

The Importance of Technology, R&D and AI in the US Economy

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Abstract

As AI technology became a trend and have entered nearly every household and firm, the topic of technology R&D and its influence on economy is tackled in the study, more particularly the United States case which is home to the most known technological firms in the world as Chat GPT, Meta, Microsoft and Google. The study suggests that while technological advance is key for the growth in the US economy, yet its impact is indirect, and while R&D monetary funding is important, yet to a much lesser extent than human capital and researchers in R&D, this statement is supported by World Bank Data, finally the study highlighted that the United States is only one of many entities that participate in technological development, and in the near future Artificial intelligence and technological firms are poised to become "one of the most lucrative investment sectors."

Keywords: *Technology, R&D, Economy, Human Capital, GDP, Artificial intelligence.*

1. Introduction

1.1 Background and Purpose

The United States is widely recognized as a global leader in the high-technology industry, with companies such as OpenAI's Chat GPT, Apple, Alphabet, Microsoft, Meta, Dell, Intel, IBM, and HP contributing to this reputation. Moreover, recent government actions such as the ban on semiconductor technology exports to China further support this argument (Funke and Wende 2022). While many acknowledge the US's dominance in technology, few have analyzed the reasons behind it. Understanding these factors could provide valuable insights for policymakers, corporations, and investors alike. Specifically, it could inform governments about how to emulate the US's success, help companies thrive in the technological field, and shed light on the potential relationship between technology, economic growth, and GDP in the US. (Lee and Lee 2020).

The study aims to scientifically analyze the significance of US technology on the US economy, and forecast the outlook of technological advancement in the future. Beyond its material benefits for US citizens and regulations, technological advancement has positive externalities on the rest of the world. For instance, OpenAI's Chat GPT is already being used by individuals, scholars, and firms on an international level, while microchips are essential components in modern hardware and are already used by firms and households throughout the world. Furthermore, Artificial intelligence and machine learning, although not yet a necessity, are tools that can aid millions of individuals and firms achieve their targets more efficiently and effectively, thereby contributing to global economic growth

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(Mishra and Tyagi 2022). By analyzing the relationship between technology, economic growth, and GDP, the study can shed light on the potential benefits and challenges of technology for both the US and the global economy.

1.2. Nature of the Research and Questions

As per above statements, the main objective of the research is to analyze how significantly does technology and Research and Development “R&D” impact economic growth, using GDP as the dependent variable to analyze how much the United States economy depends on technological advances, and what criterion within technology is most significant on economic growth through the use of hypothesis testing and multiple regression analysis.

Furthermore, using Excel’s add in for Data Analysis, Artificial intelligence in Analysis, and Monte Carlo Simulation the study attempts to compare the technological level of the United states to other countries, while forecasting in both a quantitative manner and a descriptive manner using visualization, the level of technological advances to be expected in the future in the United States, sample countries and the rest of the world, thus answering whether the influence of technology on economic growth is expected to be increasing or decreasing, and the rate of growth of technology in the past decades (Kumar, Tiwari et al. 2019), a technical analysis in which we can to a large extent expect the future due to the certainty and accuracy of past events.

To provide a standardized, transparent, and objective way to measure technological and economic progress, properly analyze the significance of the former on the latter and identify challenges, World Bank official indicators would be used by this study to provide insightful information and to assist policymakers as well as investors to make evidence-based decisions.

2. Literature review

2.1 Literature and Context

Previous studies shown that economic growth is promoted by exports owing to the productivity differential between the sectors that export and those that do not, as well as the beneficial external effect on non-exporting sectors (Raiher, do Carmo et al. 2017, Bayar 2018). In principle, the more advanced the technology of the exported goods, the more pronounced these impacts become. The differing impact of export on economic growth, whether it is due to the nature of an export portfolio or not, has become a crucial topic in literature. The empirical literature also examines the notion that exporting more sophisticated products would lead to higher growth in gross domestic product as opposed to exports of simpler products. This is justified by the fact that producing such items has a higher potential for producing economies of scale, productivity improvements, and knowledge (Cuaresma and Wörz 2005, Hausmann, Hwang et al. 2007, Ribeiro, Carvalho et al. 2016). A study conducted by Raiher and do Carmo (2017) examining the impact of exports with high technological level on the economic advancement of microregions in Brazil confirms the more technologically advanced the products exported, the greater the growth, due to higher benefits in terms of externality and productivity. According to Peneder (2003), the growth of per capita GDP is closely linked to the positive correlation between the export of technology-focused high-skilled industries in both the manufacturing and service sectors (Kamel & Beainy 2023). Trlaković, Despotović et al. (2018) conducted a study on the correlation between technology-based exports and economic growth in Western Balkan Countries (WBCs) from 2005 to 2015. According to their research, the export of manufactured goods has the greatest impact on boosting GDP per capita, particularly in medium to low-tech industries.

