ISSN: 2958-2326

AJoCsOpen
Sharing Knowledge in Business

African Journal of Commercial Studies

Publisher's Home Page: https://ijcsacademia.com/

AFRICAN JOURNAL OF COMMERCIAL STUDIES

Research Paper | Peer Reviewed | Open Access

Rethinking Technological Export Performance: The Dominant Role of Innovation Beyond Digital Connectivity

Fayssal Moukafi[1]*, Abdelilah Azhar[1], Amine Dafir[1], Youssef Moflih[1]

[1]*Hassan II University in Casablanca, Morocco*
* Corresponding Author

Article Info

Volume 7, Issue 6

***Publication history*:**
Accepted on 5 October 2026;
Published: 18 November 2026

***Key Words*:**
High-Technology Exports; Digital Connectivity; Internet Penetration; Trade Openness; Technological Competitiveness; Digital Economy

***Article Doi*:**
10.59413/ajocs/v7.i6.2

Abstract

With the rapid development of digital technologies, the existing interest in understanding the factors that influence technological competitiveness and exporting of high technology has increased. This study examines the impact that Internet use, research and development (R&D) expenditure, GDP per person, and Trade Openness have on high technology exports using cross-country data from the 2023 World Development Indicators for 74 different countries. The study uses a quantitative approach including descriptive statistics, ordinary least squares (OLS) regression, HC3 heterogeneous consistency, k-means cluster analysis, and principal component analysis (PCA) to determine which factors are most important to technological export competitiveness. The Analyses show that after applying HC3 robust standard errors, only R&D expenditure was statistically significant, while the other factors tested were found not to be statistically significant under the robust specification. K-means cluster and PCA analyses reveal significant heterogeneity among countries and demonstrate different development profiles (e.g., Digital Innovators, Digital Laggards) based on different levels of Development. As such, this study makes a major contribution to the literature by providing an empirical framework to investigate together digital connectivity, innovation, economic development and Trade Openness while establishing the need for strong econometric inference.. The findings suggest that strengthening innovation ecosystems through sustained investment in R&D remains the most effective strategy for enhancing technological export competitiveness.

1. Introduction

The global economy has been changed significantly by the rapid growth of digital technologies. Technology improvements in communications and information (ICT) technologies, artificial intelligence (AI), cloud computing, and digital platforms lead to changes in production systems, business models, and international trade. Digital transformation is now seen as a strategic driver of economic development, productivity growth, and global competitiveness, and is considered an important tool for stimulating innovation and increasing engagement with the global economy. In this environment, high-tech exports have become a key measure of a nation's technological competitiveness. Unlike traditional manufactured goods, high-tech products require significant research and development (R&D), a significant level of advanced technology capabilities, and a very high level of highly educated (skilled) workers. Therefore, the ability of a nation to export high-tech goods is both an indicator of productive capacity and an indicator of how well a nation's innovation system works. Digital connectivity is most often categorized by measuring the rate of internet access (or penetration) within a country. Digital connectivity (i.e., internet access) is widely considered as a fundamental enabler of technological advancement because it provides opportunities to exchange information; diffuse knowledge; and participate in digital marketplaces, and therefore, internet access will also help increase the productivity of companies and their international competitiveness. Consequently, many national governments have made significant investments in digital infrastructure under the presumption that increased levels of connectivity will improve their export performance and as a result, receive a higher return on their investment(s). While countries with similar levels of internet penetration have varying levels of high-tech exports, things that will contribute to the economic benefits that are associated with digitalization will depend on how those countries also perform with respect to other requirements for technological export success, such as innovation and research and development capacity, level of economic development and trade integration, and not just on the existence of digital infrastructure itself. A considerable amount of literature exists that examines these different determinants, however, the majority of the research on those factors has been completed independently (i.e., separate from each other), most often with regard to the relationship between economic growth and innovation; therefore, only limited research has been completed on the impact that these four different determinants have on export performance of high-technology goods. As a result of the limited research that has been conducted on the relationships of those four different determinants, the overall significance of digital connectivity, research and development expenditures, GDP per capita, and trade openness on high-technology export performance is still relatively unknown, especially regarding their differential levels of contribution.

To address this gap, this study investigates the determinants of high-technology exports using cross-country data from 74 countries drawn from the World Development Indicators database. Four explanatory variables are examined: internet penetration, R&D expenditure, GDP per capita, and trade openness. A quantitative approach combining Ordinary Least Squares (OLS) regression, cluster analysis, and Principal Component Analysis (PCA) is employed to identify the main drivers of technological export competitiveness, addressing the following questions: RQ1: What is the effect of internet penetration on high-technology exports? RQ2: To what extent do R&D expenditure, GDP per capita, and trade openness determine technological export competitiveness?

Copyright © 2026 Author(s) retain the copyright of this article. This article is published under the terms of the Creative Commons Attribution Liscense 4.0.

This study contributes to the literature by providing an integrated empirical assessment of these determinants, offering evidence that innovation capacity and trade openness, rather than digital connectivity alone, constitute the main pillars of high-technology export performance.

2 Literature Review

2.1 Digital Connectivity and Economic Performance

Digi-connectedness has become a major indicator of economic growth and global competition in today's economy. Digi-connection can be measured by the proportion of people using the internet and therefore indicates the spread and availability of digital technologies within an economy (Rafik & Sbiti, 2024). Digital connectivity enables the exchange of information to occur, reduces costs for all businesses, and increases the ability of a business to have access while trading on a global scale. Digital connectivity helps a business to engage in the global supply chains and to have greater overall economic performance (Mirzaye & Mohiuddin, 2025).

There is considerable empirical and theoretical support for this assertion. Economic growth theory supports this idea through endogenous growth theory (Romer, 1990), which asserts that knowledge creation and technological advancement are the two primary factors driving long-term economic growth. Alternately, Rogers (2003), the creativity theorist, states that access to digital technology accelerates the process of adopting new ideas and concepts. These findings together reinforce the understanding that having internet connectivity supports the distribution of knowledge and makes it easier for all economies to undergo a digital transformation. In the past two decades, the increased access to the internet has led to a widespread increase in e-commerce, digitization of services, and and international commerce. Myovella et al. note in (2019) that digitalization positively influences economic growth through productivity improvements and innovation stimulation. The digital infrastructure that leads to digital connectivity is made up of complementary infrastructures, such as broadband networks, cloud computing, telecommunications and digital platforms. According to the theory of network effects, the benefits and efficiency associated with each digital network increase as the number of users of the network increases, which improves information flows, coordination and market integration (Mirzaye & Mohiuddin, 2025). There is empirical evidence to suggest that high technology export performance does not only depend on digital connectivity but rather relies on a larger set of structural factors (Kraus et al., 2021). For example, Navarro Zapata et al. (2023) identify R&D expenditure, education, foreign direct investment and institutional quality as being the most important factors affecting high technology exports; while Ersin et al. (2022) identify research activity, patents and innovation capability as being significant contributors to high technology exports. Finally, Loučanová et al. (2025) demonstrate that, when combined with innovation investments and trade openness, digitalization can lead to greater economic benefits through the usage of digital technologies.

2.2 Innovation and Technological Competitiveness

Innovation is widely recognized as a key driver of technological competitiveness, enabling countries to strengthen productive capabilities and sustain competitive advantages in international markets (Lundvall, 2010).

Research and development (R&D) expenditure is commonly regarded as one of the most reliable indicators of a country's innovation capacity. As emphasized by Endogenous Growth Theory (Romer, 1990), investments in knowledge creation stimulate technological progress, productivity, and long-term economic growth. Likewise, the Theory of Creative Destruction (Aghion & Howitt, 1992) highlights the role of continuous innovation in replacing obsolete technologies and improving economic performance. Consequently, sustained investment in R&D enables firms to develop new products, improve production processes, and enhance technological sophistication (Lundvall, 2010).

There is increasing evidence from empirical studies that innovation and technology-based competitiveness are closely correlated (Castellacci & Natera, 2016). Research by Ersin et al. (2022) shows that the level of R&D expenditures, patents granted, and innovation activity in OECD nations is related to technological advancement and growth in their economies. Likewise, research by Navarro Zapata et al. (2023) demonstrates that R&D is one of the primary determinants in how much nation exports in high-technology products along with other factors including; human resources, foreign direct investments, qualitative institutions. Therefore, these studies suggest that having an innovative capacity is an essential element for the production and commercialization of technology-oriented products.

