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Modelling the Interconnection Between Technological Leadership and the Level of Use of Information and Communication Technologies

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Abstract: *This article presents an empirical analysis of the link between technological leadership and the use of information and communication technologies. This paper aims to formalize the factors that determine the country's potential for technological leadership. The methodological toolkit for analyzing the link between the development of information and communication technologies and the technological leadership of the country is the methods of panel regression analysis: the fixed effects model, the random effects model, the Hausman test for correlated random effects, the combined regression model with dummy variables, the Wald test and the model fixed effects with dummy variables. The information base of the research is World Bank data, data files of national accounts of the Organization for Economic Cooperation and Development, and Eurostat data. The object of the study is the data of ten countries of the world (Brazil, India, China, South Africa, South Korea and Turkey, France, Germany, Italy and Spain), the period of the study is 2008-2016 years. The indicator of innovative development of the country, which is evaluated by the number of issued patents, was used as a dependent variable. The influence of factor indicators is considered in terms of four components: entrepreneurship (the number of new enterprises founded in the country during the fiscal year), export of high-tech goods (the share of the export of high-tech goods in the total export of goods according to 2007 data), GDP per capita (in US dollars for according to 2010 data), startups (number of registered startups). According to the results of building a model with fixed effects, a positive relationship between the technological leadership of the country and the development of information and communication technologies has been proven. In addition, the results of empirical calculations prove that the share of export of high-tech goods in the total export of countries is insignificant during the analyzed period. The study proves the essential role of information and communication technologies in technological progress and empirically confirms the potential difference in profits between manufacturers and exporters of technological products.*
Keywords: technologies, technological leadership, export, innovative development, startup.
JEL Classification: E22, L26, O47.

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Introduction

Sustainable economic growth is closely related to increased productivity, competitive edge and potential conditions of existence, especially in highly competitive fields. Within this framework, innovation and technological efficiency are key functions. They are indispensable components for fostering sustainable economic growth, as they contribute to increased productivity, competitive advantage, and the viability of businesses operating in fiercely competitive industries. With the continuous development of technology, these elements have assumed a paramount role in both business growth and the overall economic advancement of nations. Following a phase of economic fragility, several emerging economies have successfully challenged developed nations by capitalizing on the transformative power of technological leadership, which has become a strategic driver of competitiveness and rapid acceleration (Archibugi & Coco, 2004). Technological competency serves as a prudent investment in technological infrastructure, enabling firms to maintain their competitive edge in the market and stay abreast of the latest advancements.

While initially conceived as a measure of distinct technological performance, the innovation index has recently been adopted to assess a nation's overall growth and economic development. Furthermore, innovation activities present a strategic dimension that can be leveraged to cultivate diverse strategic positions, ultimately fostering competitiveness. However, this pursuit necessitates a unique set of knowledge and skills. Moreover, the ability to effectively utilize and adapt existing technologies, achieving cost and quality competitiveness, remains of greater significance than merely focusing on innovation alone, such as developing novel products and processes.

Kleinknecht et al. (2002) identified key factors used to compute the innovation index, encompassing patents, scientific publications, R&D intensity, R&D expenditures, the number of organizations, and the count of researchers and technicians. Another crucial element is information and communication technology (ICT), which provides the framework and elements necessary for current computing technologies such as enterprise resource planning, ERP, EDI, or electronic data interchange. The importance of information and communication technology lies in its ability to drive progress, innovation and societal development. Its transformative impact on communications, economics, and governance has reshaped how we interact with the world and has become an essential tool for achieving individual and collective goals (Xiong et al., 2022).

Sustainable spending on innovation and infrastructure represents a significant engine of economic expansion, advancement, and industry expansion. Improvements in technology make it possible to provide long-term answers for economic and environmental concerns, particularly employment development and energy conservation. Supporting a sustainable industry and promoting technical advancements and innovation are two significant methods to assist sustainable growth. In conclusion, technological advances play a pivotal role in enhancing the capability of economic agents to effectively apply technological knowledge by assimilating, adapting, and transforming current technologies. It refers to domestic efforts aimed at adapting foreign technology to significant applications. The main purpose of this research is to quantitatively evaluate the factors that influence a country's technological leadership in some economies. The study aims to collect data from ten world countries: Brazil, India, China, South Africa, South Korea and Turkey, France, Germany, Italy and Spain. A panel regression approach will be applied, focusing on the period from 2008 to 2016, corresponding to pertinent data availability.

