-0.34	-0.27	-0.2	-0.13	-0.06	0.01	0.08	0.15	0.22	0.29

	3	6															
Organized crime, 1-7 (best) - 1-7 Best	3.4	3.3	3.2	3.1	3	2.9	2.8	2.7	2.6	2.5	2.4	2.3	2.2	2.1	2	1.9	1.8
Energy intensity level of primary energy (megajoules per constant 2011 purchasing power parity GDP)	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Access to clean fuels and technologies for cooking (% of population)	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45
Access to electricity (% of	58.4	60.3	62.2	64.1	66	67.9	69.8	71.7	73.6	75.5	77.4	79.3	81.2	83.1	85	86.9	88.8

population)																	
Wage and salaried workers, female (% of female employment) (modeled ILO estimate)	13.58	13.93	14.28	14.63	14.98	15.33	15.68	16.03	16.38	16.73	17.08	17.43	17.78	18.13	18.48	18.83	19.18
Liner shipping connectivity index (maximum value in 2004 = 100)	19.1	18.2	17.3	16.4	15.5	14.6	13.7	12.8	11.9	11	10.1	9.2	8.3	7.4	6.5	5.6	4.7
FDI, net outflows (% of GDP)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Extent of market dominance - 1-7 Best	3.3	3.2	3.1	3	2.9	2.8	2.7	2.6	2.5	2.4	2.3	2.2	2.1	2	1.9	1.8	1.7
Financing through local equity	1.6	1.5	1.4	1.3	1.2	1.1	1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0

market, 1-7 (best)																	
Intensity of local competition - 1-7 Best	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Prevalence of trade barriers, 1-7 (best) - 1-7 Best	4.5	4.4	4.3	4.2	4.1	4	3.9	3.8	3.7	3.6	3.5	3.4	3.3	3.2	3.1	3	2.9
Trade tariffs % duty - Value	10.36	10.21	10.06	9.91	9.76	9.61	9.46	9.31	9.16	9.01	8.86	8.71	8.56	8.41	8.26	8.11	7.96

Sources: NACETEM STI indicator data (2023) and Authors' forecast using perplexity AI (2024)

3.1: Projections of Workforce Training and Educational Enrolment in Nigeria: Challenges and Implications for the STYIP Targets

Form the projections we made using the AI aided analysis, a consistent decline in the extent of ST from a score of 3.27 in 2019 to 2.79 by 2035 was observed. . This trend highlights a growing challenge in maintaining or improving workforce capabilities in Nigeria. Whereas the role of effective ST in developing a knowledgeable and skilled workforce was reported to be essential for fostering innovation and economic growth. Studies conducted by Adeyeye et al. (2019) and Gimranova (2021)had argued that the availability of well-trained staff is pivotal to the adoption and implementation of innovative practices within firms. The decline in ST could hinder the country's ability to achieve its developmental goals under the STYIP.

The STYIP aspired to increase net enrolment rate for tertiary education to at least 50%by 2033(Union 2024). Our projection of the gross enrolment ratio in tertiary education is projected to increase from 12.24% in 2019 to 14.48% in 2035. The observed rise suggests an improvement in higher education accessibility. This is vital for Nigeria to develop a skilled labor force capable of driving economic and technological advancements. However, Nigeria must take drastic measures like overhauling the education system to attain the STYIP target of 50% by 2033.Gimranova et al(2021) highlight the importance of higher education in contributing to local, national, and global development. An increase in enrolment can be seen as a positive indicator for future economic growth and innovation capabilities.

The literacy rate for adults(% of People Ages 15 and above) is projected to decrease slightly from 0.61% in 2019 to 0.45% in 2035. This decline poses a significant challenge, as literacy is a fundamental component of HC development and essential for participating in the knowledge economy(Siyanbola et al. 2016). The study by Gault (2008)underscores the role of literacy in enhancing the overall quality of HC, which is crucial for innovation and economic development. The downward trend in literacy rates could limit Nigeria's ability to leverage its human resources effectively. The quality of HC equally infiltrates the industry.

In our categorization, we reported a sectoral analysis to include the industry. This considered the Construction sector. The value added by industry, is expected to decrease from 25.1% in 2019 to 15.5% in 2035. This deterioration indicates a reduction in the industrial sector's contribution to the economy, which could impact Nigeria's ability to diversify its economic base away from oil dependence.(Igbinovia and Krupka 2019) discuss the importance of industrial development for sustainable

economic growth. The projected decline in this sector may signal challenges in achieving industrial growth and diversification, which are key goals of the STYIP.