Innovation also consists of more than simply investing in research. The National Innovation Systems approach to innovation states that an organization's performance related to innovation is the result of the interaction between organizations involved with produce, universities, research-oriented (laboratories), and public sector organization. These types of innovative systems create the conditions necessary for knowledge creation, technological learning and collaboration thus providing nations with the capability to develop sophisticated industries and enhance their competitive position in exporting. The recent studies indicate that the impact of innovation is multiplied when combined with other factors including; digitalization, openness in trade, skilled labour and institutional qualities (Loučanová et al. 2025; Manzetti & Osang 2024). Subsequently, knowledge creation and absorption have become significant contributors to the overall competitiveness of nations when talking about industries. Castellacci and Natera (2016) demonstrate that economies capable of generating, absorbing, and exploiting knowledge are more successful in transforming technological resources into productive and commercial opportunities. Investments in research, education, technological collaboration, and innovation therefore strengthen countries' capacity to develop technology-intensive industries and sustain competitive advantages in international markets. Overall, the literature indicates that innovation enhances technological competitiveness through sustained R&D investment, effective innovation systems, and strong knowledge absorption capabilities.

2.3 Economic Development and Trade Integration

It has been widely agreed that economic development, along with trade integration, is a crucial factor in achieving international competitiveness. In today's global economy, countries that can develop their productive capacity and achieve a high degree of integration into world markets generally have greater technological development and export performance than those that cannot. GDP per capita has traditionally been used to measure a country's ability to generate wealth, fund innovation and provide the technological capabilities needed for industrial upgrading; however, it is only one of many determinants of economic development. Countries with higher income levels generally enjoy better infrastructure, education and institutions, which fosters productivity gains and technological advances. Fagerberg (1988) claims that the main drivers of international competitiveness are technological capability, economic development, and how well countries utilize the available knowledge. In addition, while economic prosperity is an important factor in obtaining technological competitiveness, successful high-technology export performance cannot be attributed solely to economic wealth. An example would be the fact that several high-income countries continue to be heavily reliant on traditional industries while several other countries, emerging economies have produced competitive high-technology sectors through deliberate industrial policies and continued investments in innovation. As a

result, it can be concluded that while GDP per capita does create a positive environment for technological development, it cannot solely explain high-technology export performance.

Another important factor in determining technological competitiveness is trade openness. This increase in country integration into global markets allows countries easier access to foreign technology, global knowledge and global supply chains. In addition, firms in open economies are subject to more competition from around the world, exposure to new technologies and greater ability to learn about how to improve their productivity through innovation.

Many of the key studies in this area demonstrate the importance of these factors. Coe and Helpman (1995) show that by allowing countries to indirectly benefit from R&D spillovers, international trade provides an avenue for international innovation. Similarly, Eaton and Kortum (1999) identify international technology diffusion as a primary source of productivity variation between countries. Technical transfer occurs via many routes, which include imports of technology-based goods, foreign direct investment, joint ventures and other partnerships, and using global value chains, and increases both technological upgrading and productive capacity. Recent studies of trade and technology competitiveness also highlight the fact that the relationship between trade openness and technological competitiveness only becomes significant when there is sufficient innovation, human capital, institutional quality and knowledge absorption capacity. (Loučanová et al., 2025; Manzetti & Osang, 2024; Navarro Zapata et al., 2023; Castellacci & Natera, 2021).

2.4 High-Technology Exports as an Indicator of Competitiveness

Exports of high technology equipment are the world's best measure of how sophisticated a country is with respect to productive capability and its ability to compete technologically. The World Bank and OECD categorize high-tech industries as aerospace, computers, electronics, pharmaceuticals, scientific instrumentation and telecommunications. The high-tech industry also has other characteristics that separate them from other industries; they have a high level of investment in research and development (R&D), a high level of technological sophistication and a high level of ongoing innovation. As the digital economy has emerged, high-tech exports have become a critical measure of nations' abilities to convert knowledge, technological capabilities and innovation into products that compete on the international stage. High-tech exports differ from traditional exports based upon either natural resource or low-value-added manufactured products in that their high-tech nature exemplifies innovation systems, human capital, technological infrastructure and integration into global value chains. There is a strong consensus in the literature that high-tech exports are a good proxy for assessing technological competitiveness. According to Castellacci and Natera (2021), "innovation capability and knowledge absorption are key drivers of converting scientific and technological resources into economic outcomes.". Navarro Zapata et al. (2023) found that R&D spending, education level, foreign direct investment, and institutional quality are key indicators of high-tech export success, while Ersin et al. (2022) showed how the level of research and development itself and the patents and innovation capabilities of a country are positively related to technological export success. Recent studies also support the idea that high-tech exports come from many different factors. For example, Manzetti and Osang (2024) demonstrated that governance quality, human capital, openness to trade, and investment in innovation all play a combined role in creating a country's technological competitiveness. Similarly, Loučanová et al. (2025) demonstrated that digitalization, openness to trade, and R&D spending enhance the country's technological performance and export competitiveness. Finally, Gulzar et al. (2024) have proven that countries that export more high-tech products have greater levels of innovation, productivity, and long-term economic growth. High-tech exports are considered a complete measure of a country's level of technological competitiveness because they represent how well a country transforms knowledge, innovation, and technology into products that can compete globally. Therefore, high-tech exports are used as the dependent variable for measuring technological export performance within this study on the digital economy (Rafik & Sbiti, 2024).

2.5 Research Gap

There has been a great deal of research done to establish the role that digitalization, innovation, economic growth and trade liberalization play in contributing to economic prosperity and improving international competitiveness. Prior studies have shown that the digital economy supports the overall economy (Myovella et al., 2020) and that innovation capability, research and development (R&D) investment, and technological resources support the development of technological competitiveness, as well as high tech exports (Ersin et al., 2022; Navarro Zapata et al., 2023; Manzetti & Osang, 2024). However, although there have been many contributions made by researchers in these areas, gaps still exist in the body of literature. Most research to date has focused on each of these factors (i.e., internet penetration rate, R&D expenditures, GDP per capita, and trade openness) on a stand-alone basis, and primarily focused on measuring them as they relate to economic growth, productivity or innovation performance, rather than using them to measure high-tech exports. Thus, little empirical evidence has been published regarding the impact of digital connectivity, innovation, economic development, and trade openness on the overall performance of technological exports. This study seeks to bridge the existing research gap by proposing an empirical framework, which examines the collective impact of the above mentioned variables on high-tech exports by providing a comprehensive quantitative analysis integrating multiple measures of the variables listed above in order to achieve a more thorough understanding of the determinants of technology export competitiveness than previous examinations (Rafik & Sbiti, 2024).

3 Methodology

This section presents the theoretical foundations, research hypotheses, and empirical model adopted to examine the determinants of high-technology exports. It also describes the variables and econometric approach used in the empirical analysis.

3.1 Theoretical Foundations

To justify the conception of the overall framework as depicted in Figure 1, the following three complementary theories are integrated into the analysis of high-technology exports: endogenous growth, innovation, and international trade. Endogenous growth theory explains how R&D spending can lead to greater levels of innovation through the generation and development of new technology (Romer, 1990), while innovation theory identifies internet connectivity as providing opportunities for knowledge to diffuse and for technology to evolve (Schumpeter, 1934; Nelson & Winter, 1982). Finally, international trade theory provides a rationale for including openness to trade and GDP per capita, which promote the transfer of technology and improve a country's productive capacity leading to greater export competitiveness (Douhid et al., 2025). Collectively, these three theories form the theoretical foundation for linking the independent variables to high-technology exports (MacKinnon & White, 1985).