The structure of this paper is organized as follows: a concise introduction section sets the context and rationale for the research. Subsequently, the literature review section is crafted to provide a comprehensive overview of the interrelationships between technological leadership, innovation, and variables about information and communication technology (ICT). Section three outlines the methodology adopted for this study, delineating the specific procedures and techniques employed for data analysis. Section four presents the empirical findings derived from applying Hausman and Wald tests across the three models examined. These findings contribute to the understanding of the factors influencing technological leadership in each of the mentioned economies. Finally, the article concludes in the last section, summarizing the key findings, discussing their implications, and suggesting avenues for further research.

Literature Review

This section will review previous research on innovation, technological leadership, and ICT measurement. Economic development and prosperity have always heavily relied on technological advancement. One of its key characteristics is that it is not distributed equally among nations, and numerous articles have examined both theoretically and empirically the factors that influence technical leadership. Increased productivity in regional economic businesses will be accelerated and encouraged by development policies that are focused on regional economic growth supported by technology. Economic growth is influenced by community economic development through entrepreneurship training, and initiatives to increase community productivity will necessitate technical innovation (Surya et al., 2021).

The era of globalization with technological progress already entails a claim to support global and national economic growth. At the same time, globalization is considered a process dependent on capital and investment driven by market integration and competition that requires deregulation (Sawaya & Bhero, 2018). In recent years, ICT technology in emerging countries has also advanced quickly, significantly impacting their economic progress. Given this situation, it is evident that globalization and technological advancement play a critical role in supporting the success of small and medium-sized businesses that have been established in society and are contributing to emerging nations' development progress and economic growth. Five crucial and strategic uses of technology that aid in the growth of Start-ups are as follows: automating manual processes, which lowers labor and operating costs; shortening the time needed to complete tasks; accelerating decision-making and improving competitive economic business performance; saving on promotion and marketing costs and system integration from process to product marketing (Surya et al., 2018).

Thus, the purpose and impact of technology will accelerate the transformation of the business sector, particularly the growth of Start-up businesses. Digital transformation and entrepreneurship, which significantly impact emerging economies and enable them to compete with developed economies, make the use of technology a driver for business sustainability. Consequently, technology has impacted many aspects of economic situations and has become crucial to economic competition. It indicates that technology is a strategy for addressing the changes occurring in the globalisation and digitalisation era. The movement of commodities and services, capital flows, and technology usage reflect globalisation's effects (Eliakis et al., 2020). Additionally, businesses that can master technology must compete in the global market. To compete in the marketing of products and reach potential markets, the corporation must maintain its technology capabilities. Digital platforms, infrastructures, and technologies continue to create new business prospects and allow established organisations to move some of their branches from offline to online settings. It has caused a new type of entrepreneurial activity known as digital entrepreneurship to arise (Jafari-Sadeghi, 2020). At the national level, the application of concepts related to digitisation and digital transformation aids in understanding the perspectives of various disciplines, such as information systems, innovation (Nambisan et al., 2018), management and business (Lanzolla et al., 2018), policy and strategy (Sahut et al., 2019).

Additionally, the literature supports the idea that enterprises can increase their market due to the technical development level (Yang & Chan, 2020). For example, according to Petersen B. et al. (2002), the internet and technological advancement have reduced businesses' costs to look for new market prospects, allowing them to grow their market continuously. In a different study, Mimoun L. et al. (2017) look at complex, innovative activities in the marketing expansion of businesses in the service sector and highlight that, while being risky, technological innovation has a significant impact on a growing market. This is crucial for small entrepreneurial businesses because they are recognized for utilizing technology to compensate for their lack of resources (Boudlaie et al., 2020).