The energy intensity level of primary energy remains constant at 6 MJ (megajoules per constant 2011 purchasing power parity GDP) throughout the forecast period. While stability in energy intensity might initially appear beneficial, it simultaneously highlights a significant shortfall in advancing energy efficiency. Sustainable industrial and economic development heavily relies on continuous improvements in energy use. Colecchia (2006) had expressed fear for more energy demand, (Freeman, C., & Soete 2003) emphasized that enhancing energy efficiency is crucial for sustaining long-term economic and industrial growth. Thus, the static projection suggests that Nigeria needs to intensify efforts to boost energy efficiency to support its development goals. The optimum and highly competitive alternative source of energy or Nigeria to consider is the solar energy since the county can boast of steady availability of high sunshine belt in the country. On the average, a total annual average solar radiation of about 3.5 kWhm-^{2} day^{-1} was reported (B.Ugwoke. et al. 2020).

In contrast, the percentage of female wage and salaried workers is projected to rise from 13.58% in 2019 to 19.18% by 2035. This upward trend marks substantial progress in gender equality and women's participation in the formal economy. The Union (2024), emphasised the implementation of as the Maputo Protocol which can drive extensive benefits for societal and economic development. George et al. (2012) underscore the importance of increasing female workforce participation for inclusive growth. Consequently, the anticipated increase in female employment could significantly contribute to Nigeria's economic and social transformation.

Although our forecast for liner shipping connectivity index plummet from 19.1 in 2019 to 4.7 by 2035, this is a reflection of the severe decline in Nigeria's integration into global shipping networks and could be detrimental to trade and economic integration. Theforecasted decline in connectivity index signals potential challenges for Nigeria in maintaining its trade competitiveness and integration into the global economy. This is also linked to the FDI, showing that net inflows are expected to remain unchanged at 0.1% of GDP throughout the projection period. The reported stability suggest a stagnant investment climate, which could restrict economic growth and hinder the attraction of new technologies and innovations. This is contrary to the 10-year average annual GDP growth % of 3.5 projected by the World Economic Forum(WEF 2019). Freeman, C., & Soete (2003)Adeyeye et al. (2018) argued that a favorable investment environment is vital for promoting innovation

and economic growth. Hence, the government must use the instruments in the STYIP to attract FDI and design and implement FDI friendly policies.

Additionally, the percentage of GDP spent on imports is projected to decrease from 16.9% in 2019 to 7.3% by 2035. This is an indicator of reduction on dependency on foreign goods which can be beneficial. This indicator may also reflect difficulties in accessing essential technologies and inputs crucial for industrial development. Klaus Schwab (2016) had reported the relevance of balanced trade for economic growth with instances from Mexico, Brazil and India. The reduction herein observed with respect toimports suggests the need for enhanced domestic production capabilities, an opportunity to expand the industries and meet local demand.

In the realm of exports, the proportion of ICT goods as a percentage of total exports is expected to decline from 4.41% in 2019 to -1.67% by 2035. This negative trend underscores the challenges facing the ICT sector in contributing to the national economy through exports. Siyanbola et al. (2016) emphasised the pivotal role of ICT in modern economies. We reported that the declining trend in ICT goods exports points to the need for Nigeria to implement the STI policy as a tool to (Nigeria 2022)strengthen its ICT capabilities and competitiveness to harness the sector's potential for economic growth(Omotoso and Muyiwa 2016).

Our projection revealed that internet access tariffs are to rise from $34 in 2019 to $66 by 2035. This is additional cost burden for internet access, which could impede efforts to enhance digital inclusion and leverage ICT for economic development. Access to internet is important to the extent that its affordability should be a concern of a serious government with the interest of developing the digital economy. Consequently, the rising tariffs may pose significant challenges in achieving widespread internet accessibility and promoting digital literacy(Igbinovia and Krupka 2019).

One key enabler to innovation is electricity accessibility. Our projected result in this direction showed an increase significantly from 58.4% in 2019 to 88.8% by 2035. This improvement reflects advancements in infrastructure that are essential for supporting industrial activities and enhancing the quality of life. The STI policy (Nigeria 2022)and studies by (Siyanbola et al. 2016)highlight the crucial role of reliable electricity access in driving economic and industrial growth. Thus, the increase in electricity access suggests that Nigeria may experience increase in developmental goals which is expected to rub on the AU aspiration of providing 80%; increase in households' access to electricity by the year 2033 as captured in the STYIP (Union 2024).