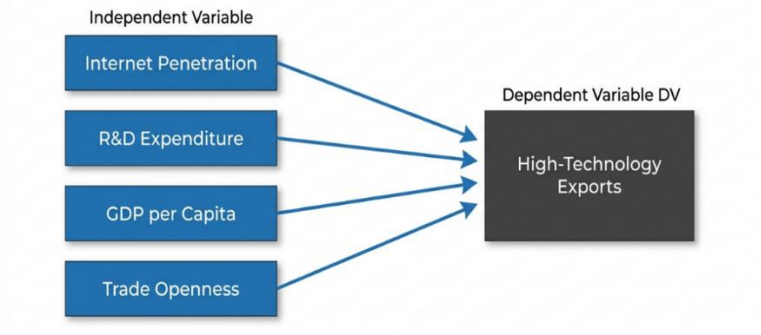


Figure 1. Conceptual Framework of High-Technology Export Determinants
Source: Author's elaboration based on Romer (1990), Schumpeter (1934), Nelson and Winter (1982), and the reviewed literature.

Their connections with the variables included in the empirical model are summarized in Table 1, providing the theoretical foundation for the research hypotheses and subsequent empirical analysis (Douhid et al., 2025).

Table 1. Theoretical Foundations and Their Links to the Variables of the Conceptual Framework

Theoretical Perspective	Main Mechanism	Related Variable(s)	Expected Effect on High-Technology Exports
Endogenous Growth Theory (Romer, 1990)	Knowledge creation through R&D drives technological progress and productivity growth.	R&D Expenditure	Positive (+)
Innovation Theory (Schumpeter, 1934; Nelson & Winter, 1982)	Innovation, learning, and knowledge accumulation enhance technological capabilities and competitiveness.	Internet Penetration; R&D Expenditure	Positive (+)
International Trade Theory	Trade openness promotes technology transfer, knowledge diffusion, and integration into Global Value Chains.	Trade Openness; GDP per Capita	Positive (+)

Source: Author's elaboration based on Romer (1990), Schumpeter (1934), Nelson and Winter (1982), and the reviewed literature.

3.2 Research Hypotheses

Based on the theoretical foundations and the empirical evidence presented in the literature review, this study develops four hypotheses to examine the determinants of high-technology exports. The proposed hypotheses assume that digital connectivity, innovation, economic development, and trade openness positively influence countries' technological export performance (Myovella et al., 2020; Loučanová et al., 2025).
Based on the theoretical framework and previous empirical evidence, the following hypothesis is proposed:
H1: Internet penetration positively influences high-technology exports.
Based on Endogenous Growth Theory and previous empirical findings (Ersin et al., 2022; Navarro Zapata et al., 2023) :
H2: R&D expenditure positively influences high-technology exports.
Based on the literature on economic development and technological competitiveness:
H3: GDP per capita positively influences high-technology exports.
Based on International Trade Theory and previous empirical evidence: (Manzetti & Osang, 2024; Loučanová et al., 2025).
H4: Trade openness positively influences high-technology exports.
The four hypotheses are summarized in Table 2, which presents the expected relationships between the explanatory variables and high-technology exports.

Table 2. Summary of Research Hypotheses

Hypothesis	Expected Relationship
H1	Internet Penetration → High-Technology Exports (+)
H2	R&D Expenditure → High-Technology Exports (+)
H3	GDP per Capita → High-Technology Exports (+)
H4	Trade Openness → High-Technology Exports (+)

Source: Developed by the author based on Romer (1990), Schumpeter (1934), Nelson and Winter (1982), and the reviewed literature.

3.3 Research Model

This research is focused on empirically analyzing the factors that lead to high-technology exports by using a multiple linear regression model in which high-technology exports (HTE's) are the dependent variable and the explanatory variables are Internet penetration rate, R&D expenditure, GDP per capita and degree of trade openness. Data for 2023 has been collected on 74 countries for this purpose, with a view of analyzing the individual contributions of each of the four driving factors to high-tech export performance in a digital economy. The econometric specification has been provided below, while the operational definitions and measurements of each of the four driving factors can be found summarized in Table 3.

Econometric Model
$HTEi = \beta 0 + \beta 1 Interneti + \beta 2 RDi + \beta 3 GDPi + \beta 4 Tradei + \varepsilon i$
Where:

HTE = High-Technology Exports
Internet = Internet Penetration
RD = Research and Development Expenditure

GDP = GDP per Capita
Trade = Trade Openness
β_0 = Constant
β_1–β_4 = Regression coefficients
ε = Error term

The expected relationships between the explanatory variables and high-technology exports were formulated through the research hypotheses presented in the previous section, while the operational definitions of all variables are provided in Table 3.

Table 3. Definition of Variables Used in the Econometric Model

Variable	Type	Definition	Measurement	Source
High-Technology Exports (HTE)	Dependent	Technological export performance	High-technology exports (% of manufactured exports)	World Development Indicators (World Bank, 2024)
Internet Penetration	Independent	Level of digital connectivity	Individuals using the Internet (% of population)	World Development Indicators (World Bank, 2024)
R&D Expenditure (RD)	Independent	National innovation effort	Research and development expenditure (% of GDP)	World Development Indicators (World Bank, 2024)
GDP per Capita (GDP)	Independent	Level of economic development	GDP per capita (current US$)	World Development Indicators (World Bank, 2024)
Trade Openness (Trade)	Independent	Degree of international trade integration	Trade (% of GDP)	World Development Indicators (World Bank, 2024)

Source: Developed by the author based on the World Development Indicators (World Bank, 2024).

4 Results

4.1 Descriptive Statistics

The descriptive statistics of the study variables from the sample of 74 countries are presented in Table 4. These results describe the relative level of digitalization, innovation, economic development, trade openness, and technology competitiveness for the selected economies. The average level of Internet penetration was 84.40% of the total population; thus, there is a relatively high level of digital connectivity in the countries included in the study sample. However, the high standard deviation (17.08) indicates that there are significant differences across the countries in terms of access to digital information. The average amount spent on research and development (R&D) was 1.30% of GDP; however, the range of R&D spending was between 0.006% to 6.35%. This large range of values indicates that the countries involved in the study have very different national innovation systems and technological investment strategies (Nait Lachgar & Ouahi, 2023). In terms of the average GDP per capita, the average amount was USD 30,446.77 with a range of USD 873.48 to over 133,230, indicating that the countries in the study range from developing to very developed economies. On average, the trade openness ratio for the countries in the sample was 106.04% of GDP; therefore, most of the countries included in the sample are integrated into the global marketplace. However, the high standard deviation (64.96) illustrates that there are considerable differences in the trade exposure of each country to the international economy. Finally, the average share of high-technology exports reached 15.02% of manufactured exports, with values varying between 0% and 72.32%. This substantial dispersion indicates that technological competitiveness differs considerably across countries, with some economies exhibiting highly specialized technological export structures while others remain less technologically intensive.

Table 4. Descriptive Statistics of High-Technology Exports and Explanatory Variables

Series Name	count	mean	std	min	25%	50%	75%	max
HighTech	74	15,02285	13,34033	0	5,069218	12,09011	19,94266	72,31549
Internet	74	84,4028	17,08081	9,287	82,22349	89,10848	93,52266	100
RD	74	1,304775	1,285113	0,00609	0,254995	0,98492	1,837508	6,34589
GDP	74	30446,77	28010,56	873,4826	8190,233	22470,45	47982	133230,6
Trade	74	106,0447	64,95624	25,29033	65,25119	87,87693	134,5834	402,567

Source: Authors' elaboration based on World Development Indicators (World Bank, 2023). Descriptive statistics computed using Python in Anaconda Jupyter Notebook.

4.2 Correlation Analysis

Table 5 presents the Pearson Correlation coefficients that were interpreted following the recommendations of Schober et al. (2018) among the variables included in the study. The objective is to examine the strength and direction of the relationships between digitalization, innovation, economic development, trade openness, and technological export competitiveness.

Table 5. Pearson Correlation Matrix of High-Technology Exports and Explanatory Variables

Series Name	HighTech	Internet	RD	GDP	Trade
HighTech	1	0,3654	0,405647	0,419799	0,38988
Internet	0,36539953	1	0,369044	0,523098	0,288765
RD	0,405647154	0,369044	1	0,565574	-0,04497
GDP	0,419799034	0,523098	0,565574	1	0,439351
Trade	0,389879816	0,288765	-0,04497	0,439351	1

Source: Authors' elaboration based on the World Development Indicators (World Bank, 2023). Pearson correlation coefficients computed using Python (Anaconda Jupyter Notebook).

