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The Role Of Technological Innovation In Enhancing Export Sophistication: A Case Of Sub-Saharan Africa

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Abstract:
Technological Innovation is essential for improving export sophistication by making products more complex, increasing their variety, and adding value to them. The purpose of this research is to examine how the level of innovation through patents affects the export sophistication as measured by the EXPY index (Hausmann, Hwang and Rodrik, 2007), with a particular focus on Sub-Saharan Africa. The analysis makes use of a panel data set for 44 countries covering the years 2007 through 2022. An instrumental variable technique is employed to help account for any potential endogeneity. The objectives of the research are to identify how factors such as technology, structural transformation, and access to financial capital and R&D assist in upgrading African exports in their unique economic and institutional environments. The results confirm that technological innovation and export sophistication exhibit a strong statistical correlation via patented technology over time, indicating that technological innovation have produced more advanced, diverse, and complex export products than before.

Keywords: *Export Sophistication, Technological Innovation, Sub-Saharan Africa, Capital, Structural Transformation*

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I. Introduction

The impact of technological innovation on global economies is always increasing. Technology increases productivity, improve competitiveness, and facilitate economic transformation. Regions that use advanced technology show positive economic growth. The export sophistication of goods and services is important to the structure of the economy, as well as to its growth and integration into global markets (Hausmann & Rodrik, 2007; WIPO, 2024).

Historically, Sub-Saharan Africa's export structure has been primarily based on primary commodities (e.g., crude oil, mineral and agricultural products). These low-value raw material exports place the Sub-Saharan African region at risk of price fluctuations, trade deficits, and slow industrial development. Other advanced economies and emerging markets were able to transition from low-value raw material exports to high-value manufactured goods and knowledge-based services, whereas the majority of Sub-Saharan African economies continue to have difficulty diversifying export products (Ado et al., 2025).

Structural transformation in Sub-Saharan Africa is constrained by weak technological capabilities and underdeveloped innovation infrastructure. These factors are nonetheless central drivers of technological innovation and play a decisive role in enabling economies to upgrade from commodity dependence toward sophisticated exports. Structural constraints still pose limitations, low levels of technological absorptive capacity, and low levels of innovation ecosystems in Sub-Saharan Africa in upgrading their exports. Therefore, it is necessary to assess the impact of technological innovation on enhancing Sub-Saharan Africa's export sophistication so that policies can be developed that promote growth in those regions.

While innovation-based export sophistication requires investments in R&D, human capital development, digital infrastructure, patent registration, and industrial policy reforms, countries such as China and South Korea that have successfully improved their export sophistication, have utilized technology, innovation ecosystems, and strong government support to do so (Hausmann & Rodrik, 2007). However, Sub-Saharan Africa faces several challenges, such as weak IP frameworks, limited private-sector investment in innovation, and skills deficits. Further, insufficient technological diffusion and poorly developed manufacturing sectors inhibit firms' ability to move up the value chain.

Sub-Saharan Africa has shown promising development of an edge in exports using technological innovation. Among countries there are Kenya, Rwanda, and South Africa. Kenya has gained worldwide attention through mobile and financial technology, which helped entrepreneurs maintain their businesses and find new ways to send goods across international borders (IMF, 2025). Rwanda is creating a technological hub with policy frameworks that are friendly to innovation and building infrastructure to support digital use. South Africa was the

third country and had a significant industrial base and was also able to provide products that used high technology, including automobiles. These types of cases show the promise of the usage of technology to create sophisticated export markets through appropriate governmental policies and investments to support the use of technology.

The issue of economic diversification has been one of the biggest obstacles to SSA's development. As a result, this market concentration limits the ability of Sub-Saharan Africa to achieve sustainable growth and maintain resiliency in international markets. While technological innovations are well-known as the principal driver of export sophistication, Sub-Saharan Africa continues to underutilize technological innovation activity to reshape its exports. Structural and technological barriers continue to inhibit the spread and use of patent-based innovations across industries.

In this context, this study will address the gap by exploring the patent based technological innovation of countries' export sophistication in Sub-Saharan Africa. It will look at significant factors that affect the usage of patentable technologies, the successful case studies as well as suggesting policy incentives to develop a patent-based, technology driven export industry.

II. Literature Review

Overview of Technological Innovation

Technological innovation is the identification, creation, and use of new technologies, processes, products, and services to increase productivity, efficiency, and competitiveness (Oyelami & Ogbuagu, 2023). By utilizing technological innovation, many businesses are able to expand and move up the value chain from low-value goods to higher-valued goods based on knowledge. Countries use technological innovation as a means to drive their economies, improve their global competitive position, and create more valuable products for the international market (WIPO, 2024).

Technological innovation includes a variety of activities that include financial investment in R&D, patenting, utilizing digital technology, creating new or improved processes, and developing human capital (Ding et al., 2024). By utilizing these activities, nations may improve the quality of their exports, create a more diverse product line, and remain globally competitive (Navarro Zapata et al., 2023).

Technological innovation promotes knowledge spillovers across industries and regions, encouraging entrepreneurship and strengthening backward and forward linkages in sectoral value chains (Khlystova & Kalyuzhnova, 2025). Innovation also builds the adaptive capacities of firms, allowing them to respond flexibly to changes in global demand and disruptions in technology. Moreover, innovation underpins emerging sectors, such as renewable energy, biotechnology, and digital services, which are gaining importance in global trade.

Product innovation is the process of creating new or substantially improved products or services that provide enhanced benefits or value to customers (Palikot, 2023). Such innovation can lead to increased export sophistication by allowing firms to make unique, competitive products that generate higher returns in the global marketplace. A prime example is the mobile-money platform M-PESA, a digital finance product innovation. These innovations highlight how product upgrades improve a country's export sophistication, M-PESA has evolved into an agile, highly valuable product with significant international adoption. As firms design and export advanced digital financial products instead of raw goods, economies ease their reliance on primary sectors and stimulate expanding, technology-based export portfolios (ECDPM, 2023).

Product innovation acts as a catalyst for capacity building. Through formal R&D and global partnerships, firms acquire the expertise needed to compete internationally. For instance, the development of M-PESA relied on extensive collaboration between regulators and international partners, which established a robust financial infrastructure in Kenya (Kingiri & Fu, 2020). This expertise now allows for the export of sophisticated fintech services (Safaricom, 2025), fostering greater market diversification and economic resilience.

Complementing these product advances, process innovation, encompassing automation, digital supply chains, and advanced manufacturing, reshapes how value is delivered (Rehman et al., 2024). In Sub-Saharan Africa, the adoption of digital production platforms and e-commerce integration has demonstrably enhanced output quality and market access (King et al., 2025). While the synergy between product and process innovation positions African economies to export higher-standard goods, realizing this potential requires overcoming persistent structural deficits in R&D, institutional capacity, and infrastructure.