The literature outlines the factors affecting economic growth (Choong, Baharumshah et al. 2010, Rodríguez-Pose 2013, Upreti 2015, Soekapdjo, Tribudhi et al. 2020). Studying variables that impact economic expansion can serve as a guide in formulating economic strategies for the government (Sahoo and Dash 2009). These variables include Infrastructure Levels, Human Resources, Technological Advancements, and Labor Market Potency (Soekapdjo, Tribudhi et al. 2020, Surya, Menne et al. 2021, Beainy 2023). Indeed, investment in transportation, communication, and roads can assist companies in decreasing expenses and broadening output. In the absence of adequate infrastructure, it can be challenging for companies to remain competitive in global markets (Anyanwu 2014, Upreti 2015). This insufficiency of infrastructure is frequently a hindrance for some developing economies. Advancements in technology influence greatly the expansion of the economy (Heitger 2001, Sarwar, Khan et al. 2021). With each new breakthrough made by the scientific community, managers explore methods to implement these developments through refined production methods (Younus 2021). The flexibility of the labor market is crucial for the expansion of an economy (Chen and Feng 2000, Acemoglu and Robinson 2008). If labor markets are adaptable, then companies will find it more straightforward to recruit the workers they require. This will facilitate expansion. Flexible labor markets make it easier for firms to recruit the workforce they require, facilitating expansion (Mahmud and Rashid 2006). However, highly regulated labor markets may discourage firms from hiring in the first place (Heitger 2001, Cai, Wang et al. 2002). Human capital refers to the productivity of the workforce, which is determined by their level of education, training, and motivation (Patel and Conklin 2012).

Solow proposes that the key elements for the expansion of an economy are focused on exports, technology, and human resources (Solow 1956). Human resources play a significant role in creating, implementing, and embracing innovative technologies, leading to enhanced efficiency and economic progress. Hence, it is imperative to invest in the education and training of the labor force for the advancement of a nation (Benhabib and Spiegel 1994, Lacasa, Jindra et al. 2019). In a different research, Chuang (2000) concludes that the development of human resources supports the expansion of the economy in Taiwan and triggers the increase of exports. In turn, exports of high-technological products encourage long-term growth by hastening the progression of human resource development. A vast literature has demonstrated that human capital is a crucial determinant of economic growth (Mehra and Musai 2013, Pelinescu 2015, Muhamad, Sulaiman et al. 2018, Olawumi 2019). This is due to its significant impact on labor productivity, known as the level effect (Romer 1993, Mankiw, Phelps et al. 1995) as well as its contribution to increase competitive advantage through innovation and technology diffusion, known as the rate effect (Societies 2005, Hanushek and Woessmann 2010, Pelinescu 2017). Benhabib and Spiegel (1994) confirmed that the inclusion of human capital as an element of production has a trifling impact on the growth of GDP per capita. However, while thinking about the effect of human capital on overall productivity, outcomes come to be visible. First, human capital impacts the inner charge of innovation, as proven by Romer (1990). Second, human capital influences the charge of era diffusion (Nelson and Phelps 1966, Funke and Strulik 2000, Chang and Lee 2010). Funke and Strulik (2000) in addition show that a 1% growth within the capital stock consequences in a 0.13% growth rate, and the procedure of catching up with technological improvement in different nations is strongly motivated via the national human capital stock.

Increasing monetary investment in the field of research is crucial for economic growth (Sarwar, Khan et al. 2021). It helps in mitigating risks and uncertainties through efficient risk management processes, sharing and utilizing savings, and reducing transaction costs. Effective regulatory bodies can oversee transactions, encourage a well-functioning market, and enable trade by exchanging services, goods, technology, knowledge, and innovation through research and development. The consistent growth rates of world development indicators (WDIs) in different regions are partially attributed to the

deepening of finance, where the progress of the financial sector plays a crucial role in growth (Sarwar, Khan et al. 2021). In brief, finance plays an expanded role in facilitating investment productivity and growth models of economics (Salloum & Beainy 2023), providing a theoretical foundation for analyzing the relationship between the development of the financial sector and economic growth. The expansion of the economy can be fostered through the monetary system by allocating funds to the most productive ventures, thereby enhancing human and material resources and reducing the costs associated with savings and investments (Shao and Yang 2014).