On the other hand, innovation is the main factor as a source of the company's competitive advantage. The amount of reading about innovation is enormous and deals with many topics. Theoretical developments were made in the 1990s (by Romer, Agion, and Hawit, as well as Grossman and Helpman, among others) based on Schumpeter's fundamental contribution from 1950; there was a significant increase in empirical investigations. This kind of research is mainly concerned with assessing innovation measuring indicators. They believe that the primary indicators of innovation capacity are research and development, patents, and scientific publications. According to Dodgson, M. and Hinze, S. (2000), the number of patents is the most widely used indicator of innovation capacity. It regards a patent as an exclusive right to exploit (produce, use, sell, or import) something for a set amount of time (20 years after filing) in the nation where the application is filed. According to Griliches Z. (1990), patent accounting is often recognized as one of the most valuable variables, enabling researchers to determine how inventively or artistically a firm performs regarding new technologies and items. In addition, it is advised to combine patent metric information with additional metrics, such as bibliometric data in academic journals and publications from scholarly publications. The innovations required to support greater productivity are being produced through some strategic measures, such as improving startups' technology competence and technical skills.

Business administration is progressing toward digitizing product marketing due to developing new products and improving the quality of the items being promoted, all while supporting innovation and fresh concepts for start-up businesses (Boldureanu et al., 2020). Along with entrepreneurship, enterprises must have access to the knowledge base of the global market to compete for economic growth, creativity, and innovation, making countries, especially emerging countries, adopt this policy as a strong competition to other countries. In developing and emerging countries, the effect of ICT on entrepreneurial activity is greater than in developed countries (Afawubo & Noglo, 2022).

Methodology and Research Methods

Methodological Approach. Business administration is progressing toward digitizing product marketing due to developing new products and improving the quality of the items being promoted, all while supporting innovation and fresh concepts for start-up businesses (Boldureanu et al., 2020). Along with entrepreneurship, enterprises must have access to the knowledge base of the global market to compete for economic growth, creativity, and innovation, making countries, especially emerging countries, adopt this policy as a strong competition to other countries. In developing and emerging countries, the effect of ICT on entrepreneurial activity is greater than in developed countries (Afawubo & Noglo, 2022). The following will be the estimation form:

$$Ln(IN)_{it} = \beta_0 + \beta_1 lnE_{it} + \beta_2 (HT\_exp)_{it} + \beta_3 ln(GDPPC)_{it} + \beta_4 STUP_{it} + \varepsilon_{it} \quad (1)$$

where **IN**: Innovation is evaluated by the number of patents granted, using data from World Bank − World Development Indicators;

E: Entrepreneurship is measured by the number of new enterprises established in a nation throughout a fiscal year (Antoncic & Prodan, 2008), utilizing statistics from the International Monetary Fund;

HT_exp: Exports of high technology products as a share of total exports from 2007, using data from Eurostat;

GDPPC: Using World Bank country accounts data and OECD National Accounts data files, GDP per capita in (constant 2010 US dollars) represents the entire value added by all producers in the national economy adding any taxes on products (Stel, Carree, & Thurik, 2005);

STUP: Start-up - Business registration processes (number) (World Development Indicators).

The choice between the Fixed effect model, Random effect model, and Pooled regression model will be the subject of our analysis. To accomplish this, we employ the Hausman and Wald tests and fictitious variables representing various nations.

Data Collection. Various prominent data sources were utilised to gather the required statistics for this study, including the World Development Indicators, the OECD National Accounts data files, and the Eurostat data collection. These databases are widely recognised for their comprehensive and reliable economic and development indicators collection. The data retrieval involved extracting relevant variables from these sources to construct the final time series dataset. The study focused on a sample of ten countries, as we mentioned before. The analysis time frame was established from 2008 to 2016, ensuring consistency and comparability across the selected countries. By employing these reputable data sources and establishing a consistent time series, the study aimed to establish a robust foundation for conducting panel regression analysis and examining the relationship between various variables and a country's technological leadership in the mentioned economies.