Drivers of Export Sophistication

Export sophistication encompasses the transition from primary commodities and low value-added manufacturing to the production of higher technological and knowledge-based goods (Anand et al., 2012). Countries with more advanced export portfolios usually possess a wider array of high value economic activities, higher worker productivity, and greater global competitiveness (Hausmann et al., 2024). As a result, export sophistication plays a vital role in Sub-Saharan Africa's economic diversification and growth. To improve their position in the global value chain, countries in the region must implement policies that support industrial upgrading, innovation, and skills development (Ambos et al., 2021).

Technological innovation is one of the main drivers for export sophistication, enabling Sub-Saharan African countries to transition from raw commodities to complex, high-value products. By modernizing production methods and diversifying into higher value-added segments, nations can significantly enhance their global competitiveness (Ado et al., 2025; Sithole et al., 2024). However, this technological bound is not automatic; it requires a devotion to R&D budgets (Hausmann, Hwang & Rodrik, 2007) and the adoption of digital tools like AI and automation, which lower costs and strengthen supply chains (Kere & Zongo, 2023; World Bank, 2023).

Nonetheless, technology cannot function on its own but rather also relies its success on the human capital available to operate it. While FDI offers a crucial pathway for transferring skills and knowledge from multinational corporations (Ali et al., 2023), these spillovers are only effective if local workforces possess the absorptive capacity to utilize them. Currently, a misalignment between education systems and industry needs obstruct this potential (World Bank, 2023). To bridge this gap, higher education institutions and policymakers must prioritize STEM education, vocational training, and continuous retraining (AUDA-NEPAD, 2024; ILO, 2023), ensuring that the workforce evolves alongside technological requirements (Sebola, 2023).

Furthermore, even a skilled workforce equipped with advanced technology will struggle without a supportive ecosystem (Shonubi, 2025). Universities and research institutes act as vital hubs for fostering entrepreneurship and aligning curricula with market demands (Suzuki, 2023; Mahalingam & Tamilselvan, 2024), but their impact is often stifled by broader structural deficits. Reliable infrastructure, spanning energy, transportation, and digital networks, is the backbone of sophisticated production; without it, transaction costs rise and competitiveness falls (AfDB, 2024; Wiese & Westhuizen, 2024). Ultimately, achieving export sophistication requires a holistic approach where digital connectivity (WEF, 2023), regulatory reform, and infrastructure investment work in tandem to unlock the region's full economic potential.

Finally, innovation-led export upgrading requires strong institutions and good governance. Higher levels of export sophistication are highly correlated with regulatory transparency, strong intellectual property protection, and effective industrial policy (Hausmann et al., 2007). In Sub-Saharan Africa, however, weak governance and limited enforcement mechanisms often act as barriers to achieving technologically sophisticated production structures (Transparency International, 2023). Participation in global value chains offers opportunities for technology diffusion, provided that countries adopt policies that create local value-added opportunities and facilitate efficient trade (UNCTAD, 2023; UNIDO, 2023). Collectively, the literature identifies technological innovation as the primary determinant of export sophistication in Sub-Saharan Africa, alongside complementary investments in human capital, infrastructure, and institutional development.

Linkages between Technological innovation and Export Sophistication

The process of technological innovation is fundamental to understanding a nation’s capacity to develop and successfully bring sophisticated products to the market, and it remains one of the main driving forces of structural transformation in global economies (Nalbant & Aydın, 2023; JRC, 2024). Technological innovation expands a nation’s productive capabilities by supporting knowledge acquisition, advanced technology absorption, and the diffusion of modified production methods, enabling firms to transform lower value commodities exports into more technologically sophisticated and higher value products (Amin et al., 2025; Petković et al., 2023).

Sophisticated exports require higher levels of embedded know-how that cannot be achieved without sustained innovation and experimentation (Sichoongwe, 2023). Digital technologies, automation, artificial intelligence, and advanced manufacturing systems further enable firms to meet rigorous international standards, enhance production efficiency, and deliver consistent high-quality goods (Rashid et al., 2024; Huang et al., 2025). As a result, firms are able to access premium global markets and advance within global value chains, thereby upgrading and diversifying their export structures (Pei & Su, 2025).

Innovation also reduces production costs while increasing productive efficiency, allowing firms to compete in technology-intensive segments that were previously unattainable (Vuković et al., 2025). Through the adoption of robotics, data-driven systems, and digitally controlled equipment, firms engage in learning-by-doing and accumulate tacit knowledge that strengthens technological capabilities. These learning effects generate spillovers across industries, reinforcing structural transformation and deepening national knowledge bases (Ferreira et al., 2024). The accumulation of technological capabilities is particularly critical because advanced production requires repeated learning cycles that occur within value chains and are most effective in the presence of active innovation (Gao et al., 2023).

Innovation further enhances export sophistication through its interaction with human capital development (Liu et al., 2025). The implementation of new technologies increases demand for skilled labor, encouraging investments in education, technical training, and science-based learning. As labor forces become more skilled, firms are better positioned to adopt and adapt complex technologies, raising export sophistication (Xholo et al., 2025). This relationship is mutually reinforcing, as innovation fosters skills development while improved skills facilitate further technological absorption.

Technological innovation also supports deeper global integration, particularly through foreign direct investment (Pham et al., 2024). Economies with stronger innovation capacities tend to attract more technologically advanced FDI, which brings access to machinery, management practices, production standards, and international networks (Sultana & Turkina, 2020). These spillovers expose domestic firms to global technologies and market requirements, accelerating their transition toward higher value-added export activities. Evidence from Sub-Saharan Africa, including South Africa, Kenya, Nigeria, and Rwanda, shows that investments in ICT ecosystems, digital services, and advanced manufacturing have supported the growth of technology-driven export sectors (Ofori & Asongu, 2021).

Moreover, innovations in agro-processing, pharmaceuticals, auto parts, fintech, and digital services are creating new export categories across Africa (Feuzeu & Kelly, 2025). In Nigeria and Kenya, expanding fintech ecosystems and digital service hubs illustrate how innovation can transform export structures by enabling firms to access global digital markets (Malyshev, 2025). Also, innovation improves firms' ability to meet international regulatory, quality, and sustainability standards, which are prerequisites for participation in advanced global markets. Compliance with such standards typically requires advanced systems for monitoring, traceability, and verification, which are more accessible to innovative firms (Wang et al., 2025; Knapp et al., 2025). Taken together, these dynamics demonstrate that technological innovation has both direct and indirect effects on export sophistication by enhancing productive capabilities, improving efficiency and quality, strengthening human capital, attracting advanced FDI, and accelerating structural transformation (Masunda et al., 2025; Yang et al., 2023).