2.2 Hypothesis Development

The paragraph outlines six hypotheses that will be tested in the study, the first four hypotheses being developed, analyses the impact of technology on Gross Domestic Product in the United States, using GDP as the dependent variable. The first two hypotheses focus on the impact of technological exports on GDP growth in the United States while the third and fourth hypotheses focus on the influence of research and development “R&D” on economic growth.

Technological export in USD is the independent variable in Hypothesis one, the goal of using this independent variable is to analyze in absolute value the effect of technological exports on GDP directly in the case of the United States.

For hypothesis two, the independent variable is the percentage of high technological exports as a part of all the exports of the United States, using relative terms to be able to properly tackle whether the effect of technology is direct – as due to selling more technology, or indirect as increasing economic growth by increasing the efficiency of the entire output of the economy.

According to Hypotheses One and two, increased levels of technological exports in USD and a greater proportion of high technological exports as a component of all exports of the United States are anticipated to have a positive correlation with GDP growth.

The third and fourth theories seek to examine the influence of research and development "R&D" on the economy's expansion in the United States. Hypothesis three posits that monetary investment in R&D, measured as a percentage of total GDP, is the most significant variable in driving economic growth. Conversely, hypothesis four suggests that other factors may be more important than monetary investment, such as the number of individuals participating in R&D per millions of people. By testing these hypotheses, the study aims to shed light on the most effective ways to promote R&D and support economic growth in the US.

The fifth hypothesis is a scenario analysis that suggests that technological advances will continue to grow significantly in the future, providing insights for investors and potential investors.

Finally, the sixth hypothesis compares the technological development and exports of the United States to other countries. It suggests that the US is the leading country in terms of technological development and technological exports.

Overall, these hypotheses form the basis for the research questions that the study will address. By testing these hypotheses, the research seeks to illuminate the influence of technology, artificial intelligence and R&D on economic growth in the United States, as well as provide insights into the future of technological advancement and the position of the US in the global technology landscape.

Table 1: Hypothesis Formulation

Hypothesis Number	Hypothesis Argument
H ₁	Technological exports value increases economic growth in the United States Significantly

H ₂	Higher levels of technological exports, relative to total exports significantly impact GDP positively in the United States.
H ₃	Increasing Monetary Investments in R&D positively and significantly increases economic growth
H ₄	Increasing individual Human participation in R&D positively and significantly increases economic growth
H ₅	Technological advances are quantitatively forecasted to grow significantly in the future
H ₆	The United States is the leading country for technological exports in the world

3. Research Methodology

3.1 Data Collection and Sampling Method

Using the world Bank Science & Technology official indicators (World Bank. 2023) , the study retrieved secondary data beginning from 1960 until 2021, then using Exploratory Data Analysis “EDA”, we excluded years with missing data for the variables of interest, and selected a sample of thirteen years based on two conditions, favoring recent years for the data to provide insightful information applicable today, and selecting years in which all Data of both the dependent and independent are accurate to provide reliable results, thus a time frame of 13 years starting 2007 was used

Table 2: Data Collection Simplified

General term	Used in the Study
Data Type	Secondary Data
Data Source	World Bank Official Indicators
Data Time Frame	13 years Starting 2007

The Specific Data Collected from world bank include but are not limited to, GDP measured in USD, High-technology exports measured in USD, technological exports measured in Percentage of total manufacturing exports, Research and Development expenditure measured in Percentage of total GDP, Researchers in R&D measured in numbers per million people.

3.2 Empirical framework and Data Treatment

The methodology used to analyze World Bank Data is statistical, using multiple regression analysis to identify the impact of different variables on economic growth, and hypothesis testing along with comparative and scenario analysis to answer the research questions quantitatively.

Through the first independent variables of High-technology exports in absolute and relative terms, we examine if technology is impacting economic growth directly through exporting technological goods or indirectly through, increasing the efficiency of everything else through the use of technological capital that encompasses a broad range of assets, including scientific research, intellectual property, human capital and physical technological infrastructure in order to create economical value.

Secondly, is the most important investment in technology monetary or is human capital and individual research the key driver of economic growth and competitiveness in the modern global economy? This is answered through multiple regression analysis of two different criterions that are directly related to research and development, R&D Expenditure and R&D number of researchers.