The data imply that all of the explanatory factors have a positive correlation with the HighTech variable. The relationship of HighTech to GDP/capita, which has a correlation coefficient (r) of 0.42, is the strongest; the second strongest relationship is HighTech to R&D expenditure (r = 0.41). There are

also positive correlations between HighTech and Trade Openness (r =0 .39) and between HighTech and Internet Penetration (r = 0.37). These statistics indicate that countries with stronger innovation capabilities, higher levels of economic development, and significantly greater degree of international integration exhibit a higher level of technological exports.

Additionally, the highest correlation between two explanatory variables occurs between GDP and R&D (r =0 .57) and the second highest between GDP and Internet Penetration (r = 0.52). Even though they are also positively correlated, their respective magnitudes are moderate. The heat map in Figure 2 confirms visually the same information represented in the correlation matrix in Table 5. The correlation heat map depicts positive relationships between the High technology exports and each explanatory variable; none of the correlation coefficients exceeded the commonly used threshold value of 0.80. This suggests that the explanatory variables exhibit only moderate correlations with each other and does not indicate significant concerns regarding multicollinearity (Schober et al. , 2018).

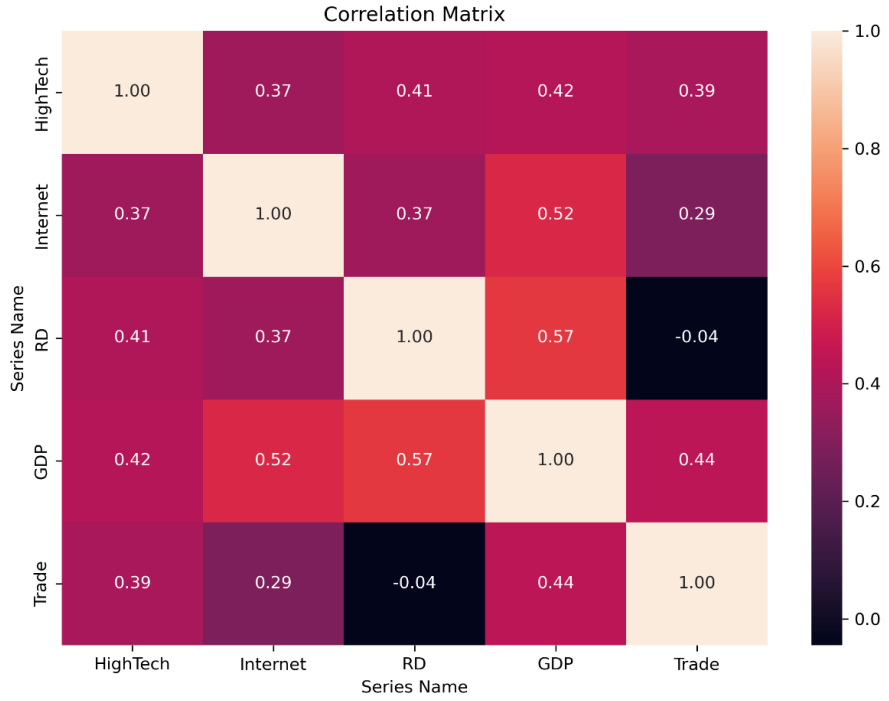


Figure 2. Heatmap of the Pearson Correlation Matrix

Source: Authors' elaboration based on the World Development Indicators (World Bank, 2023). Visualization generated using Python (Anaconda Jupyter Notebook).

4.3 Regression Results

To examine the determinants of digital trade competitiveness, an Ordinary Least Squares (OLS) regression model was estimated using high-technology exports as the dependent variable. Internet penetration, research and development expenditure (R&D), GDP per capita, and trade openness were introduced as explanatory variables. The regression coefficients, standard errors, t-statistics, and significance levels are presented in Table 6.

Table 6. Results of the Ordinary Least Squares (OLS) Regression Analysis

	Coefficient	Std_Error	T_statistic	P_value
const	-6,73837457	7,058916671	-0,954590468	0,343117261
Internet	0,100282646	0,090665869	1,106068335	0,27253847
RD	4,177892357	1,352280227	3,08951671	0,002889042
GDP	-2,23971E-05	7,12656E-05	-0,314275633	0,754259985
Trade	0,080417041	0,024500563	3,282252734	0,001617974

Source: Authors' calculations based on the World Development Indicators (World Bank, 2024). Regression analysis performed using Python (Anaconda Jupyter Notebook).

Diagnostic Tests of the OLS Assumptions

Table 7. Breusch–Pagan Test for Heteroskedasticity

Test	LM Statistic	LM p-value	F Statistic	F p-value
Breusch-Pagan	33,76299128	8,33419E-07	14,47452528	1,24414066117E-08

Source: Authors' calculations based on the World Development Indicators (World Bank, 2024). Breusch–Pagan heteroskedasticity test performed using Python (Anaconda Jupyter Notebook).

The Breusch-Pagan test indicates whether constant error variance was an appropriate assumption. The LM test statistic was 33.763 and the p-value was small ($p < 0.001$) indicating there are significant differences in variance terms. Similarly, the F-statistic indicates there are significant differences with a value of 14.475 ($p < 0.001$). Therefore, both the LM and F-statistics provide evidence against the null hypothesis of no differences between error terms,

and indicate that there are heteroskedastic error terms in the regression residuals.

Table 8. White Test for Heteroskedasticity

Test	LM Statistic	LM p-value	F Statistic	F p-value
White	49,85665485	6,453172540199210E-06	8,702612954	8,2031902893551E-10

Source: Authors' calculations based on the World Development Indicators (World Bank, 2024). White heteroskedasticity test performed using Python (Anaconda Jupyter Notebook).

To detect heteroskedasticity, the White test was performed as a supplementary diagnostic measure. This test identifies heteroskedasticity without requiring any particular specification for the form of variance of the residuals. The results indicate a statistically significant LM statistic (49.857, $p < 0.001$) and F-statistic (8.703, $p < 0.001$), thereby confirming the presence of heteroskedasticity. The agreement between Breusch-Pagan and White tests provides strong support to ascertain that the variance of the residuals is not constant. As such, HC3 heteroskedasticity-consistent robust standard errors will be used for subsequent analyses (MacKinnon & White, 1985).

Table 9. OLS Regression Results Using HC3 Robust Standard Errors

Variable	Coefficient	Robust Std. Error	Robust t-statistic	Robust p-value
const	-6,73837457	4,886354067	-1,379018892	0,172342842
Internet	0,100282646	0,082973472	1,208610939	0,230937963
RD	4,177892357	1,631122109	2,561360878	0,012615594
GDP	-2,23971E-05	0,000142098	-0,157616607	0,875219259
Trade	0,080417041	0,064599518	1,244855108	0,217396498

Source: Authors' calculations based on the World Development Indicators (World Bank, 2024). HC3 robust OLS regression estimated using Python (Anaconda Jupyter Notebook).

Due to the presence of heteroskedasticity, a second estimation of the regression model was performed using HC3 heteroskedasticity-consistent standard errors. The results of this analysis found that an increase in R&D expenditure ($\beta = 4.178$, $p = 0.013$) continues to be positively correlated with an increase in high-technology exports and was statistically significant under the HC3 specification. In contrast, the variables for internet penetration, GDP per capita, and Trade Openness had no statistically significant influence on high-technology exports in the HC3 setting (MacKinnon & White, 1985). The only variable that was determined to be robust to heteroskedasticity in these estimates was R&D expenditure (Lu & White, 2014).

Table 10. Normality Tests of Regression Residuals

Test	Statistic	p-value
Jarque-Bera	26,54136	1,724315410156520E-06
Shapiro-Wilk	0,913333	8,81074211094048E-05

Source: Authors' calculations based on the World Development Indicators (World Bank, 2024). Residual normality tests performed using Python (Anaconda Jupyter Notebook).