Results

The descriptive data in Table 1 provide an overview of the ten nations and the five variables studied from 2008 to 2016. The average value for the High Technology export variable is reported as 13.37, ranging from a minimum of 1.61 to a maximum of 29.46 across the 90 observations. It indicates variations in the level of high-tech exports among the countries studied. The LnGDPPC variable, representing the natural logarithm of Gross Domestic Product per capita, exhibits a low standard deviation of 1.04. It suggests a relatively homogeneous distribution of per capita GDP among the sample countries, indicating similar levels of economic development. Similarly, the LnE variable, which measures Entrepreneurship through the number of new businesses registered annually, demonstrates the lowest standard deviation of 0.58 compared to the other variables. It implies a relatively consistent level of entrepreneurial activity across the sample countries. The total amount of patents, representing the Innovation factor, has a higher standard deviation of 1.84, showing greater variation in patent issuance between countries.

Lastly, the STUP variable, representing the number of procedures required to register a business, demonstrates differences across countries. The mean value of 8.6 procedures and a maximum of 15 procedures highlight differences in the regulatory processes for business registration across the sample countries. These descriptive statistics provide valuable insights into the distribution and variability of the variables under consideration, offering a foundation for further analysis and interpretation of the relationship between these variables and a country's technological leadership.

Table 1. Descriptive Statistics

	HT_EXP	LNE	LNGDP	LNIN	STUP
Mean	13.37667	11.25901	9.564732	9.516668	8.600000
Median	9.372174	11.26612	9.749021	9.085626	9.000000
Maximum	29.46593	12.83928	10.73472	14.00197	15.00000
Minimum	1.616625	9.819725	7.053527	6.410175	2.000000
Std. Dev.	9.091301	0.585366	1.041414	1.843835	2.967237
Skewness	0.493790	0.162168	-0.838797	0.607432	0.025119
Kurtosis	1.680383	3.717613	2.816877	2.702556	2.510554
Jarque-Bera	10.18764	2.325607	10.67946	5.866374	0.907803
Probability	0.006135	0.312609	0.004797	0.053227	0.635145
Observations	90	90	90	90	90

Source: Compiled by the authrors

The results of the least squares regression using the fixed effect model, as displayed in Table 2, demonstrate a high coefficient of determination, indicating a strong fit of the model to the data. Moreover, the adjusted R2, which considers the number of independent variables, is also notably high, suggesting that the model possesses substantial explanatory power. In general, the findings from the fixed effect model provide empirical evidence that supports a positive and significant association between innovation, GDP, and entrepreneurship in the ten nations. These results contribute significantly to our understanding of the factors influencing a country's technological leadership. They highlight the critical role of promoting innovation, fostering economic growth, and encouraging entrepreneurial activities as key drivers of technological development. By identifying the significant determinants of technological leadership, this research provides valuable insights for policymakers, businesses, and academics alike. It underscores the importance of creating an environment that encourages and nurtures innovation and entrepreneurship, as these factors play a vital role in enhancing a nation's technological leadership and overall competitiveness in the global economy.

Table 2. Fixed Effect Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-13.54323	1.861857	-7.274046	0.0000
LNE	0.533134	0.119199	4.472652	**0.0000**
HT_EXP	0.022964	0.018542	1.238528	0.2193
LNGDPPC	1.727193	0.236848	7.292411	**0.0000**
STUP	0.026745	0.014845	1.801593	0.0756
Effects Specification				
Cross-section fixed (dummy variables)				
R-squared	0.993471	Mean dependent var		9.516668
Adjusted R-squared	0.992354	S.D. dependent var		1.843835
S.E. of regression	0.161229	Akaike info criterion		-0.669942
Sum squared resid	1.975614	Schwarz criterion		-0.281083
Log likelihood	44.14740	Hannan-Quinn criter.		-0.513131
F-statistic	889.5231	Durbin-Watson stat		1.137176
Prob(F-statistic)	0.000000			

Source: Compiled by the authors

Table 2 presents the results of the Fixed Effect Model, a statistical method used to analyze panel data, specifically in this study, data from 10 different countries over nine years (from 2008 to 2016). The dependent variable in this analysis is represented by "LNIN", which stands for the natural logarithm of innovation. The "Panel Least Squares" method is utilized for the regression analysis, which allows us to examine the relationship between the dependent variable (LNIN) and several independent variables, including "IN" (innovation), "E" (entrepreneurship), "HT_EXP" (exports of high-technology items as a percentage of overall exports), and "GDPPC" (GDP per capita in constant 2010 US dollars). The sample consists of data collected from 10 countries over the nine years, resulting in 90 observations in the panel data, ensuring a balanced dataset.