Finally, using the secondary data gathered and technical analysis, we predict data trends in the future using different scenarios, visualization is then used to compare the United States technological investment trends and export success to different countries that are considered as close to the United States in terms of technological development.

Table 3: Variable type and measurement

Variable	Type	Measurement
GDP	Dependent	Us Dollars
High-Technology Exports	Independent	Us Dollars
Technological Exports	Independent	Percentage of Total exports
R&D Expenditures	Independent	Percentage of GDP
R&D Researchers	Independent	Number of individuals

Table 4: Analytical Methods used in the study

Types of Analysis	Objective
Multiple Regression Analysis	To explore the correlation between economic expansion and various technological factors.
Hypothesis Testing	To Test competing hypotheses, as the third hypothesis determines monetary expenditure as the most important R&D variable while the fourth human capital as the most significant criterion in R&D and technological advance
Exploratory Data Analysis	To make sure the Secondary Data collected are reliable
Technical Analysis and Forecast	To predict the future of technological development using historical actual data about technological progress
Comparative analysis	to gain insights into the similarities and differences between the countries being compared

4. Results and Discussions

4.1 Results and interpretation

Table 5: Summary Output

Impact on Economic Growth

Regression Statistics	
Multiple R	0.966547679
R Square	0.934214416
Adjusted R Square	0.901321623
Standard Error	7.3723E+11
Observations	13

Significance F
8.87183E-05

ANOVA

	df	SS	MS	F

Regression	4	6.17465E+25	1.54366E+2 5	28.40179723
Residual	8	4.34807E+24	5.43509E+2 3	
Total	12	6.60946E+25		

	Coefficients	Standard Error	t Stat	P-value
Intercept	- 5.81223E+1 2	5.86203E+12	- 0.991504822	0.350477077
Tech Exports in USD	25.39584122	15.38193635	1.651017182	0.137340696
High Tech % Total Exports	- 2.67673E+1 1	1.62325E+11	- 1.648994109	0.137759474
Research and Development Expenditures	- 2.11904E+1 2	4.50774E+12	- 0.470089945	0.650839211
Number of researchers in R&D per millions of people	7244752494	2433284447	2.977355361	0.017671593

Over a time of 13 years in the case of the United States, beginning R square and Adjusted R-Square are statistical measurements that indicate how accurately a regression model fits the data. These measurements indicate that 90.13% of the variation in GDP can be accounted for by the technology-related independent variables utilized in the study. Similarly, an F value of nearly zero, indicates that the null hypothesis of the F-test, which states that all regression coefficients are zero, is rejected. On the other hand, the alternative hypothesis, which states that at least one regression coefficient is not zero, is accepted with a high level of confidence. The positive coefficient in the final variable suggests that an increase in the number of researchers in R&D per millions of individuals is significantly linked to an increase in Economic Growth.

Table 6: Rejected hypotheses

Hypothesis Number	Hypothesis Argument	P value (Should Be < 0.05)
H ₁	Technological exports value increases economic growth in the United States Significantly	0.137340696>0.05
H ₂	Higher levels of technological exports, relative to total exports significantly impact GDP positively in the United States.	0.137759474>0.05
H ₃	Increasing Monetary Investments in R&D positively and significantly increases economic growth	0.650839211>0.05

Table 7: Confirmed Hypothesis

Hypothesis Number	Hypothesis Argument	P value (Should Be < 0.05)
H ₄	Increasing individual Human participation in R&D positively and significantly increases economic growth	0.017671593<0.05