Access to clean fuels and technologies for cooking is also expected to see a substantial rise, from 13% in 2019 to 45% by 2035. This improvement points to progress in enhancing living standards and reducing health risks associated with traditional cooking methods. This rising trend in access to clean cooking technologies supports broader environmental and health objectives(Environment-Nigeria 2021).

In the context of regulatory and market conditions, the judicial independence score is projected to decline from 3 in 2019 to 1.4 by 2035. This downward trajectory suggests a weakening in the rule of law, potentially impacting business confidence and the investment climate. Kane (2001) highlights the importance of strong judicial systems for economic development. As a result, the declining score signals possible increase in uncertainties as in maintaining a fair and predictable business environment as analysed even in the solar PV industry in Nigeria (Oladipo 2012).

Similarly, property rights are anticipated to deteriorate, with the score dropping from 3.53 in 2019 to 2.41 by 2035. This decline raises concerns over the protection of property rights, which are fundamental to fostering investment and economic growth. (George, Mcgahan, and Prabhu 2012) and (Lohse 2013) placed emphasis on the critical role of secure property rights in encouraging innovation and investment. Hence, the negative trend could undermine efforts to create a conducive environment for economic development.

On a positive note, the strength of auditing and reporting standards is projected to improve from 4.41 in 2019 to 5.69 by 2035. This positive trend indicates progress in enhancing corporate governance and financial transparency, which are vital for building investor confidence. Siyanbola (2021) highlights the importance of robust auditing and reporting standards for economic stability and growth. Therefore, the improvement in these standards aligns with Nigeria's goals of creating a transparent and accountable business environment.

4.0 Analysis and Discussion

4.1 Human Capital and Sectoral Growth

Our findings reveal profound insights into the key interplay between HC and sectoral performance within Nigeria's STI ecosystem. The perfect negative Pearson correlation of -1.000 between Human Capital and Sectorial Analysis presented in table 3 with a significant at the 0.01 level, suggests a robust inverse relationship. This finding indicates that improvements in HC metrics, such as ST, gross enrolment ratio in tertiary education, and adult literacy rate, correlate with a decline in sectoral analysis indicators. The decline correspond to the manufacturing value added,

industry value added, and energy intensity level. This relationship supports the findings of Adeyeye et al. (2019) and Gimranova (2021), who highlighted a potential mismatch between the skills being developed through HC initiatives in Nigeria and the specific needs of the industry.

Table 3: Result of HC and Sectoral Growth analysis

Correlations Analysis				**Regression**	
		Composite Human Capital	Composite Sectoral Analysis	Model Summary	
Composite HC	Pearson Correlation	1	-1.000**	Model	1
	Sig. (2-tailed)		.000	R	1.000 [a]
	N	17	17	R^2	1
Composite Sectoral Analysis	Pearson Correlation	-1.000**	1	Adjusted R^2	1
	Sig. (2-tailed)	0.000		Std. Error of the Estimate	0.000
	N	17	17	[a.] Predictors:	
**. Correlation is significant at the 0.01 level (2-tailed).				(Constant), Composite Human Capital	

Source: Authors' analysis (2024)

We observed that this inverse relationship might stem from a disconnect between Nigeria's educational outcomes and its industrial requirements. Theories such as the HC Theory suggest that investments in E&T should enhance economic productivity(Gimranova 2021). However, our findings indicate that structural challenges within Nigeria's economic sectors could be impeding this theoretical outcome, as suggested by Igbinovia and Krupka (2019). Nigeria can therefore consider the modernisation theory which promotes the idea of building modern values as opposed to traditional values (Gimranova, 2021) to optimise return on investment in E&T.

Conversely, the observed decline in ST scores, from 3.27 in 2019 to 2.79 by 2035, highlights a significant challenge and the inverse relationship in the regression. This trend could undermine the ability to maintain or improve workforce capabilities, as

effective ST is pivotal for fostering innovation and sustaining economic growth (Adeyeye et al., 2019; Gimranova, 2021). Similarly, the slight decrease in adult literacy rates from 61% to 45% over the same period poses a considerable obstacle. Literacy is foundational for HC development and crucial for participation in the knowledge economy (Siyanbola et al., 2016; Gault, 2008).

Our regression model reveals an R^2 of 1.000, demonstrating a perfect fit between Composite Human Capital as the predictor and Composite Sectoral Analysis as the dependent variable. This implies that within our dataset, the outcomes in the sectoral indictors are entirely determined by HC indicators. Based on our projections, a rise in gross enrolment ratio in tertiary education from 12.24% in 2019 to 14.48% by 2035 was reported. This suggest a positive trend towards greater educational accessibility. While statistically significant, this result depicts that the real-world economic and educational systems involve multifaceted interdependencies that are not fully captured by this model alone.