The table displays each independent variable's coefficients, standard errors, t-statistics, and probabilities. The coefficients indicate the strength and direction of the relationship between the independent and dependent variables. The standard errors represent the precision of the coefficient estimates. The t-statistic measures how many standard errors the coefficient estimate is away from zero, and the probability (Prob.) shows the significance level of the coefficient. The results from the random effect model, as presented in Table 3, confirm a positive relationship between the dependent variable and two independent variables: GDP and entrepreneurship. Furthermore, the proxy variable for information and communication technology (ICT) represented by STUP (a variety of phases for registering a business) is found to have a significant impact. However, High-tech exports as a percentage of total exports are not statistically significant.

In Table 3, the authors discuss the results of a statistical analysis using the Random Effect model with the Panel EGLS (Cross-section random effects) method. The analysis focuses on panel data, which includes data collected from 10 different cross-sections (countries) over nine years (from 2008 to 2016). Overall, the Random Effect model with Panel EGLS (Cross-section random effects) is applied to study the relationship between the dependent variable (LNIN) and the independent variables across the ten selected countries for the specified 9-year period. This model accounts for the potential differences between the countries and allows for a more accurate analysis of the impact of the independent variables on the level of innovation (LNIN) in these countries. The inclusion of random effects also acknowledges that unobserved country-specific factors may influence the dependent variable.

The coefficient of determination (adjusted-R2) for the random effect model is approximately 60%, indicating moderate explanatory power. These results contribute to understanding the determinants of a country's technological capacity, highlighting the importance of GDP, entrepreneurship, and ICT development while suggesting that the number of high technology exports in the overall exports may not be a significant determinant.

Table 3. Random Effect Model

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	-10.94110	1.724085	-6.346036	0.0000
LNE	0.699637	0.110735	6.318106	0.0000
HT_EXP	0.045560	0.016960	2.686381	0.0087
LNGDPPC	1.226243	0.198479	6.178200	0.0000
STUP	0.028189	0.014708	1.916547	0.0587
Effects Specification				
			S.D.	Rho
Cross-section random			1.180581	0.9817
Idiosyncratic random			0.161229	0.0183
Weighted Statistics				
R-squared	0.603378	Mean dependent var		0.432775
Adjusted R-squared	0.584714	S.D. dependent var		0.286889
S.E. of regression	0.184879	Sum squared resid		2.905316
F-statistic	32.32750	Durbin-Watson stat		0.845040
Prob(F-statistic)	0.000000	Mean dependent var		
Unweighted Statistics				
R-squared	-0.267376	Mean dependent var		9.516668
Sum squared resid	383.4771	Durbin-Watson stat		0.006402

Source: Compiled by the authors

In the context of our study, we applied the Hausman test to determine which model (Random Effect or Fixed Effect) is better suited for our dataset. The null hypothesis for the Hausman test is that the individual-specific effects are not correlated with the independent variables in the model, which implies that the random effects model is appropriate. The alternative hypothesis is that the individual-specific effects are correlated with the independent variables, suggesting that the fixed effects model is more appropriate. Based on the results presented in Table 4, the p-value associated with the Hausman test is less than 0.05 (0.00005), the significance level commonly used to determine statistical significance. Since the p-value is less than 0.05, the authors reject the null hypothesis and conclude that the individual-specific effects are indeed correlated with the independent variables in our model. It indicates that the fixed effects model is more appropriate for our dataset.