Figure 1: R&D Expenditures relative to GDP

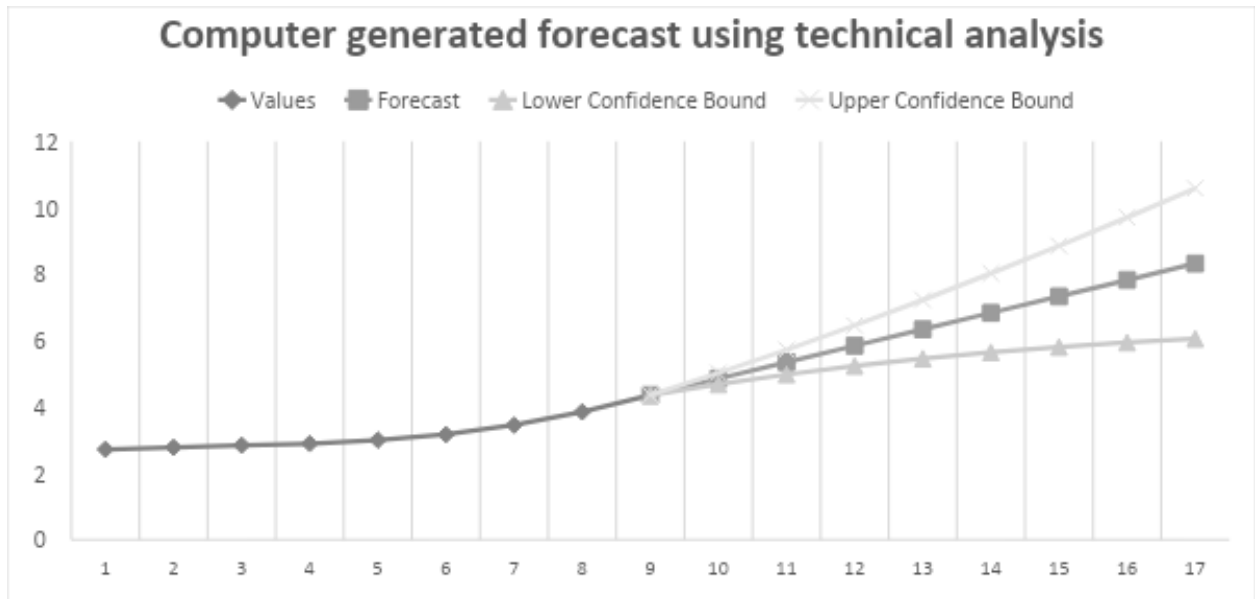
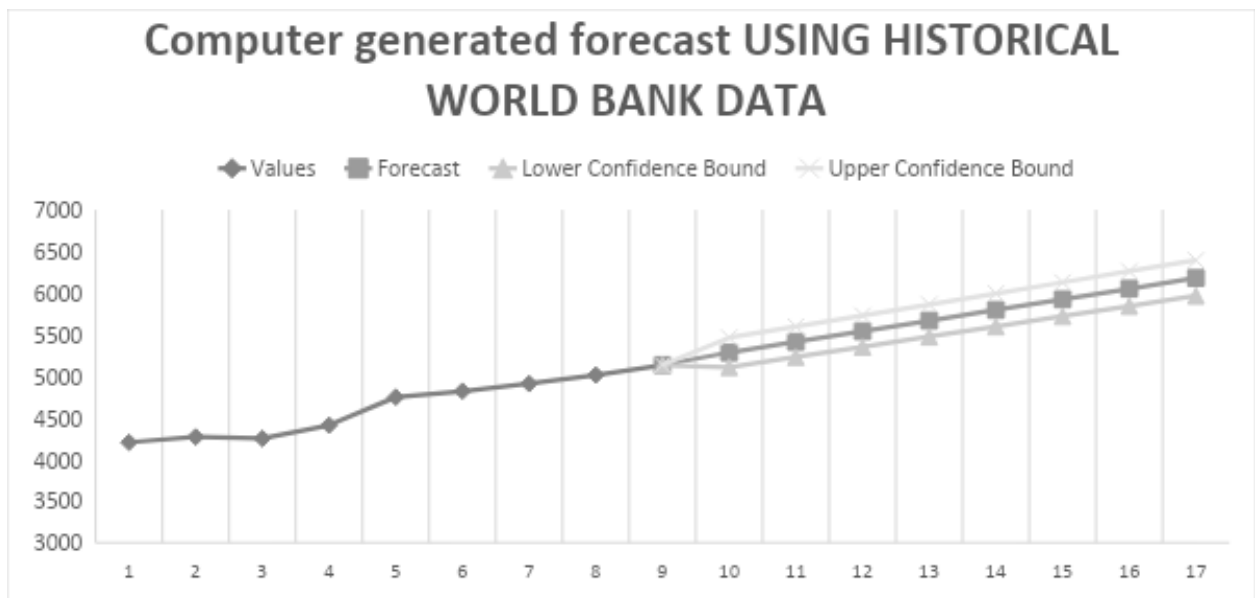
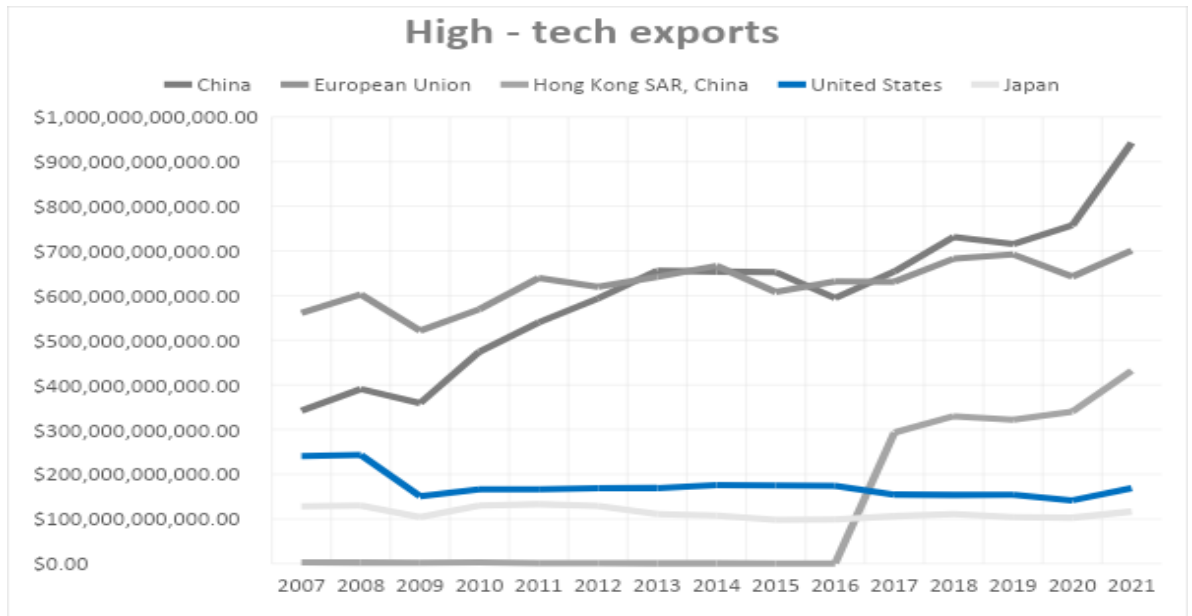