Critical Reflection on Existing Literature

The literature on technological innovation and export performance is comprehensive but also has some notable gaps. The majority of the literature focused on a small sample of advanced economies, including the North and some countries in Europe, and fast industrializing areas of Asia and Latin America. In these places, innovation systems were more developed, data were of better quality and more abundant, and industrial policy was more institutional, as a rule. The general results from these studies suggest a very strong statistically significant relationship between innovation and export performance. In contrast, Sub-Saharan Africa has been a kind of afterthought. While there is growing interest in technological upgrading and export diversification within Sub-Saharan nations, quantitative assessments linking technological innovation directly to export sophistication in this region remain scarce.

Furthermore, in the studies that are cross country but include Sub-Saharan Africa, the region is often regarded as a homogeneous block where relevant differences in institutional quality, infrastructure and policy environment relevant to innovativeness, are ignored. In short, studies in developed economies will have little relevance to turning economic models in Sub-Saharan Africa, given that informal innovation is prevalent, absorptive capacity for new knowledge is low, and linkages between industry and research institutions are either weak or poorly integrated. The article contributes to the emerging literature on innovation led export upgrading particularly in the unexplored and under-researched regions of the globe specifically the Global South.

III. Data And Methods

Data Sources and Description

The empirical analysis in this study is developed from a panel dataset created from Sub-Saharan African countries, covering the period 2007 to 2022. The dataset incorporates variables from a number of nationally-recognized international bodies to increase the reliability and comparability of resources across countries and across time. The key variables that were used in the analysis are defined in **Table 3.1** along with their associated data sources. This gives a better understanding of how the dataset has been constructed and what measures were used to conduct the empirical estimation.

Table 3.1: Variable Definitions and Data Sources

Variable Name	Measurement and Definition	Data Source
Export Sophistication (log_expy)	EXPY index, capturing the productivity level embodied in a country's export basket. Higher values indicate a more sophisticated and value-added export structure.	Author's calculation based on Hausmann, Hwang & Rodrik (2007)
Technological Innovation (log_patents)	Total resident and non-resident patent applications per million population, measuring national innovative activity.	World Intellectual Property Organization
Human Capital (log_edu)	Gross secondary school enrollment ratio, capturing educational attainment and skill development.	World Bank – World Development Indicators
Governance (log_c_control)	Control of Corruption index, reflecting institutional quality and governance effectiveness.	World Bank – Worldwide Governance Indicators

Variable Name	Measurement and Definition	Data Source
Economic Size (log_pop)	Total population, representing market size and potential economies of scale.	World Bank – World Development Indicators
Foreign Direct Investment (log_fdi)	Net FDI inflows, capturing foreign capital participation and potential technology spillovers.	World Bank – World Development Indicators
Economic Growth (log_gdp)	Gross Domestic Product, reflecting overall economic size and development level.	World Bank – World Development Indicators
Internet Usage (log_iui)	Internet users as a percentage of the population which measures digital connectivity and technological diffusion.	International Telecommunication Union

Methodology and Hypothesis

Model Specification

This research investigates technological innovation's impact on export sophistication in the Sub-Saharan Africa region. The baseline regression model is specified as follows:

$$\mathbf{log\_expy_{it}} = \mathbf{\beta_0 + \beta_1 log\_patents_{it} + X'_{it}\gamma + \varepsilon_{it}} \quad \textbf{(3.1)}$$

Where:

i represents the country and t represents the year. This format allows the analysis to capture cross-country and within-country variations over time which helps to detect long-term trends and controlling for unobserved heterogeneity.

X'_{it} is a vector of control variables which are log_fdi, log_pop, log_iui, log_edu, and log_c_control.

εit is the error term that captures unobserved factors that may influence export sophistication but are not included in the model.

Export Sophistication

Evaluating the level of export sophistication is important to understanding their technological content and productivity in a country's export basket. This research uses the EXPY framework, adapted from Hausmann, Hwang, and Rodrik (2007). The basic idea of the EXPY approach is that we can use the income level of a country as a proxy for the sophistication of any exported goods. Therefore, we can determine overall export sophistication of a country from the income levels of its export structure. The construction of EXPY follows a two-step procedure.

First, we have PRODY which is calculated as follows:

$$\boldsymbol{PRODY_j} = \sum_{\boldsymbol{i}} \left(\frac{\boldsymbol{x_{ij}} / \sum_j \boldsymbol{x_{ij}}}{\sum_i \boldsymbol{x_{ij}} / \sum_i \sum_j \boldsymbol{x_{ij}}} \right) * \boldsymbol{Y_i} \quad \textbf{(}\text{Error! No text of specified style in document.}\textbf{.2)}$$

In which:

X*ij* is the value of exports of commodity *j* by country *i*,

Y*i* is the per capita GDP of country *i*, the term in parentheses is the normalized revealed comparative advantage weight for country *i* in commodity *j*.

After getting the PRODY figures, the author dives into the calculation of the EXPY. The EXPY index measures the sophistication of the overall export basket of a country, aggregating the PRODY values to determine the overall sophistication. Specifically, for a country *i*, EXPY is calculated as:

$$\boldsymbol{EXPY_i} = \sum_{\boldsymbol{j}} \left(\frac{\boldsymbol{x_{ij}}}{\sum_j \boldsymbol{x_{ij}}} \right) * \boldsymbol{PRODY_j} \quad \textbf{(}\text{Error! No text of specified style in document.}\textbf{.3)}$$

Where $\frac{x_{ij}}{\sum_j x_{ij}}$ represents the share of product *j* in the total exports of country *i.*

We interpret the EXPY variable to indicate that when high, a country's export structure resembles that of a high-income country, which suggests that the country is producing and exporting a number of goods for which the technology or activities are complex enough to require significant added value, human and physical capital. For example, machines, electronics, precision instruments, specialized manufactured products. That the country exports such products suggests that it has the organizational capabilities, institutions, infrastructures and educational resources that allow it to take advantage of these efficiencies of innovation and to compete with such products in a global market.

In contrast, a lower EXPY value indicates an export structure dominated by exports that typically come from low and some middle-income countries. These exports are usually resource based. While these exports can

generate growth in the short-run, they offer a limited pathway for structural change over the longer term since they are more sensitive to prices, weaker linkages to the wider economy.

Hence, monitoring EXPY values over some time can be a good way to assess a country's development on the actual asset aspects of economic diversification and structural upgrading. A rising EXPY path may indicate the effectiveness of industrial policy actions, advances in capabilities and technology, or improvements in integration into global value chains. For policymakers, EXPY is a valuable measure for assessing the effectiveness of export-led development strategies, as well as identifying where subsequent investments in skills, technology and innovation and economic diversification are necessary, based on the evidence of the EXPY measurement.

Hypothesis 1: Countries that exhibit more technological innovation activity will also experience higher levels of export sophistication.

Hypothesis 2: Structural transformation, mediates the relationship between technological innovation and export sophistication.

Hypothesis 3: Capital enhances the effect of technological innovation on export sophistication.

IV. Empirical Results And Discussions

Descriptive Statistics

Table 4.1 shows the summary statistics for all variables used in the empirical analysis.