Table 4. Correlated Random Effects-Hausman Test

Test Summary		**Chi-Sq. Statistic**	**Chi-Sq. d.f..**	**Prob**
Cross-section random		30.764743	4	**0.0000**
Cross-section random effects test comparisons				
Variable	Fixed	Random	Var(Diff.)	Prob.
LNE	0.533134	0.699637	0.001946	0.0002
HT_EXP	0.022964	0.045560	0.000056	0.0026
LNGDPPC	1.727193	1.226243	0.016703	0.0001
STUP	0.026745	0.028189	0.000004	0.4734
Cross-section random effects test equation:				
Dependent Variable: LNIN				
Method: Panel Least Squares				
Sample: 2008 2016				
Periods included: 9				
Cross-sections included: 10				
Total panel (balanced) observations: 90				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	-13.54323	1.861857	-7.274046	0.0000
LNE	0.533134	0.119199	4.472652	0.0000
HT_EXP	0.022964	0.018542	1.238528	0.2193
LNGDPPC	1.727193	0.236848	7.292411	0.0000
STUP	0.026745	0.014845	1.801593	0.0756
Effects Specification				
Cross-section fixed (dummy variables)				
R-squared	0.993471	Mean dependent var		9.516668
Adjusted R-squared	0.992354	S.D. dependent var		1.843835
S.E. of regression	0.161229	Akaike info criterion		-0.669942
Sum squared resid	1.975614	Schwarz criterion		-0.281083
Log likelihood	44.14740	Hannan-Quinn criter.		-0.513131
F-statistic	889.5231	Durbin-Watson stat		1.137176
Prob(F-statistic)	0.000000			

Source: Compiled by the authors

We estimate the following:

LNIN=C(1)+C(2)*LNE+C(3)*HT_EXP+C(4)*LNGDPPC+C(5)*STUP+C(6)*D2+C(7)*D3+C(8)*D4+C(9)*D5+C(10)*D6+C(11)*D7+C(12)*D8 +C(13)*D9+C(14)*D10 (2)

In the given equation, we are estimating the relationship between the dependent variable LNIN (Log of Innovation) and several independent variables represented by C(1) to C(14). By estimating this equation using panel regression techniques (such as Panel Least Squares or EGLS with cross-section random effects), we can assess the impact of each independent variable on the log of innovation while controlling for country-specific effects. The coefficients C(2) to C(14) represent the respective effects of each independent variable on LNIN, and their statistical significance helps determine the strength and direction of the relationship. Table 5 presents the results of the Pooled Regression model with Dummy variables, which estimates the relationship between the dependent variable LNIN (Log of Innovation) and several independent variables, including LNE, HT_EXP, LNGDPPC, STUP, and dummy variables D2 to D10 representing different countries or regions.

Including dummy variables (D2 to D10) allows for country-specific effects in the analysis. Each dummy variable takes the value of 1 if the observation corresponds to the respective country or region and 0 otherwise. By incorporating these dummy variables, the model accounts for potential heterogeneity among countries or regions in their impact on innovation. Overall, the Pooled Regression model helps assess the relationships between the independent variables and the log of innovation while considering country-specific effects. The results provide insights into the factors influencing innovation across different countries and regions in the specified period.

Table 5. Pooled Regression Model with Dummy Variables

	Coefficient	**Std. Error**	**t-Statistic**	**Prob.**
C(1)	-15.41729	2.006752	-7.682710	0.0000
C(2)	0.533134	0.119199	4.472652	0.0000
C(3)	0.022964	0.018542	1.238528	0.2193
C(4)	1.727193	0.236848	7.292411	0.0000
C(5)	0.026745	0.014845	1.801593	0.0756
C(6)	1.760926	0.235090	7.490425	0.0000
C(7)	5.414078	0.760478	7.119307	0.0000
C(8)	6.958682	0.592187	11.75082	0.0000
C(9)	-0.134653	0.455451	-0.295646	0.7683
C(10)	3.245399	0.398437	8.145331	0.0000
C(11)	1.366900	0.254954	5.361365	0.0000
C(12)	-0.251163	0.342895	-0.732478	0.4661
C(13)	1.188791	0.169765	7.002569	0.0000
C(14)	-0.808367	0.092953	-8.696561	0.0000
R-squared	0.993471	Mean dependent var		9.516668
Adjusted R-squared	0.992354	S.D. dependent var		1.843835
S.E. of regression	0.161229	Akaike info criterion		-0.669942
Sum squared resid	1.975614	Schwarz criterion		-0.281083
Log likelihood	44.14740	Hannan-Quinn criter.		-0.513131
F-statistic	889.5231	Durbin-Watson stat		1.137176
Prob(F-statistic)	0.000000	Mean dependent var		