Figure 2: R&D Number of researchers per millions



Through increased human and monetary investments in the future, it is forecasted that the level of technological advancement, including artificial intelligence and enhancement of existing technologies, will massively increase. Even in scenario three, which assumes reduced R&D progress, there is a positive outlook for growth, although to a lesser extent than that of the forecast result and the upper confidence bound, supporting Hypothesis five according to which technological advances including are quantitatively forecasted to grow significantly in the future.

Figure 3: High Technology Exports by Entity



Although the United States ranks among the top 5 entities in technology exports, the data suggests that it is not the leading entity in this field, thus rejecting hypothesis six according to which the United States is the leading country for technological exports in the world. Technological advances are the result of collective efforts, rather than the work of a single country, by working together, entities can reap the benefits of technological advances and provide better technology for individuals.

4.2 Limitation and Further research

To analyze potential limitations of the study, we conduct a data quality analysis, for accuracy, completeness, consistency, timeliness, relevance, validity, reliability and accessibility.

Table 8: Data Quality Analysis

Data Characteristics	Argument	Binary Score
Accuracy	Exact	1
Completeness	In rejecting Hypothesis six according to which the united states is the leading technological exporter of the world, we did not have complete information as many Us Firms produce their goods outside US territories	0
Consistency	Data are uniform	1
Timeliness	Years specified	1
Relevant	Results are insightful	1
Validity	Data specifically measures R&D and Exports	1
Reliability	Same results can be replicated	1
Accessibility	https://data.worldbank.org/indicator	1

Further research could address the limitation of data incompleteness and enhance the analysis of US firms' exports from outside the United States territories. While the study scores 7 out of 8 in data quality analysis, there is still potential to improve the reliability of the results.

5. Conclusion

5.1 Contributions, Findings and Implications

The study's findings suggest that while technological development in the United States may not directly contribute to economic growth through the sale of high-tech products, it does have an indirect impact by improving the efficiency and effectiveness of producing other goods and services, thanks to the use of technology

Moreover, the study's finding that human capital in research and development has a greater impact on economic growth than monetary investment in R&D underscores the value of individual creativity and innovation. Therefore, rather than solely focusing on funding research and development, governments should prioritize education and support for individuals. The study clearly shows that human capital is key to technological advancement, including in the field of artificial intelligence, and to economic growth as measured by GDP.

Finally, investors and potential investors can now make evidence-based decisions when investing in technology and artificial intelligence. With the importance of technology projected to continue growing for the next decade, these investments offer a high chance of realizing profits. To maximize returns, investors should focus on sectors rather than geography, as the United States is among the world's top technology exporters but not the sole leader.

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