Table 4.1: Descriptive Statistics

	mean	sd	min	max	count
log_expy	8.969538	.7027563	3.669512	10.25718	699
log_patents	2.790056	1.818291	0181143	9.546098	699
log_rd	.3201173	.2250544	.01019	.80567	699
log_gdp	7.209214	.9503215	5.112968	9.859614	699
log_pop	15.89551	1.65924	11.35079	19.22336	699
log_edu	-.0530145	.0985612	-.4615276	.1620168	699
log_fdi	18.99397	3.558978	-2.594678	24.42848	699
log_iui	2.279058	1.245559	-1.427805	4.401744	699
log_c_control	-1.359373	1.293352	-4.95221	.5295389	699
log_power	-.4805885	.8587995	-3.312951	1.201015	699
log_hte	5.675367	9.343631	0.211834	95.61794	678
log_fbs	9.489487	2.112081	4.143135	14.48234	592
Observations	704				

Baseline Results

The baseline model determines the effect of technological innovation on export sophistication. The model is specified in a log-linear form and estimated with OLS including robust standard errors for possible heteroskedasticity.

Table 4.2: Panel Regression Results

	(1)	(2)	(3)	(4)
log_patents	0.1051***	0.2373***	0.0800***	0.0759***
	(7.58)	(9.50)	(5.36)	(4.80)
log_fdi		0.0868**	0.0423**	0.0392**
		(7.80)	(5.44)	(4.69)
log_gdp		0.0379	0.2849**	0.1717
		(1.21)	(2.26)	(1.29)
log_pop		-0.0866***	0.2125	-0.0144
		(-4.77)	(1.14)	(-0.03)
log_iui		-0.0185	-0.0115	-0.0222
		(-0.95)	(-0.65)	(-0.87)
log_edu		1.5918***	0.4012**	0.3534*
		(6.20)	(2.22)	(1.83)
log_c_control		0.3614***	0.1235***	0.1125***
		(10.39)	(7.25)	(6.55)
Constant	8.6763***	11.6773***	4.3319	8.4550
	(157.30)	(21.06)	(1.43)	(0.98)
N	699	699	699	699
R-Square	0.0740	0.5800	0.2854	0.3405
Country FE	No	No	Yes	No
Year FE	No	No	No	Yes

*Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.10*

Regression analysis shows a strong and positive correlation between technological innovation and export sophistication for each of the regression models used. In the first regression model, there is a statistically

significant ($p < 0.01$) positive relationship between technological innovation and export sophistication. The coefficient of this relationship is 0.105. Once control variables are added to the regression model, the coefficient rises to 0.237. This suggests that previous estimates of the relationship between innovation and higher export sophistication based on technological innovation by the omitted macroeconomic controls were likely to yield lower estimates of the contribution of innovation to export upgrading through FDI. Although the coefficient declines after controlling for country and year fixed effects, 0.08 and 0.076, respectively, it remains statistically significant ($p < 0.01$) regardless of whether country characteristics and global shocks are held constant. This supports the conclusion that innovation continues to drive the increased sophistication of exports.

From the above analysis, we find that human capital has the largest influence on the export sophistication. The coefficients for human capital range from 1.592 in the pooled regression to 0.353 in the fully specified regression. These coefficients show that education is the most important input to the production of complex and sophisticated export products. The effect of control of corruption also remains positive and statistically significant, the coefficients range from 0.361 to 0.113, and is consistent with the idea that effective governance is a necessary condition for innovation driven upgrading of the productive capacity of an economy through FDI.

On the contrary, there are no correlations between population size and export sophistication with the inclusion of country fixed effects. Additionally, internet usage is found to be statistically insignificant across all models examined. Overall, strong evidence supports the hypothesis and conclusion of both hypotheses that technological innovation has a positive effect on export sophistication in Sub-Saharan Africa especially if the country has significant improvements in education, the quality of institutions, knowledge-intensive foreign direct investment. Overall, the evidence supports the conclusion that sustainable export upgrading does not rely primarily on scale or connectivity but rather on building out productive capabilities and establishing an effective set of productive institutions.

Instrumental Variable Analysis

The section above provides insights generated by OLS; however, this method is susceptible to endogeneity problems associated with the variable of primary interest, log_patents. Endogeneity can stem from several potential causes, including reverse causation in which an increase in export sophistication produces higher levels of innovation, and omitted variables, such as industrial policy and/or institutional quality that affect both levels of innovation and capitalizing on increased export sophistication. To resolve the endogeneity issue with respect to log_patents through an Instrumental Variables framework, we provide the following.

Instrumental Variables Estimation

In order to address the possibility of endogeneity, the author created an instrumental variable using historical rolling averages of patent data. The rolling averages were created by calculating a mean over the log_patent number during a 3-year time period. Because historical averages of patent data are likely to be correlated with current patent data, while only having data prior to any current year specific shock to export sophistication, they serve as an appropriate instrument for estimating the effect of innovation on sophistication of exports.

Table 4.3: 2SLS Estimates of Technological Innovation on Export Sophistication

	(1)	(2)	(3)	(4)
	OLS	First Stage	Reduced Form	2SLS
log_patents	0.258***			0.466***
	(0.0282)			(0.0500)
log_gdp	0.0208	0.274***	0.0853**	0.213***
	(0.0347)	(0.0756)	(0.0392)	(0.0507)
log_fdi	0.0724***	0.0931**	0.0597***	0.103*
	(0.0103)	(0.0131)	(0.00950)	(0.0120)
log_pop	-0.139***	0.208***	-0.173***	-0.270***
	(0.0221)	(0.0441)	(0.0258)	(0.0362)
log_iui	0.0354*	0.236***	0.106***	-0.00409
	(0.0199)	(0.0425)	(0.0261)	(0.0236)
log_c_control	0.359***	-0.347***	0.288***	0.450***
	(0.0368)	(0.0413)	(0.0335)	(0.0400)
Lagged Rolling Avg. Patents		0.643***	0.300***	
		(0.0502)	(0.0324)	
Constant	12.39***	-7.073***	12.78***	16.07***
	(0.643)	(1.100)	(0.706)	(0.998)
Observations	699	699	699	699
R-Square	0.550	0.702	0.501	0.439
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

*Robust Standard errors in parentheses: * p < 0.10, ** p < 0.05, *** p < 0.01*

The constructed rolling historical average of log patents serves as an external instrument within the two-stage least squares system. This first stage shown in **Table 4.3** in Column (2) displays a tight and significant association between the generated instrument and patent usage which provides evidence for the relevance of this instrument.

Export sophistication and technological innovation are positively related according to the instrumented effect of technological innovation in Column (3) of the reduced form estimates. Technological innovation produces a positive effect on export sophistication because it is significant when controlling for endogeneity, as indicated by the 2SLS results in Column (4). Overall, the IV results show that technological innovation increases export sophistication significantly for Sub-Saharan Africa.