The assessment of residuals for their normality was performed using the Jarque-Bera (JB) test and the Shapiro-Wilk (SW) test. The null hypothesis of normality based upon the residuals was rejected at the $p < 0.001$ level of significance for both tests. Although the residuals demonstrate non-normality, the OLS estimator will still be unbiased under the Gauss-Markov assumption. Furthermore, to make inferences, the HC3 (covariance estimator) type of residuals were used. This type of residual has a lower degree of sensitivity to violation of the underlying conditions of normality or homoskedasticity for small samples than the standard covariance type estimator (MacKinnon & White, 1985).

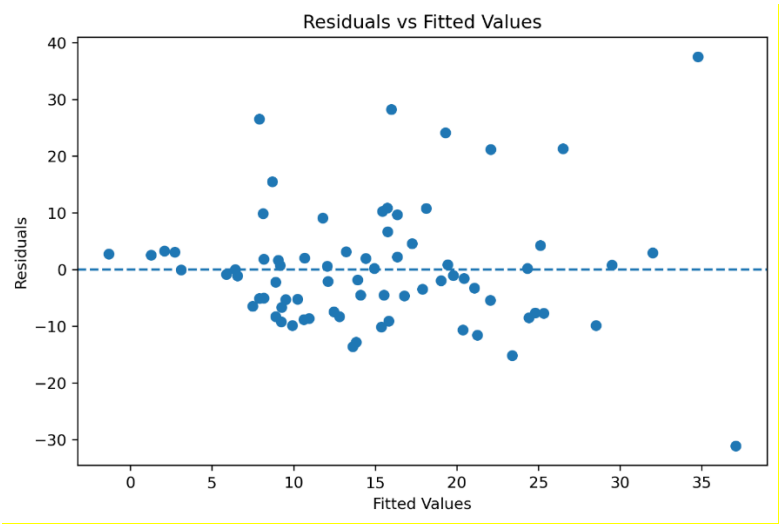


Figure 3. Residuals versus Fitted Values

Source: Authors' calculations based on the World Development Indicators (World Bank, 2024). Residual diagnostic plot generated using Python (Anaconda Jupyter Notebook).

Figure 3 suggests no obvious nonlinear pattern between fitted values and residuals, supporting the adequacy of the linear specification despite a moderate dispersion of residuals.

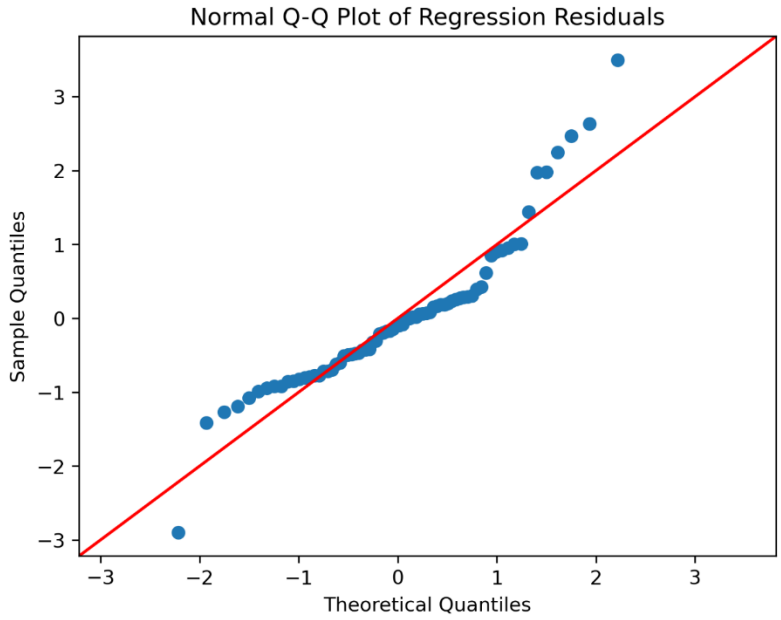


Figure 4. Normal Q–Q Plot of Regression Residuals

Source: Authors' calculations based on the World Development Indicators (World Bank, 2024). Normal Q–Q plot generated using Python (Anaconda Jupyter Notebook).

The normal Q-Q plot of the regression residuals can be seen in Figure 4. The majority of the observations follow closely along the theoretical reference line in the centre of the distribution, with substantial deviations in both tails. These deviations further support the conclusion that the distribution is not normally distributed, and particularly so at either end of the distribution's tails. The graphical evidence is consistent with the results of the Jarque-Bera and Shapiro-Wilk test results, indicating the absence of normal distribution of the regression residuals.

Model Diagnostics and Goodness-of-Fit

The explanatory power of the regression is adequate. The R-squared (R^2=0.343) shows that approximately 34.3% of the variance in high technology exports can be explained by the independent variables, while an Adjusted R^2=0.305 indicates that the model still has a reasonable level of explanation after controlling for the number of parameters. In general, the regression has significant overall significance (F=9.010, p 0.001) and demonstrates that together they explain a substantial amount of variation in technological export performance. To evaluate possible multicollinearity, Variance Inflation Factors (VIF) were estimated (see Table 11). The VIF values for all independent variables were much less than the conventional cut-off value of 5, ranging from 1.42 to 2.35. This finding suggests that multicollinearity is of minimal concern and that the regression coefficients are interpretable and sufficiently robust (Lu & White, 2014).

Table 11. Multicollinearity Diagnostics Using Variance Inflation Factors (VIF)

Variable	VIF
const	29,81265
Internet	1,415534
RD	1,782508
GDP	2,351904
Trade	1,494891

Hypothesis Testing

Based on the HC3 heteroskedasticity-consistent regression estimates, the proposed hypotheses were evaluated according to the statistical significance and direction of the estimated coefficients. H1: Internet penetration does not exert a statistically significant effect on high-technology exports (β = 0.100, p = 0.231). Therefore, H1 is rejected.

H2: R&D expenditure has a positive and statistically significant effect on high-technology exports (β = 4.178, p = 0.013). Therefore, H2 is supported.

H3: GDP per capita does not exert a statistically significant effect on high-technology exports (β = −0.00002, p = 0.875). Therefore, H3 is rejected.

H4: Although Trade Openness exhibits a positive coefficient (β = 0.080), the effect is not statistically significant under the HC3 robust specification (p = 0.217). Therefore, H4 is rejected.

Overall, the HC3 regression results indicate that R&D expenditure is the only explanatory variable that remains statistically significant after correcting for heteroskedasticity. Consequently, only H2 is supported, whereas H1, H3, and H4 are rejected.

Robustness Analysis

To look at how well the baseline OLS estimates can withstand changes in modelling assumptions, an alternative log-log regression model will also be estimated by transforming the dependent variable and the explanatory variables to their natural logarithms. Both logarithmic functional specifications are commonly used for several reasons: they help lessen the effect of extreme values; they lead to more robust estimates because they stabilize variance; and they allow the relationship among variables to be viewed in a manner that is more consistent with the elasticities of the respective variables than by using non-logarithmic specification alone (Razali & Wah, 2011). By comparing results from the baseline OLS model and the log-log model, one may confirm whether the conclusions drawn from the OLS model are robust under an alternative functional specification (Wooldridge, 2021; Lu & White, 2014).

Table 12. Log–Log Robustness Regression Results

Variable	Coefficient	Robust Std. Error	Robust t-statistic	Robust p-value
const	-1,94593083	2,069886797	-0,940114615	0,350486416
log_Internet	0,057625429	0,762242974	0,075599817	0,93995946
log_RD	0,314374266	0,226766097	1,386337152	0,17017289
log_GDP	0,328333574	0,353443226	0,928957044	0,356197284
log_Trade	0,174507402	0,317619621	0,549422612	0,584515353

Source: Authors' calculations based on the World Development Indicators (World Bank, 2024). Log–log robustness regression estimated using Python (Anaconda Jupyter Notebook).

Results of the log-log robustness regression are shown in Table 12. The estimated coefficients experienced a small change in magnitude due to the transformation of the data; however, the conclusions drawn from this type of analysis (Razali & Wah, 2011), which align with those obtained from the baseline OLS analysis, do not differ significantly in magnitude or direction. Specifically, the three independent variables used in this analysis: internet penetration, GDP per capita, and trade openness, were found to be insignificant; however, the relationship between research and development expenditure and high-technology exports was still positive and significant, but the statistical significance of the coefficient decreased when the model was estimated using the log-log functional form. The results of this regression suggest that the primary conclusion of this research was not altered by changing the form of analysis therefore, the robustness analysis further supports that the baseline regression results are valid, thereby confirming that innovation is still the most important factor in determining the international competitiveness of technologically-exported products.