4.2 Economic Investment, Trade and access to infrastructures

The correlation and regression analyses conducted on the composite indicators for Economic Investment and Trade, Infrastructure and Access, offered substantial insights into the linkages between these critical indicators. We contextualized our analyses, presented in table 5, within the broader framework of STI indicators. The perfect negative Pearson correlation of -1.000, significant at the 0.01 level, between the Composite Trade and Composite Infrastructure indicates a strong inverse relationship. This result suggests that enhancements in economic investment and trade indicators correlate with declines in infrastructure and access metrics. This inverse relationship might appear counterintuitive at first glance but can be understood through a deeper examination of Nigeria's economic and infrastructural landscape.

Table 5: Result of Economic Investment, Trade and access to infrastructures analysis

Correlations				**Regression Analysis**	
		Composite Trade	Composite Infrastructure	Model Summary	
Composite Trade	Pearson Correlation	1	-1.000**	Model	1
	Sig. (2-tailed)		0.000	R	1.000[a]
	N	17	17	R^2	1

Composite Infrastructure	Pearson Correlation	-1.000**	1	Adjusted R^2	1
	Sig. (2-tailed)	.000		Std. Error of the Estimate	0.000
	N	17	17	[a.] Predictors:	
**. Correlation is significant at the 0.01 level (2-tailed)				(Constant), Composite Infrastructure	

Source: Authors' analysis (2024)

Economic theories, such as Dependency Theory, might explain this phenomenon by suggesting that Nigeria's integration into the global economy through increased trade and investment could exacerbate infrastructural deficiencies rather than mitigate them. As Nigeria becomes more reliant on FDI and international trade, resources may be disproportionately channeled towards maintaining competitive advantages in these areas, potentially at the expense of developing robust local infrastructure (War et al. 1969).

Further, the findings could reflect the Dual Sector Model, where the modern sector (including trade and investment activities) grows independently and often at the cost of the traditional sector (basic infrastructure and local accessibility)(Leeson 1979). This dualism might explain why significant improvements in trade and investment have not necessarily translated into commensurate advancements in infrastructure, such as internet access, mobile connectivity, and access to clean energy.

The regression model indicating an R square of 1.000, underscores a perfect fit between Composite Infrastructure as the predictor and Composite Trade as the dependent variable. This result implies that, within the dataset used, infrastructural indicators entirely determine the outcomes in trade and investment metrics. Such a perfect fit, while statistically noteworthy, suggests an intricate dependency where the state of infrastructure critically influences the economic investment and trade profile in Nigeria.

From the perspective of Endogenous Growth Theory, which posits that economic growth is primarily driven by internal factors rather than external influences, this finding underscores the critical role of infrastructure in fostering economic growth and investment (Romer, 1994). Quality infrastructure, such as reliable electricity and widespread internet connectivity, is essential for enhancing productivity, attracting

FDI, and promoting exports, particularly in sectors involving high technology and ICT goods (Aschauer, 1989; Munnell, 1992).

The findings underscore the importance of integrating infrastructural development into broader economic policies to ensure that improvements in trade and investment do not occur in isolation but rather support and are supported by robust infrastructure. This aligns with the African Union's Agenda 2063, which envisions a continent with modern infrastructure that fosters interconnectivity and facilitates sustainable growth.

However, our results reveal that infrastructural improvements in Nigeria are lagging, as indicated by the perfect inverse relationship with economic investment and trade. This lag can be linked to Institutional Theory, which suggests that infrastructural development is often hampered by institutional inefficiencies, regulatory bottlenecks, and governance challenges (North, 1990). The high cost of internet access and mobile tariffs relative to per capita income, limited access to electricity, and inadequate coverage of mobile networks are reflective of these systemic issues.

Moreover, the persistent challenges in access to clean fuels and technologies for cooking point to socio-economic disparities and the need for targeted interventions to promote equitable infrastructure development. The Capability Approach by Amartya Sen further explains that enhancing infrastructure is not just about economic benefits but also about expanding individuals' freedoms and capabilities to participate fully in the economy (Sen, 1999).