Alternative Measures

Research and Development as the Independent Variable

The baseline model considers patents to be the most appropriate measure of technological innovation. Although patents account for the outputs of inventive activity, they are not guaranteed to capture the diffusion or adoption of technology, especially in developing areas like Sub-Saharan Africa, which is likely to under-report formal innovation. In order to assess whether the key finding, that technological innovation is positively related to export sophistication, is contingent solely on the use of patents as the measure of innovation, we re-estimate the model to use research and development (log_rd) as a measure of technological innovation. R&D expenditure provides input measures into innovation, as it is a precursor to patents, but it also tells us about what investments a country is making in regards to technological development, which could be related to export sophistication prior to tangible outputs like patents being produced.

Table 4.4: R&D Expenditure as a Proxy for Innovation

	(1)	(2)	(3)	(4)
log_rd	0.774***	0.543***	0.853***	0.977***
	(0.247)	(0.167)	(0.180)	(0.229)
log_gdp		0.194***	0.549***	0.421***
		(0.0572)	(0.109)	(0.122)
log_edu		1.002**	0.322	0.566
		(0.475)	(0.639)	(0.807)
log_fdi		0.0215	0.00697	0.00401
		(0.0210)	(0.0238)	(0.0380)
log_pop		0.0814***	0.185	-1.190
		(0.0265)	(0.405)	(0.786)
log_iui		0.0481	0.0271	0.0129
		(0.0318)	(0.0408)	(0.0502)
log_c_control		0.123***	0.0989***	0.118***
		(0.0284)	(0.0374)	(0.0300)
cons	8.854***	6.723***	1.911	25.84*
	(0.114)	(0.621)	(6.726)	(13.46)
Observations	699	699	699	699
R-Square	0.286	0.637	0.876	0.905
Country FE	No	No	Yes	No
Year FE	No	No	No	Yes

*Robust standard errors in parentheses: * p < 0.10, ** p < 0.05, *** p < 0.01*

The relationship between R&D investment and export sophistication is consistently and strongly supported by the regression analysis. Regardless of the specification used in the analysis, R&D expenditure was statistically significant throughout. The effect of R&D is still significant and considerable when other economic and institutional variables are taken into account. The correlation between log GDP and export sophistication is positive and statistically significant in the four models (with a coefficient of 0.421 in the fully specified model), Economic production capacity and volume positively contribute to supporting complex exports The relationship between log Internet usage may be negative and statistically insignificant, which suggests that having access to the digital economy alone will not lead to the transformation of exports into more sophisticated products. The relationship between log corruption control and Log GDP is consistently positive and statistically significant throughout the models, indicating the influence of institutional quality and R&D on the development of export sophistication in Sub Saharan Africa. In conclusion, results suggest that R&D investment plays a major role in developing export sophistication in Sub Saharan Africa, along with economic production capacity, and quality of governance.

Mobile Penetration as a measure for Technological Innovation

In order to ensure that our findings are not biased by a certain definition of technology innovation, we estimated the baseline model using mobile penetration as a different way of measuring innovation capability. Mobile penetration coverage is an indicator of how much people use digital technologies for spreading information and increasing productivity, also, it reflects how well institutions and businesses have utilized these technologies. The results of this analysis will allow us to determine if the connection between innovation and export sophistication still exists when innovation is defined as the ability to use and implement new technology rather than as producing it. The results from this analysis are provided in the **Table 4.5** below.

Table 4.5: Mobile Penetration as a Proxy for Innovation

	(1)	(2)	(3)	(4)
log_mobp	0.00257***	0.00301***	0.00296***	0.00256***
	(0.000744)	(0.000605)	(0.000719)	(0.000672)
log_gdp		0.221***	0.221**	0.117
		(0.0561)	(0.109)	(0.107)
log_edu		0.159	0.0991	0.133
		(0.136)	(0.143)	(0.147)
log_fdi		0.00745	0.0134*	0.0104
		(0.00604)	(0.00691)	(0.00639)
log_pop		0.0423*	0.0137	-0.639*
		(0.0254)	(0.203)	(0.358)
log_iui		0.00853	0.0108	0.0137
		(0.0167)	(0.0211)	(0.0231)
log_c_control		0.0373***	0.0350***	0.0309**
		(0.0116)	(0.0127)	(0.0132)
cons	9.087***	6.978***	7.628**	19.42***
	(0.0478)	(0.702)	(3.566)	(6.111)
Observations	699	699	699	699
R-Square	0.000	0.399	0.780	0.805
Country FE	No	No	Yes	No
Year FE	No	No	No	Yes

*Standard errors in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$*

There is a strong statistical relationship between the mobile penetration rate and export sophistication at the 1% level for every model that was used. These results were consistent with the results from other research that assessed innovation using patent measures. Mobility also reflects the technological diffusion and utilization aspects of innovation rather than the cutting-edge technologies in a developing economy. So, while the impact of mobility on exports was less than the impact of patent-based measures, it is not surprising since mobility is related to the way we use technology to transmit information, reduce costs associated with the distribution of goods and services, and increase access to global markets for exporters.

In addition, the stepwise estimation strategy shows a high degree of robustness, as the mobile penetration estimate remains relatively stable throughout multiple controls and fixed effects. The mobile penetration coefficient decreases very slightly when year fixed effects are added to the fully specified model, suggesting that the relationship is not driven by omitted macroeconomic trends or country-specific shocks. The results using mobile penetration as an alternate measure of innovation support our primary conclusion that technological capacity, whether through invention, diffusion or use, is a major component in determining export performance. The convergence of evidence from input and diffusion-based measures enhances confidence that innovation capacity is a critical factor influencing export results.

Robustness Checks

Omitted Variable Bias Test

In order to evaluate possible omitted variable bias in our main specification, we utilize a progression of models which add different kinds of control variables to the specification one at a time. The progression of models allows us to see how the relationship between patent activity and exports changes as we add potentially confounding variables. The results of this testing process are featured in **Table 4.6**.

Table 4.6: Robustness to Omitted Variable Bias

	(1)	(2)	(3)	(4)
log_patents	0.0566***	0.0872***	0.0732***	0.0676***
	(0.0190)	(0.0136)	(0.0148)	(0.0151)
log_gdp		0.194***	0.228*	0.0992
		(0.0412)	(0.117)	(0.117)
log_edu		0.479***	0.455**	0.436**
		(0.165)	(0.185)	(0.176)
log_fdi		0.0361***	0.0381***	0.0346***

		(0.00802)	(0.00798)	(0.00792)
log_pop		0.00417	0.230	-0.218
		(0.0188)	(0.153)	(0.307)
log_iui		-0.00581	-0.0289*	-0.0483**
		(0.0133)	(0.0164)	(0.0225)
log_c_control		0.135***	0.123***	0.111***
		(0.0176)	(0.0179)	(0.0182)
log_power		-0.0127	-0.00756	-0.0141*
		(0.0407)	(0.0512)	(0.0533)
log_rulelaw		-0.0971**	0.0497*	0.0817
		(0.0435)	(0.127)	(0.136)
cons	8.810***	8.188***	4.392*	12.81**
	(0.138)	(0.511)	(2.472)	(5.058)
Observations	699	699	699	699
R-Square	0.074	0.519	0.700	0.729
Country FE	No	No	Yes	No
Year FE	No	No	No	Yes

*Robust standard errors in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$*

The progressive modeling allows us to identify a number of key patterns that provides us with confidence in the primary findings.