4.4 Cluster Analysis

To complement the regression analysis, a K-Means cluster analysis was performed to classify countries according to their levels of digitalization, innovation, economic development, trade openness, and technological competitiveness. Cluster analysis makes it possible to identify relatively homogeneous groups of countries that share similar structural characteristics. The optimal number of clusters was determined using the Elbow Method and confirmed through the Silhouette Score, ensuring an appropriate balance between within-cluster homogeneity and between-cluster separation (Hair et al., 2019).

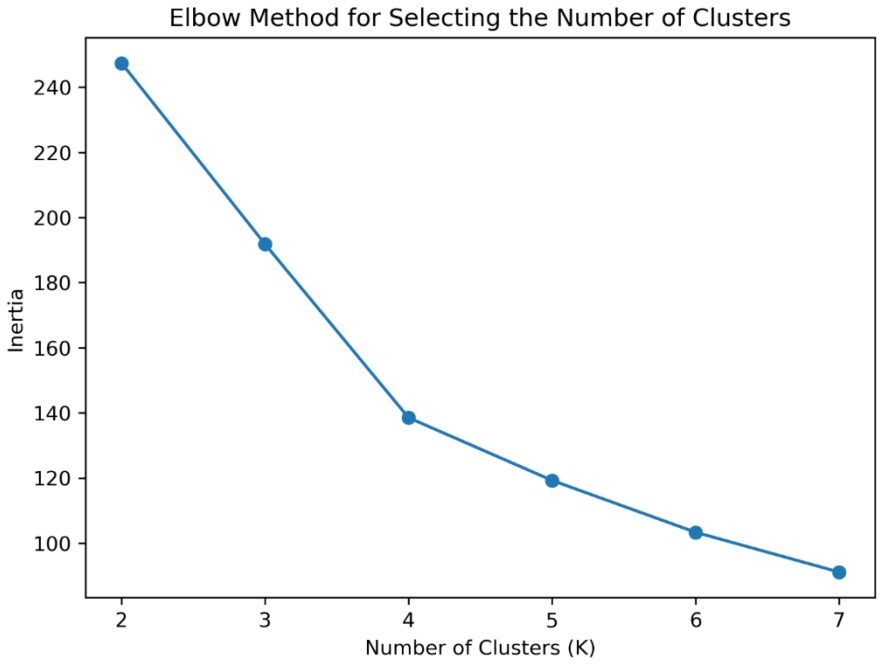


Figure 5. Elbow Method for Selecting the Optimal Number of Clusters

Authors' calculations based on the World Development Indicators (World Bank, 2024). Elbow Method generated using Python (Anaconda Jupyter Notebook).

Figure 5 presents the Elbow Method used to determine the optimal number of clusters. The curve exhibits a pronounced reduction in inertia between two and four clusters, after which the rate of improvement decreases substantially. The inflection point is observed at K = 3, indicating that a three-cluster solution provides the best compromise between model simplicity and explanatory power. Consequently, three clusters were retained for the subsequent K-Means analysis.

The three-cluster solution was further supported by the Silhouette Score, confirming satisfactory cohesion within clusters and adequate separation between clusters. Consequently, the K = 3 solution was retained for the empirical analysis.

Table 13. Characteristics of the K-Means Clusters

Cluster	Internet	RD	GDP	Trade	HighTech
0	94.54	2.79	64,722.85	132.53	26.71
1	38.73	0.24	2,414.63	66.66	3.69
2	86.72	0.79	19,064.75	99.95	11.41

Source: Authors' calculations based on the World Development Indicators (World Bank, 2023). K-Means cluster analysis performed using Python (Anaconda Jupyter Notebook).

The three clusters represent the various stages of technological advancement of various countries.

Cluster 0, Digital & Innovations Leaders 42 out of 194 countries are in this cluster, have the highest internet penetration average of 94.54%, R&D expenditure of 2.79% of GDP, GDP per capita of $64,722.85, and high technology exports at 26.71%. The countries that comprise this cluster include Germany, the US, South Korea, Switzerland, Sweden, Ireland, Israel, Hong Kong, and the UK. These countries possess both robust innovation ecosystems as well as deep interconnectedness to global technology and knowledge networks (Nait Lachgar & Ouahi, 2023).

Cluster 1, Digital Laggards about 38 out of 194 countries in this cluster, collectively have low connectivity rates, low levels of investment in innovation, and low levels of technological competitiveness. They have an average internet penetration rate of only 38.73%, R&D expenditure of 0.24% of GDP, and high technology exports at only 3.69%. The countries that comprise this cluster include Burkina Faso, Uganda, Mali, Kenya, and Lesotho and suffer from major structural constraints in digital infrastructure and innovation capacity.

Cluster 2, Emerging Digital Economies-130, or almost 69 out of 194 countries that have become part of this cluster, lie in between these two groups. Countries in this cluster exhibit both relatively high internet penetration rates (86.72%) and trade openness (99.95%) while having much lower levels of R&D expenditure (0.79%) and high technology export (11.41%) than do countries in Cluster 0. Countries in this group such as China, Brazil, Mexico, Türkiye, Poland, Portugal, Thailand, and Vietnam serve as examples of emerging digital economies that have achieved considerable advancement within their respective digital economies, yet are in the process of building their respective levels of innovation capabilities.

Overall, the cluster analysis reveals substantial heterogeneity in technological development across countries. The results reinforce the regression findings by showing that economies combining high R&D investment with strong international trade integration consistently achieve superior high-technology export performance.

4.5 PCA Results

To further explore the multidimensional structure of the dataset and visualize similarities and differences among countries, a Principal Component Analysis (PCA) was conducted using the five variables included in the study: Internet penetration, research and development expenditure (R&D), GDP per capita, trade openness, and high-technology exports. PCA is particularly useful for reducing data dimensionality while preserving the maximum amount of information contained in the original variables (Jolliffe & Cadima, 2016).

The graphical representation of the PCA results is presented in Figure 6. The first two principal components (PC1 and PC2) summarize the main sources of variation observed across the countries included in the sample.

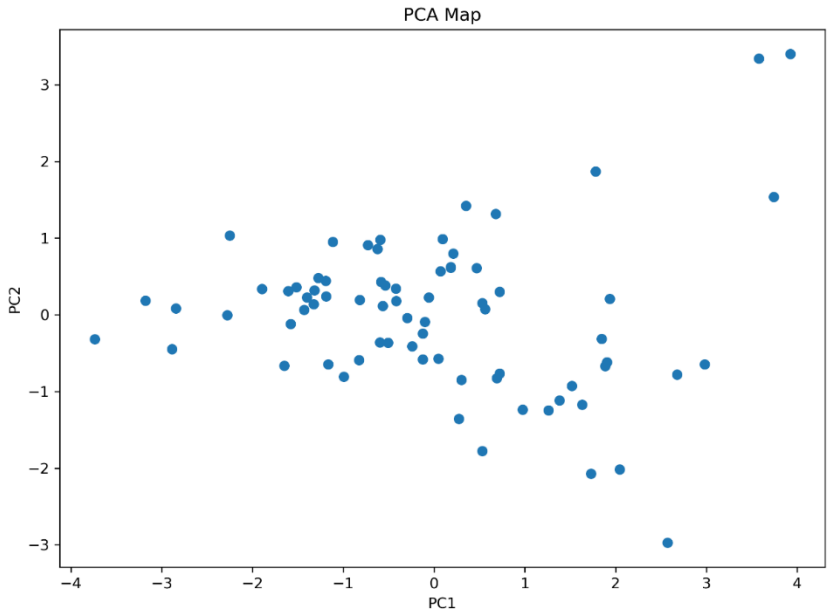


Figure 6. Principal Component Analysis (PCA) Map of the Study Countries

Source: Authors' calculations based on the World Development Indicators (World Bank, 2024). Principal Component Analysis (PCA) performed using Python (Anaconda Jupyter Notebook).