Source: Compiled by the authors

The outcome of the Null Hypothesis test for the Pooled Regression model is that all dummy variables are equal to zero. In this test, the country-specific effects represented by the dummy variables significantly impact the dependent variable (LNIN) in the Pooled Regression model. If all dummy variables are not significant (p-value > 0.05), it suggests that the country-specific effects do not substantially influence the log of innovation. Table 5 presents the results of the Pooled Regression model with dummy variables, confirming the findings of the Fixed Effect model. It denotes that the relationship between the independent variables (LNE, HT_EXP, LNGDPPC, STUP, and dummy variables) and the dependent variable (LNIN) remains consistent and significant when using the Pooled Regression model.

Finally, the authors apply the Wald test to determine if all dummy variables are jointly equal to zero. The Wald test is a statistical test used to assess the overall significance of a group of coefficients in a regression model. In this case, it evaluates whether the country-specific effects, represented by the dummy variables, collectively impact innovation. If the Wald test yields a significant result (p-value < 0.05), it indicates that the dummy variables as a group have a meaningful influence on the innovation log. On the other hand, if the Wald test is insignificant (p-value > 0.05), it suggests that the combined effects of the dummy variables are not statistically significant. The Wald test helps determine the relevance of including country-specific effects in the model. If the test confirms the significance of the dummy variables, it supports the inclusion of country-specific factors in explaining the variation in innovation across different countries or regions.

Table 6. Wald Test

Test Statistic	**Value**	**df**	**Probability**
F-statistic	349.4886	(9, 76)	0.0000
Chi-square	3145.398	9	0.0000
Null Hypothesis: C(6)=C(7)=C(8)=C(9)=C(10)=C(11)=C(12)=C(13)=C(14)=0			
Null Hypothesis Summary:			
Normalized Restriction (= 0)		Value	Std. Err.
C(6)		1.760926	0.235090
C(7)		5.414078	0.760478

Table 6 (cont.). Wald Test

C(8)		6.958682	0.592187
C(9)		-0.134653	0.455451
C(10)		3.245399	0.398437
C(11)		1.366900	0.254954
C(12)		-0.251163	0.342895
C(13)		1.188791	0.169765
C(14)		-0.808367	0.092953
Restrictions are linear in coefficients			

Source: Compiled by the authors

The Fisher statistics, or F-test or F-statistic, is a statistical test used to compare the goodness-of-fit of two nested regression models. In this context, Fisher statistics is used to test the hypothesis of whether the fixed effect model or the random effect model is more appropriate for the study. If the Fisher statistics is found to be significant at the 5% level, it indicates a significant difference in the goodness of fit between the fixed effect model and the random effect model. In other words, one of the models provides a significantly better fit to the data than the other.

Based on the results of the Fisher statistics, the Hausman test and other F statistics, we conclude that the fixed effect model is the best fit for the study. It suggests that the country-specific effects, represented by the fixed effects, play a significant role in explaining the variation in the dependent variable (LNIN), and these effects are not purely random. The fixed effect model is considered appropriate when time-invariant factors specific to each country affect the outcome variable. Overall, the significance of the Fisher statistics and other relevant statistical tests supports the researchers' choice of the fixed effect model as the more suitable approach for exploring the relationship between ICT and technological leadership in various nations.