Technological innovation has a consistent and reliable positive effect on export sophistication across all model specifications, demonstrating that the relationship between innovation and export sophistication is stable. The findings suggests that the baseline model does not suffer from extreme omitted variable bias following the inclusion of technological innovation. The addition of the economic control variables demonstrates that the simpler models tend to underestimate the level of innovation's true impact on export performance, as economic control variables, like GDP and education are associated with innovation outcomes. The addition of country and year fixed effects provides a more modest adjustment to the Intellectual property activity to 0.0676, since this takes into account inconsistencies due to country-specific characteristics and temporal shocks that occur at the country-level, yet the impact of technological innovation still has statistically and economically significant effects on export performance.

Placebo Test

This study has also included a placebo test as an additional robustness check to further reinforce the credibility of the estimates quantifying the effect of technological innovation on export sophistication. The primary aim of this test is to demonstrate that the baseline results are not merely the result of coincidental associations, or idiosyncratic model effects, but rather represent a valid and systematic relationship. The placebo test serves as a rigorous standard against which to evaluate the robustness of the baseline estimates and, therefore, to substantiate the causal interpretation of the association between technological innovation and export sophistication by comparing the baseline estimates with those produced under conditions where there should be no genuine effect.

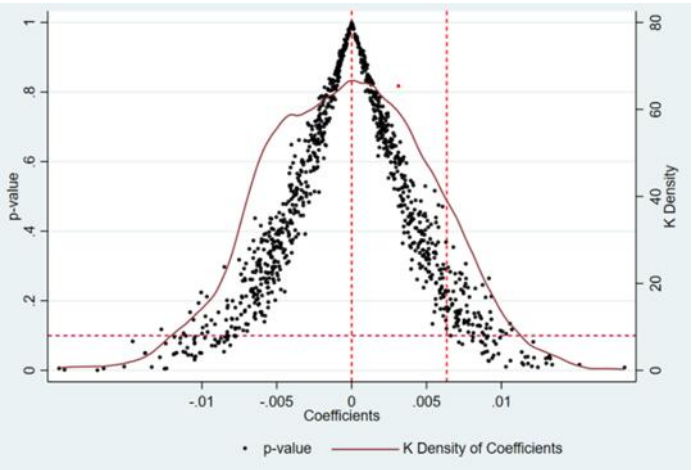

Figure 4.1

The results are shown in **Figure 4.1** which were obtained based on random assignment are expected to show a symmetric distribution around zero, thus, the majority of the p-values are expected to be relatively large,

indicating that the innovations were assigned randomly, and do not indicate that they have any statistically significant effect on the market.

Additionally, the true estimated co-efficient from the baseline regression appears on the extreme end of the placebo coefficient distribution and has a significantly lower p-value when compared to the placebo p-values associated with random assignment. Therefore, the chances of obtaining the estimated baseline effect simply due to chance is a very low probability. Hence, the findings from the placebo test bolster the credibility of the primary findings and demonstrate that the positive impact of technological innovations on export sophistication is not due to spurious correlations or random variation, but demonstrates a legitimate, strong association between the two variables.

Propensity Score Matching Analysis

To support the conclusions of this study and to reduce the concerns about selection bias and systematic differences between countries with distinct levels of technological innovation, we applied PSM as an additional robustness test for our findings. It is possible that observable variables will differ between countries that do not exhibit technology based on the level of innovation; thus, traditional regression methods may be affected by these differences. With PSM, we create a more appropriate control group that enhances the reliability of assessing the relationship between technological innovation and sophistication in exports.

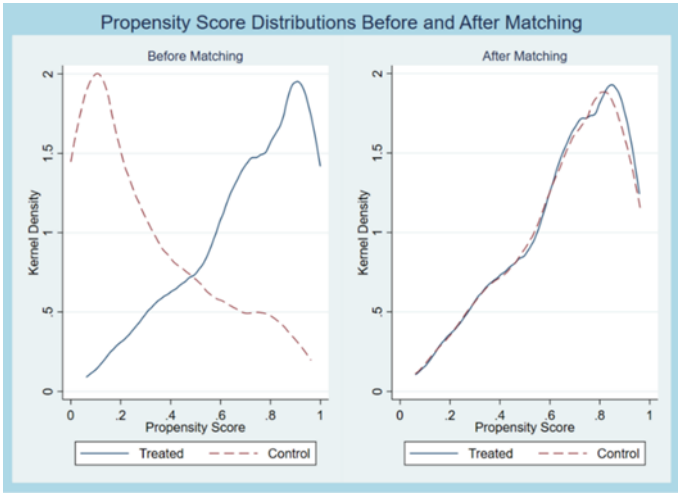

Figure 4.2

Figure 4.2 displays the distribution of propensity scores for both the treated and control group, before and after matching. Prior to matching the two groups, there was a distinct lack of overlap between their respective distributions, which represents a significant difference between the two groups with respect to their observable characteristics, creating the possibility of selection bias. However, once matched, the propensity score distributions of both the treated and control groups are now closely aligned. This indicates that the matching process effectively equalizes covariate distribution between the two groups and, therefore, improves comparability.

After treatment and control groups were matched and improved covariate overlap confirmed, there are now no statistically significant differences among the observable characteristics of members of the treatment and control groups that may cause any systematic bias on the effects of the independent variable on the dependent variable being analyzed. This provides further validity for the results of the PSM analysis and confirms the hypothesis that there is a positive relationship between the level of technological innovation and export sophistication, even after adjusting for the possibility of selection bias.

Reverse Causality and Sensitivity to Model Specification

To reinforce the validity of our central finding that innovation affects export performance, we subject the baseline model to an extensive set of robustness checks. We address two central questions: reverse causality concerns using lagged controls, and robustness of results to the inclusion of specific control variables. The outcomes from our robustness testing are shown in **Table 4.7**.