4.6 Discussion

It follows from the data analysis that investments in research and development (R&D) are the most significant determinant of successful exports of high technology products. The statistical significance and positive coefficients coefficient of R&D expense demonstrate that the continuing investments made toward innovation remain one of the most important factors contributing to a country's technological competiveness relative to other countries (Nait Lachgar & Ouahi, 2023). These empirical results are consistent with Endogenous Growth Theory as outlined by Romer (1990) which states that long-term competitiveness is largely determined by the continued expenditure of money on knowledge, creating new knowledge, and developing improved technology. Furthermore, these results support the empirical findings of Ersin et al. (2022) and Navarro Zapata et al. (2024) who, independently of each other, found that R&D was one of the most important factors determining high technology exports. In addition to being an important factor for improving innovativeness, investments in R&D have also been found to increase firms' ability to absorb new technologies, hasten the upgrade of existing technologies, and support the introduction of new advanced products to the marketplace Magazzino et al. (2025). While Trade Openness has a positive coefficient, the statistical significance of this relationship is not present when the model is adjusted for heteroskedasticity using HC3 robust standard errors. Therefore, the results indicate that the degree of trade liberalisation and high technology exports has a varying level of significance depending on which econometric model was used to estimate the effects of trade on high technology. International trade and Trade Openness as a way of transferring technology, facilitating the spread of knowledge, and participating in global value chains do not show a strong direct relationship with the sample's technological export performance. Therefore, Trade Openness should be viewed with caution and is likely to be influenced by other institutional or innovation-related conditions not included in this analysis. At the same time, the fact that there is no statistically significant correlation between the level of internet penetration and the amount of high-technology exports raises questions about whether digital connectivity necessarily leads to position in the international market. Digital infrastructure will enable high-tech, but it is not adequate to drive this. Without further investments in research, investing in human capital, and industrial innovation, even if a country has high levels of connectivity, it will not generate high-value technology-intensive exporting. Manzetti and Osang (2024) and Loučanáová et al. (2025) note that the returns from digitalization depend upon a network of complementary, innovation-related, and institutional factors. Likewise, the lack of significance regarding GDP per capita as an indicator of technological leadership suggests that economic wealth alone is not sufficient to provide a competitive position. Economic development will indirectly influence competitiveness by providing the financial resources for innovation and/or supporting productive specialization rather than directly influencing competitiveness. The findings are shown in two different ways: the various profiles of developing nations found in the cluster and PCA analysis, indicating that Digital and Innovation Leaders show high levels of R&D expenditure coupled with high levels of trade; Emerging Digital Economies in moderate income countries show how targeted innovation strategies can improve the countries' competitiveness; and Digital Laggards illustrate the lack of connectivity and the low level of investment in innovative activities. This demonstrates that no one factor is responsible for the success of high technology exporters as all three profiles show how the interplay between many factors is necessary for establishing high export levels (Jolliffe & Cadima, 2016). The evidence also suggests that R&D investment is the most significant factor that positively influences high technology export levels. In contrast, none of these three variables (Internet Penetration, GDP per Capita, or Trading Openness) is found to have a statistically significant impact on high technology export levels when examining the HC3 results. Therefore, the conclusion is that, to improve technological competitiveness in the Digital Economy, the most effective method is to invest in and strengthen national systems for innovation.

5 Conclusion, Contributions and Limitations

5.1 Theoretical Contributions

This research adds to the development of knowledge concerning international trade competitiveness, innovation, and digital transformation through the development of a new model of the key determinants of high-tech export success (Rafik & Sbiti, 2024). The current study differs from previous ones in that it combines previously examined variables, such as innovation, digitalization, and trade openness, to analyze their impact on the high-tech export success of countries. More specifically, the current study analyzed all four variables—trade openness, internet penetration, R&D, and GDP—together in a single empirical model. The findings of the current study provide new insights into high-tech export competitiveness as a result of its finding that R&D capacity, as measured by R&D expenditure, is the key determinant in determining a country's high-tech export competitiveness. In addition, the robustness of the relationship between R&D expenditure and high-tech export competitiveness provides new evidence against the previous assumption that merely constructing enough digital infrastructure will lead to greater technological competitiveness. Therefore, this article emphasizes the importance of developing an ecosystem that transforms digital capabilities into a sustainable competitive advantage through innovation. Although Trade Openness (top countries contribute positively towards its overall R&D contribution), Trade Openness effects lose their significance when adjusted for heteroskedasticity, demonstrating their country-specific nature and suggests that care should be exercised in interpreting the results of Trade Openness using different econometric specifications. Methodologically, the current study's use of a combination of OLS regression analyses, cluster analysis, and PCA provides multiple perspectives on the high-tech export competitive advantage of countries. The identification of three distinct country profiles further demonstrates that technological development follows heterogeneous trajectories shaped by differences in innovation intensity, economic integration, and productive capabilities (Abdi & Williams, 2010).

5.2 Practical Implications

This study has important implications for managers and policymakers who want to enhance a country's technology competitiveness. For businesses seeking to establish a technological base that enables them to compete on an international scale, this study concludes that companies must invest in providing their companies with: an increased R&D investment level; continuous technological advancement in the industry; and to continuously upgrade their existing capabilities and ability to innovate. Evidence indicates that global technology transfer and learning can be enhanced through increasing a company's engagement in international markets; however, the majority of evidence supports the idea that governments should first invest in strengthening their national innovation system and allowing for continuous R&D investment in order to create policies that support companies competing globally. For government policymakers, evidence from the study indicates that developing a country's digital infrastructure infrastructure is not likely going to create sustainable technology competitiveness at the same time; therefore, in order for a nation's governments to achieve and provide sustainable technology competitiveness, the following items must become the primary focus of government policy and investment: (a) to focus on incentivizing and supporting R&D and innovation; (b) to create alliances with industry and universities; and (c) to develop an innovation ecosystem to support the development of high-value exports as a result of using technology to create competitive advantage. By using these strategies, nations will improve their ability to produce and deliver technology-enabled, high-value-added exports.

5.3 Research Limitations and Future Research

While this study provides useful insights, it also has a number of limitations. First, since this analysis relies on a single year's cross-sectional data, it does not allow us to look at changing trends over time. Future studies should use longitudinal or panel datasets to better understand how digitalization, innovation, and technological competitiveness have developed over an extended period of time. Second, the study's analysis is limited to a narrow selection of macroeconomic indicators. Future studies could look at other factors relating to institutional quality, human capital, digital governance, the adoption of artificial intelligence, and technological readiness, to give a fuller picture of what accounts for high-technology export performance. Finally, high-technology exports have been used as the primary variable for measuring technological competitiveness. While high-technology exports are commonly used as a measure in the literature, they do not account for all aspects of the digital services sector or platform-based businesses. It would be beneficial for future research to look at macroeconomic and firm-specific evidence to gain a deeper understanding of how developing technologies are impacting international competitiveness in the digital economy.

5.4 Conclusion

This study examined the determinants of high-technology export performance in the digital economy by analyzing the effects of Internet penetration, research and development (R&D) expenditure, GDP per capita, and Trade Openness using cross-country data from 74 countries. Employing Ordinary Least Squares (OLS) regression, HC3 heteroskedasticity-consistent estimation, Cluster Analysis, and Principal Component Analysis (PCA), the study provided a comprehensive assessment of the factors influencing technological export competitiveness. The findings indicate that R&D expenditure is the only variable that remains statistically significant after correcting for heteroskedasticity using HC3 robust standard errors, highlighting innovation investment as the most robust determinant of high-technology export performance. In contrast, Internet penetration, GDP per capita, and Trade Openness do not exhibit statistically significant direct effects under the robust specification. These results suggest that digital infrastructure alone is insufficient to enhance technological competitiveness and should be complemented by sustained investment in innovation and knowledge creation. The Cluster Analysis and PCA further reveal substantial heterogeneity across countries, identifying three distinct development profiles characterized by different levels of innovation intensity, productive capabilities, and technological development. These findings demonstrate that countries follow diverse pathways toward technological competitiveness rather than a single development trajectory. This study contributes to the literature by integrating digital connectivity, innovation, economic development, and Trade Openness within a unified empirical framework while highlighting the importance of robust econometric inference, as empirical relationships may vary depending on the estimation method employed. From a policy perspective, the findings emphasize that strengthening national innovation systems, increasing R&D investment, and fostering collaboration among governments, universities, research institutions, and industry should constitute the primary priorities for improving technological competitiveness. Future research should extend this analysis using longitudinal or panel data, broader measures of innovation and digital transformation, and firm-level evidence to further validate these relationships under alternative econometric specifications.