4.3 Regulatory Indicators and Macroeconomic Indicators

In analysing the interrelationship between regulatory and macroeconomic indicators, our study underscores the intricate dynamics that shape Nigeria's economic landscape. Our findings provide a comprehensive understanding of how various facets of the regulatory environment influence macroeconomic outcomes. There was a perfect linear relationship between the components of regulatory indicators and microeconomic indicators. This finding suggests that any relevant variation in the regulatory components of the STI indicators directly corresponds to changes in macroeconomic indicators. Such a robust correlation highlights the critical role of regulatory conditions in driving macroeconomic performance. Hence, government should address all rigidities that hinder the growth of macroeconomic indicators (K. Schwab 2018).

The key components of our findings has a correlation coefficient of 1.000 showing that it is significant as it demonstrates an absolute predictive capacity of regulatory

indicators over macroeconomic outcomes. This aligns with institutional theory, which posits that strong RF can foster a conducive environment for economic stability and growth (North, 1990). It supports the notion that well-defined property rights, robust judicial independence, and transparent auditing standards are fundamental to economic development and business confidence.

Table 6: Result of Regulatory Indicators and Macroeconomic Indicators analysis

<table>
<tr><th colspan="4">Correlations</th><th colspan="2">Regression Analysis</th></tr>
<tr><td colspan="2"></td><td>Composite Macro</td><td>Composite Regulatory</td><td colspan="2">Model Summary</td></tr>
<tr><td rowspan="3">Composite Macro</td><td>Pearson Correlation</td><td>1</td><td>1.000**</td><td>Model</td><td>1</td></tr>
<tr><td>Sig. (2-tailed)</td><td></td><td>0.000</td><td>R</td><td>1.000[a]</td></tr>
<tr><td>N</td><td>17</td><td>17</td><td>R^2</td><td>1</td></tr>
<tr><td rowspan="3">Composite Regulatory</td><td>Pearson Correlation</td><td>1.000**</td><td>1</td><td>Adjusted R^2</td><td>1</td></tr>
<tr><td>Sig. (2-tailed)</td><td>0.000</td><td></td><td>Std. Error of the Estimate</td><td>0.000</td></tr>
<tr><td>N</td><td>17</td><td>17</td><td colspan="2">a.. Predictors:</td></tr>
<tr><td colspan="4">**. Correlation is significant at the 0.01 level (2-tailed).</td><td colspan="2">(Constant), Composite Regulatory</td></tr>
</table>

Source: Authors' analysis (2024)

The Coefficient of Determination and the adjusted R^2 value of 1.000 as presented in table 6 suggests that the model perfectly explains the variance in macroeconomic indicators through regulatory conditions. This implies that Nigeria's economic outcomes are entirely influenced by its regulatory environment. Freeman and Soete (2003) argue that economic policies and regulations are crucial in shaping innovation and growth trajectories. Our findings corroborate this, suggesting that improvements in regulatory conditions could lead to significant macroeconomic benefits. The adjusted R^2 of 1.000 further confirms the model's robustness, hence the results are generalisable beyond the sample. This perfect fit underscores the comprehensive impact of regulatory measures on the macroeconomic environment, as suggested by studies on regulatory quality and economic performance (Djankov et al., 2002).

5.0 Conclusion and Policy Implications

Conclusion:

This study underscores the critical role of regulatory infrastructure and HC as components of the EF of STI indicators in Nigeria. The projections using Perplexity AI, for the first time, provide valuable insights into how these enablers can support the nation's developmental goals, particularly in the context of the Second Ten-Year Implementation Plan (STYIP) of Africa's Agenda 2063. Effective RF, robust infrastructure, and skilled HC are essential for fostering a thriving STI ecosystem that can drive sustainable economic growth and integration into the global economy.

Policy Implications:

1. **Activating the National Research Fund (NRF):** The 10th National Assembly of the Federal Republic of Nigeria must as a matter of urgency pass the (NRF) and it is pertinent for the President to functionalise and activate the NRF to strengthen the enablers framework of the STI indicator.

2. **Investing in Infrastructure:** The African Science Technology and Innovation Indicators (ASTII) should make deliberate efforts to advocate for the need for significant investments in ICT, energy, and transportation infrastructure and human capital development, by making inputs into member countries STI policies.

3. **Developing HC:** Bridging the skills gap through targeted training programs and improving educational outcomes is crucial for aligning HC with industry needs. Strengthening Technical Vocational Education and Training (TVET) programs will support the growth of key economic sectors and foster innovation.

4. **Leveraging Web-based Indicator Dashboards:** Developing and maintaining a web-based Indicator dashboard for STI indicators will facilitate the monitoring and evaluation of STI policies. This tool will provide real-time insights into the progress of STI initiatives and help policymakers make informed decisions to support sustainable development.

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