Table 7 presents the results of the fixed effect model with dummy variables, which is used to examine the relationship between the dependent variable LNIN (technological leadership or innovation) and various independent variables. The analysis uses panel least squares, and the sample spans from 2008 to 2016. The dataset includes nine periods and ten cross-sections, resulting in 90 observations in the balanced panel. This table presents the statistical results of the fixed effect model with dummy variables, which allows for an understanding of the extent to which the independent variables impact technological leadership or innovation in the studied countries over the specified period. The findings contribute valuable insights into the factors influencing technological leadership and can be used to inform policy and strategic decision-making related to innovation and technological development.

Table 7. Fixed Effect Model with Dummy Variables

	Coefficient	**Std. Error**	**t-Statistic**	**Prob.**
C(1)	-15.41729	2.006752	-7.682710	0.0000
C(2)	0.533134	0.119199	4.472652	**0.0000**
C(3)	0.022964	0.018542	1.238528	0.2193
C(4)	1.727193	0.236848	7.292411	**0.0000**
C(5)	0.026745	0.014845	1.801593	0.0756
C(6)	1.760926	0.235090	7.490425	0.0000
C(7)	5.414078	0.760478	7.119307	0.0000
C(8)	6.958682	0.592187	11.75082	0.0000
C(9)	-0.134653	0.455451	-0.295646	0.7683
C(10)	3.245399	0.398437	8.145331	0.0000
C(11)	1.366900	0.254954	5.361365	0.0000
C(12)	-0.251163	0.342895	-0.732478	0.4661
C(13)	1.188791	0.169765	7.002569	0.0000
C(14)	-0.808367	0.092953	-8.696561	0.0000
R-squared	0.993471	Mean dependent var		9.516668
Adjusted R-squared	0.992354	S.D. dependent var		1.843835
S.E. of regression	0.161229	Akaike info criterion		-0.669942
Sum squared resid	1.975614	Schwarz criterion		-0.281083
Log likelihood	44.14740	Hannan-Quinn criter.		-0.513131
F-statistic	889.5231	Durbin-Watson stat		1.137176
Prob(F-statistic)	0.000000			

Source: Compiled by the authors

The findings from the fixed effect model support the primary hypothesis of the article since they reveal a positive correlation between technological leadership (represented by innovation) and ICT (represented by entrepreneurship and STUP) in some nations. It suggests that countries with higher levels of innovation, greater entrepreneurial activity, and ICT development are more likely to have stronger technological leadership. The significant results and the confirmation of the main hypothesis contribute valuable insights to the existing body of knowledge. The empirical evidence provided in this study sheds light on the factors that influence a country's technological leadership. The positive relationship between innovation and ICT underscores the importance of promoting innovation and enhancing ICT infrastructure to foster technological development in the mentioned economies.

Further research and analysis may be required to explore additional factors that could influence technological leadership. Additionally, to assess the generalizability of these findings, future studies might consider examining a broader range of countries or extending the analysis to different periods. In conclusion, the results of this study offer valuable implications for policymakers and stakeholders, emphasizing the significance of supporting innovation and ICT development as key drivers of technological advancement. Countries can enhance technological leadership and improve their economic competitiveness in today's global business environment by investing in these areas.

Conclusion

This paper investigates the relationship between technological leadership and ICT in ten countries, using a panel regression analysis based on 90 panel-balanced observations from 2008 to 2016. The researchers introduced proxy variables to address data challenges for the two country groups. The results of the panel regression analysis indicate that the proportion of high-technology exports in total exports does not significantly impact the relationship between technological leadership and ICT. Instead, the fixed effect model was deemed suitable for the sample. The study highlights GDP and entrepreneurship as the primary predictors of innovation, as measured by the total number of patents issued.

Additionally, the findings reveal that internet penetration plays a significant role in fostering innovation, although its effect tends to diminish over time. To validate this observation, the researchers explored multiple models and variable measures (Xiong et al., 2022). Future research possibilities in this domain could further investigate the comprehensive impact of ICT on each independent variable. Specifically, exploring how ICT influences factors such as GDP and entrepreneurship, which are identified as determinants of innovation in this study, may provide valuable insights for understanding the dynamics of technological development and innovation in different country contexts.

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