Table 4.7: Robustness to Reverse Causality and Model Specification

Variables	(1) Baseline	(2) Lagged Controls	(3) No GDP	(4) No Education	(5) No Population	(6) No FDI	(7) No IUI	(8) No C-Control
Lagged Patents	0.030**	0.052***	0.036***	0.030**	0.030**	0.027**	0.030**	0.030***
(Standard Error)	(0.011)	(0.014)	(0.012)	(0.011)	(0.012)	(0.011)	(0.011)	(0.011)
Controls Included								
log_gdp	Yes	Yes (L)	**No**	Yes	Yes	Yes	Yes	Yes
log_edu	Yes	Yes (L)	Yes	**No**	Yes	Yes	Yes	Yes
log_pop	Yes	Yes (L)	Yes	Yes	**No**	Yes	Yes	Yes
log_fdi	Yes	Yes (L)	Yes	Yes	Yes	**No**	Yes	Yes
log_iui	Yes	Yes (L)	Yes	Yes	Yes	Yes	**No**	Yes
log_c_control	Yes	Yes (L)	Yes	Yes	Yes	Yes	Yes	**No**
Observations	699	699	699	699	699	699	699	699
R-squared	0.137	0.074	0.096	0.134	0.138	0.122	0.138	0.078
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

*RobustStandard errors in parentheses: ***p < 0.01, **p < 0.05, *p < 0.1.*
All models estimated using fixed-effects panel regression with robust standard errors.
(L) indicates the control variable is lagged by one period.

The **Table 4.7** above illustrates that our main finding is quite robust when examining all alternative specifications. Some notable patterns which we have already introduced via the robust standard errors arise.

The second column (2) of the results table uses a lagged model to help control for any bias due to simultaneous impacts from patenting activity onto exports. The resulting estimate is slightly larger and thus more accurate than the estimate provided in the baseline model, with a lagged patent coefficient increasing from 30% ($p < 0.05$) to 52% ($p < 0.01$). This results in estimates that may have been understated in the previous table's baseline estimates, therefore supporting evidence for a causal interpretation that prior patenting issues can help contribute to later improvements in export performance. Columns (3) – (8) of the results table test the validity of the lagged patenting estimate by sequentially omitting individual control variables, but continue to produce positive and statistically significant lagged patenting coefficients across all model specifications, albeit with minor variation. This indicates that the coefficient produced in the standard control models is highly consistent with the estimate produced in the baseline coefficient, supporting the conclusion that the observed relationship is stable and not influenced by any single variable or model choice.

Accounting for the COVID-19 Structural Shock

The author also assessed how sensitive the baseline results are to including the impacts of the COVID-19 pandemic on the data. As a major worldwide shock to trade activities, innovation activities, capital transfers, and production systems, COVID-19 could potentially disrupt long-term relationships between technological innovation and export performance. Therefore, using data collected during the years prior to 2019 to estimate the baseline model is necessary.

Table 4.8: Accounting for the COVID-19 Period

	(1)	(2)	(3)
	Full Sample	Pre-2020	Pre-2021
L1_log_patents	0.034***	0.030***	0.028**
	(0.012)	(0.011)	(0.011)
Observations	699	699	699
R-Square	0.128	0.161	0.147
Year FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes

*Robust standard errors in parentheses: * p < 0.10, ** p < 0.05, *** p < 0.01*

The robustness testing without the COVID-19 period shows that with the lagged patent variable included, the impact of technological innovation continues to be consistently positive on export sophistication. The coefficients ,0.034, 0.030, and 0.028, from all three models indicate a strong correlation not only in the overall sample, but also prior to 2020 and 2021 respectively.

Mechanism Analysis

Structural transformation as a Mechanism

In this section, we assess structural transformation (increases in manufacturing value added as a percentage of total GDP), which represent the measurement of how technological innovations contribute to export sophisticated goods and services. Research conducted in Sub-Saharan Africa indicates that improved innovation performance increases rates of manufacturing growth and increases the potential for integrating into or being part of global manufacturing networks, therefore, the ability to produce more sophisticated exports improves. As such, this study examines whether there is an effect of technological innovation on structural transformation and whether structural transformation mediates the effect of technological innovation on export sophistication.

Table 4.9: Channel Analysis: Structural transformation as Mediator

	(1)	(2)	(3)
	Export Sophistication	Structural transformation	Export Sophistication
log_patents	0.258***	0.00216***	0.121***
	(0.0282)	(0.00940)	(0.0130)
log_gdp	0.0208	0.881***	0.198***
	(0.0347)	(0.0187)	(0.0467)
log_fdi	0.0724***	0.000376	0.0232***
	(0.0103)	(0.00315)	(0.00511)
log_pop	-0.139***	0.996***	0.0827
	(0.0221)	(0.0105)	(0.0516)
log_iui	0.0354*	0.0607***	0.00971
	(0.0199)	(0.0112)	(0.0145)
log_c_control	0.359***	-0.0136	0.151***
	(0.0368)	(0.00945)	(0.0154)
log_strtrans			0.105**
			(0.0504)
cons	12.39***	0.458*	8.971***
	(0.643)	(0.252)	(0.344)
Observations	699	699	699
r2	0.550	0.973	0.509
Country FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

*Robust Standard errors in parentheses: * p < 0.10, ** p < 0.05, *** p < 0.01*

As shown in **Table 4.9**, technological innovation greatly mediates the structural transformation of Sub-Saharan Africa, leading to greater export sophistication. The coefficient of log_patents is positive and statistically significant, which shows the strong link between innovation and export sophistication. Technological innovation is also significant when structural transformation is controlled, meaning that structural transformation partially mediates this relationship. Therefore, technological innovation both directly increases export sophistication and indirectly contributes to export sophistication through industrial upgrading and the expansion of manufacturing.

The Combined Effects model also supports the hypothesis as indicated by the positive and statistically significant coefficient for structural transformation; this further supports the importance of manufacturing value added in facilitating the advancement of technological innovation to result in more sophisticated export products. The results support the foundational hypotheses which states that Technological Advancements direct or indirectly cause the sophistication of exported products to increase via Structural Transformation within Sub-Saharan Africa.

Capital as a Mediator of Innovation and Export Sophistication

This section explores using capital accumulation as a mediator variable through which technological innovation affects export sophistication. Innovation extends producers' production capacity and allows them to invest in new technologies. Therefore, countries that have more capital are able to produce more complex exports at higher sophistication levels than those countries without large amounts of capital. A two-step methodology was used to evaluate the first step of how innovation affected capital accumulation (log_capital), then to evaluate how capital affected export sophistication, this was presented in **Table 4.10.**

Table 4.10: Channel Analysis: Capital as Mediator

	(1)	(2)	(3)
	Direct Effect	Effect on Capital	Combined Effects
log_patents	0.258***	0.111***	0.126***
	(0.0282)	(0.0398)	(0.0135)
log_gdp	0.0208	0.620***	0.118***
	(0.0347)	(0.0645)	(0.0243)

log_fdi	0.0724***	0.0479**	0.0211***
	(0.0103)	(0.0216)	(0.00700)
log_pop	-0.139***	0.293***	-0.0186
	(0.0221)	(0.0450)	(0.0144)
log_iui	0.0354*	0.0683**	0.00587
	(0.0199)	(0.0306)	(0.0139)
log_c_control	0.359***	0.0774	0.167***
	(0.0368)	(0.0677)	(0.0171)
log_capital			0.00175**
			(0.0130)
cons	12.39***	-6.959***	8.722***
	(0.643)	(1.030)	(0.369)
Observations	699	699	699
R-Square	0.550	0.305	0.525
Country FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

*Robust standard errors in parentheses: * p < 0.10, ** p < 0.05, *** p < 0.01*

The results shown in **Table 4.10** above indicate that technological innovation promote capital accumulation, therefore, there is evidence of part mediation for this relationship between innovation and export sophistication. It was also found that capital accumulation positively impacts export sophistication and serves as an additional transmission mechanism in the link between technological innovation and export sophistication. This evidence supports the hypothesis, which asserts that capital accumulation serves as an important transmission mechanism through which technological innovation enhances export sophistication for all products and provides evidence of part mediation.