References

Abdi, H., & Williams, L. J. (2010). Principal component analysis. WIREs Computational Statistics, 2(4), 433–459. Portico. https://doi.org/10.1002/wics.101

Aghion, P., & Howitt, P. (1992). A Model of Growth Through Creative Destruction. Econometrica, 60(2), 323–351. https://doi.org/10.2307/2951599

Breusch, T. S., & Pagan, A. R. (1979). A Simple Test for Heteroscedasticity and Random Coefficient Variation. Econometrica, 47(5), 1287–1294. https://doi.org/10.2307/1911963

Castellacci, Fulvio & Natera, Jose Miguel, 2016. "Innovation, absorptive capacity and growth heterogeneity: Development paths in Latin America 1970–2010," Structural Change and Economic Dynamics, Elsevier, vol. 37(C), pages 27-42.

CHAYMAE DOUHID, MOHAMMED CHEMLAL, YOUNES ABID (2025). THE IMPACT OF DIGITALIZATION ON CORPORATE GOVERNANCE: THE CASE OF MOROCCAN COMPANIES. REMAREM, vol. 17, n° 2, p. 561-579. https://doi.org/https://doi.org/10.48376/IMIST.PRSM/remarem-v17i2.58448

Coe, D. T., & Helpman, E. (1995). International R&D Spillovers. European Economic Review, 39, 859-887.

Eaton, J. and Kortum, S. (1999), International Technology Diffusion: Theory and Measurement. International Economic Review, 40: 537-570. https://doi.org/10.1111/1468-2354.00028

Ersin, Özgür & Ustabaş, Ayfer & Acar Kara, Tuğçe. (2022). THE NONLINEAR EFFECTS OF HIGH TECHNOLOGY EXPORTS, R&D AND PATENTS ON ECONOMIC GROWTH: A PANEL THRESHOLD APPROACH TO 35 OECD COUNTRIES. Romanian Journal of Economic Forecasting. 25. 26-44.

Fagerberg, Jan. (1988). International Competitiveness. Economic Journal. 98. 355-74. 10.2307/2233372.

Gulzar, Y., Oral, C., Kayakus, M., Erdogan, D., Unal, Z., Eksili, N., & Caylak, P. C. (2024). Predicting High Technology Exports of Countries for Sustainable Economic Growth by Using Machine Learning Techniques: The Case of Turkey. Sustainability, 16(13), 5601. https://doi.org/10.3390/su16135601

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019). Multivariate Data Analysis (8th ed.). Cengage Learning.

IMANE RAFIK, MORAD SBITI (2024). THE IMPACT OF DIGITAL TRANSFORMATION ON SUSTAINABLE SUPPLY CHAIN PERFORMANCE: A CONCEPTUAL FRAMEWORK INTEGRATING INFORMATION SHARING. REMAREM, vol. 16, n° 2, p. 85-108. https://doi.org/https://doi.org/10.48376/IMIST.PRSM/remarem-v16i2.55807

Jolliffe, I.T., & Cadima, J. (2016). Principal component analysis: a review and recent developments. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 374.

Loučanová, Erika & Olšiaková, Miriam & Paluš, Hubert. (2025). Trade Openness and Innovation Performance in the EU: An Analysis of Cluster Dynamics. Economies. 14. 4. 10.3390/economies14010004.

Lundvall, B.-Å. (Ed.). (2010). National Systems of Innovation: Toward a Theory of Innovation and Interactive Learning. Anthem Press. http://www.jstor.org/stable/j.ctt1gxp7cs

MacKinnon, J. G., & White, H. (1985). Some heteroskedasticity-consistent covariance matrix estimators with improved finite sample properties. Journal of Econometric 29(3), 305–325.

Magazzino, C., Laureti, L., Costantiello, A., Leogrande, A., & Gattone, T. (2025). Innovating trade: How high-tech exports, ICT services and R&D expenditure shape global trade patterns with advanced machine learning insights. Journal of Economic Studies, 52(9), 193–214. https://doi.org/10.1108/JES-03-2025-0174

Manzetti, Luigi & Osang, Thomas. (2024). High-Tech Exports and Governance Institutions. PS: Political Science & Politics. 57. 1-10. 10.1017/S1049096524000052.

Mirzaye, S., & Mohiuddin, M. (2025). Digital Transformation in International Trade: Opportunities, Challenges, and Policy Implications. Journal of Risk and Financial Management, 18(8), 421. https://doi.org/10.3390/jrfm18080421

Myovella, Godwin & Karaçuka, Mehmet & Haucap, Justus. (2019). Digitalization and economic growth: A comparative analysis of Sub-Saharan Africa and OECD economies. Telecommunications Policy. 44. 101856. 10.1016/j.telpol.2019.101856.

Nelson, R. R., & Winter, S. G. (1982). An Evolutionary Theory of Economic Change. Harvard University Press.

Organisation for Economic Co-operation and Development (OECD). (2023). OECD Science, Technology and Innovation Outlook 2023. Paris: OECD Publishing.

Peter C. Verhoef, Thijs Broekhuizen, Yakov Bart, Abhi Bhattacharya, John Qi Dong, Nicolai Fabian, Michael Haenlein, Digital transformation: A multidisciplinary reflection and research agenda, Journal of Business Research, Volume 122, 2021, Pages 889-901, ISSN 0148-2963, https://doi.org/10.1016/j.jbusres.2019.09.022.

Razali, N. M., & Wah, Y. B. (2011). Power comparisons of Shapiro–Wilk, Kolmogorov–Smirnov, Lilliefors and Anderson–Darling tests. Journal of Statistical Modeling and Analytics, 2(1), 21–33.

Rogers, E. M. (2003). Diffusion of Innovations (5th ed.). New York: Free Press.

Romer, P., 1990. Endogenous technological change. Journal of Political Economy, 98(5), Part 2: S71-S102.

Sascha Kraus & Paul Jones & Norbert Kailer & Alexandra Weinmann & Nuria Chaparro-Banegas & Norat Roig-Tierno, 2021. "Digital Transformation: An Overview of the Current State of the Art of Research," SAGE Open, , vol. 11(3), pages 21582440211, September.

Schober, P., Boer, C., & Schwarte, L.A. (2018). Correlation Coefficients: Appropriate Use and Interpretation. Anesthesia & Analgesia, 126, 1763–1768.

Schumpeter, J. A. (1934). The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle. Harvard University Press.

TAIB NAIT LACHGAR, LHOUCINE OUAHI (2023). PERFORMANCE OF INNOVATION CLUSTERS IN THE MORROCAN CONTEXT: CASE OF MENARA CLUSTER. REMAREM, vol. 15, n° 2, p. 1-23. https://doi.org/https://doi.org/10.48376/IMIST.PRSM/remarem-v15i2.45632

White, H. (1980). A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity. Econometrica, 48(4), 817–838. https://doi.org/10.2307/1912934

Wooldridge, J. M. (2021). Introductory Econometrics: A Modern Approach (7th ed.). Cengage Learning.

World Bank. (2024). World Development Indicators: High-technology exports (% of manufactured exports). Washington, DC: World Bank.

Xun Lu, Halbert White, Robustness checks and robustness tests in applied economics, Journal of Econometrics, Volume 178, Part 1, 2014, Pages 194-206, ISSN 0304-4076, https://doi.org/10.1016/j.jeconom.2013.08.016.

Zapata, Amadeo & Arrazola, Maria & de Hevia, Jose. (2023). Determinants of High-tech Exports: New Evidence from OECD Countries. Journal of the Knowledge Economy. 15. 10.1007/s13132-023-01116-z.