Heterogeneity Analysis

Country Characteristics

In order to investigate the extent to which the relationship between technological innovation and export sophistication varies from country to country, the author will conduct an analysis of heterogeneity by estimating the initial model on six separate groups, Countries with high and low levels of export sophistication as well as four regional groupings of Sub-Saharan Africa, East, West, Central and Southern Africa. The analysis allows for identification of the differences between the innovation export sophistication relationships that are created by differing levels of economic complexity and geographic characteristics that are frequently obscured when viewed in aggregation terms. Such heterogeneity is anticipated because of the wide variability in cross-country systems of development, institutional quality, innovation capacity and access to the global marketplace. Therefore, identification of these subgroups specific effects provides a much greater depth of understanding in regards to the results and assists in providing a more refined model of the implications for policy formation based on differing contexts.

Table 4.11: Heterogeneity Analysis results

	(1)	(2)	(3)	(4)	(5)	(6)
	High Sophistication	Low Sophistication	East	West	Central	South
log_patents	0.0180*	0.0841***	0.0814*	0.0917***	0.0749*	0.0047**
	(0.0085)	(0.0185)	(0.0364)	(0.0208)	(0.0446)	(0.0169)
Constant	21.1797***	0.8625	82.2286**	42.8422**	13.4380	6.0835
	(4.2567)	(5.3685)	(26.8962)	(22.9161)	(11.8747)	(5.6254)
Observations	349	346	112	208	80	144
Adj. R-squared	0.7325	0.9387	0.7367	0.5858	0.9701	0.9029
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

*Robust standard errors in parentheses: * p < 0.10, ** p < 0.05, *** p < 0.01*

The heterogeneity analysis indicates that technology innovation affects export sophistication differently in different nations. In countries with low export sophistication, technology innovation has a strong and statistically significant relationship with export sophistication (0.0841, $p < 0.01$). Thus, technology innovation is particularly important in economies that are still developing their economic complexity. Small improvements in technology can result in large increases in the quality and variety of exports and allow these nations to leapfrog technologically. However, in nations with high export sophistication, the effect of technology innovation on export sophistication is smaller (0.0180) and only marginally significant ($p < 0.10$). This shows that there are diminishing returns on technology innovation.

Regional innovation ecosystems have a more direct positive effect on developing export sophistication in East Africa (0.0814, $p < 0.10$) and West Africa (0.0917, $p < 0.01$). In contrast to Central Africa (0.0749, $p < 0.10$) and Southern Africa (0.0047, $p < 0.05$), where structural constraints impede the successful adoption of innovation for new products, the results indicate less complex economies in East and West Africa can benefit more from technological innovation compared to Central and Southern Africa and that countries in Central and Southern have greater difficulty developing the capacity to leverage innovation for improved export quality. Therefore, the overall conclusions of this study suggest that it is crucial to develop regionally tailored export development strategies and policies for technological innovation.

V. Conclusions And Policy Recommendations

Conclusions

Based on the findings of this research, a significant positive relationship was found between technological innovation and export sophistication throughout Sub-Saharan Africa. In addition to providing evidence that technological innovation leads to a structural transformation of economies through economic diversification, increased manufacturing value added, and a reduction of low-value goods exported, this latest study has also indicated that an increase in the dominance of innovation in the region will lead to an increase in strategic investment opportunities. It has been found that new capital generated through technological innovation will produce higher complexity goods. Thus, these studies indicate that countries with lower levels of economic sophistication may benefit from fostering an environment of technological innovation, in order to improve their export competitiveness.

The results from this research also shows that innovation has an important role to play in the process of economic development and industrialization in Sub-Saharan Africa. This provides the opportunity for countries to transition from being solely primary producers to producing more advanced high-value items. The use of technology as part of the economy increases the diversification of products being produced, increases productivity of the workforce, and improves competitiveness in international markets. Therefore, the results of this study demonstrate that countrys' economic growth and increased export capacity will result from a combination of both improved innovation and increased globalization.

Furthermore, the findings of the study suggest that the growth of innovation and the accumulation of physical and human capital are interdependent, with the creation of new technologies generating new capital. In developing nations with low levels of economic sophistication, providing resources for improving their technological aspect will lead to a greater degree of export sophistication and lay down the basis for accelerated expansion of their manufacturing and industrial sectors in the future.

Finally, the diminishing return on innovation experienced by high level economy countries can be an increased impact on the developing countries. The developed economies will benefit significantly from their utilization of new technology. Nations with emerging economies will utilize new technologies to enhance the complexity and quality of their exported products, while simultaneously moving further into global value chains. As such, innovation provides the means for these countries to increase their economic resilience, diversify their export portfolio and enter into global markets with higher value products.

Policy Recommendations

The results indicate that there are numerous approaches to address how technology is impacting the sophistication of exports from SSA countries. To begin with, policymakers must prioritize building an ecosystem for innovation by increasing financial support for research and development and creating conditions for private sector companies to support innovative practices, for example, through tax breaks, providing subsidies for research and development, developing centers of innovation and technology incubators. Also, policymakers should work toward building human capital with vocational training and changing the culture of innovation. Policymakers should also work towards improving the country's level of intellectual property protection and technology protection, which will increase both local and foreign investments in innovation.

The policies must promote structural changes that allow for the shift away from relying on commodity exports to producing more advanced, manufactured products. Policies that support this will require government intervention by creating an environment conducive for businesses to develop high-value, manufactured products through the necessary infrastructural development, building an industrial base and supporting the establishment of value-added industries. The primary area of focus should be to develop the manufacturing industry. Another important means of supporting this process is through regional integration so that there are larger markets to sell more complex and higher value-added goods, thus enhancing the competitiveness of Sub-Saharan Africa relative to developed countries.

Lastly, policymakers must assist companies with the development of both physical and human capital. Businesses can enhance their production capacities by committing resources to develop their physical and human capital through creating better physical infrastructure, providing additional investment into education and

enhancing access to finance. In order for governmental authorities to assist business in gaining access to capital, they need to create programs that offer entrepreneurs financing options and other tools to encourage growth and stability. It is especially important for small to medium businesses looking to expand into existing and new markets and have an impact on exporting.

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