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Unveiling the Economic Impact of Technology Trade in Leading Global Economies

Maxim CETULEAN*
Bucharest University of Economic Studies[1], Bucharest, Romania
**Corresponding author, maximcetulean@gmail.com*

Laurențiu-Mihai TĂNASE
Bucharest University of Economic Studies, Bucharest, Romania
laurentiu.tanase95@yahoo.com

Abstract. *In today's rapidly evolving technological era, high-tech trade is not just a part of international commerce but a key factor that shapes the economic landscapes of nations. The objective of this paper is to analyze how technological innovation, as represented by high-tech exports, contributes to economic growth and to identify the disparities in economic progress among countries with different levels of integration into the global high-tech market. This paper focuses on the importance of high-technology trade in economic development. Specifically, it aims to establish a connection between technology-intensive exports and Gross Domestic Product in three major global economies: China, the United States, and the European Union. The study's empirical evidence strongly supports a notable association between high-technology exports and the growth of gross domestic product, thereby reaffirming the crucial role of technological trade in enhancing economic development. Furthermore, the analysis provides additional insight by highlighting those economies with extensive involvement in the global high-technology market experience superior economic growth. This underscores the vital significance of technological innovation and trade integration in attaining a competitive advantage in the global economic landscape. This study adds to the existing literature by providing empirical evidence of the economic consequences of technology trade, highlighting the need for policy frameworks that encourage innovation and integration into the global high-technology market.*

Keywords: high-technology trade, economic growth, international commerce, innovation, global market.

Introduction

In the current era of globalization and digital transformation, the exchange of technology-based goods and services plays a crucial role in driving economic development and progress (Schwab, 2016). With increasing interconnectedness across the globe, the flow of innovative products and digital solutions across borders is reshaping the economic landscapes of nations, fueling growth, and propelling industries towards greater efficiency and competitiveness (Gomes & Dias, 2023). This study aims to delve into the intricate relationship between technology exports and Gross Domestic Product (GDP) growth in three key economies: the European Union, China, and the United States. By closely examining these regions, the research endeavors to uncover the nuanced dynamics that govern the economic strategies of the digital era.

The analyzed regions hold immense significance not only as markets for technology-based goods and services but also as drivers of innovation and digital progress. The role of technology in fostering economic growth cannot be emphasized enough (Beckman & Sinha, 2005). It serves as

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a catalyst for transforming traditional industries, opening up new markets, and revolutionizing consumer experiences (Alecke et al., 2006). Despite their shared prominence, each of these economies follows a unique approach and trajectory in adopting and incorporating technology into their economic frameworks.

The European Union's approach to technology trade is characterized by a focus on regulatory frameworks that aim to strike a balance between market growth, data protection, and consumer rights (Aydalot & Keeble, 2018). This approach aligns with the EU's broader commitment to sustainable development and social welfare, which may moderate the pace of technological adoption but ensures long-term economic resilience and inclusivity (Hunady et al., 2022). In contrast, China's technology sector has experienced rapid growth due to aggressive investments in innovation and a state-supported model that prioritizes global competitiveness (Cui et al., 2023). This strategy has propelled China to become a dominant force in technology exports, reshaping global trade patterns and significantly impacting its GDP trajectory (Danli & Xiaojie, 2023). On the other hand, the United States combines a strong culture of innovation with a laissez-faire economic policy, creating an environment that fosters technological breakthroughs and entrepreneurial ventures. This has positioned the United States as a global leader in high-tech exports, driving economic growth and solidifying its role as a central hub in the digital economy (Bieri, 2010).

The importance of this subject cannot be overstated, as technology trade not only drives innovation and competitiveness but also plays a crucial role in determining the economic health and strategic positioning of nations on the global stage. By examining the relationship between GDP and technology exports, this research seeks to provide insights into the economic benefits and challenges posed by technology trade, thereby informing policy decisions and strategic initiatives aimed at harnessing the potential of technology for economic advancement (Sanli &Konukman, 2021).

Employing a unifactorial linear model as the primary instrument of analysis, this study adopts a quantitative approach to investigate the correlation between technology trade and GDP growth. The choice of a unifactorial linear model is instrumental in isolating the impact of technology exports on economic indicators, allowing for a precise and nuanced understanding of the economic dynamics at play. This methodological approach underscores the rigor and depth of the analysis, ensuring that the findings are robust, relevant, and capable of contributing significantly to the existing body of knowledge on the economic implications of technology trade.

In addressing this research topic, the study highlights the critical role of technology trade in shaping the economic trajectories of the European Union, China, and the United States. By identifying the correlation between GDP and technology exports, the research provides valuable insights into how these economies leverage technology trade as a catalyst for economic growth and development. Furthermore, the study explores the broader implications of these findings, including the potential for technology trade to drive innovation, enhance global competitiveness, and foster economic resilience in the face of global challenges.

Therefore, it is essential to recognize the importance of the subject and the approach undertaken. This research not only contributes to our understanding of the economic impact of technology trade but also offers a framework for policymakers, scholars, and industry leaders to navigate the complexities of global economic integration in the digital age. Through a rigorous examination of the correlation between GDP indicators and technology exports, this study provides a critical lens through which the economic significance of technology trade can be assessed, paving the way for informed decision-making and strategic planning in the pursuit of economic prosperity.

The rest of paper is organized as follows: We begin by exploring relevant literature that constructs a conceptual framework, shedding light on the two main aspects of our investigation, the impact of high-tech exports on economic growth and the driving forces behind the increase in high-tech exports in the context of economic development. This section aims to analyze the theoretical foundations and empirical data that emphasize the importance of digital transformation in shaping the dynamics of high-tech exports and their role in promoting economic prosperity.

After conducting the review of the relevant literature, we proceed to provide an explanation of the methodology employed in our study to investigate the correlation between gross domestic product (GDP) and exports of high technology (HT) products. This section holds utmost importance as it not only elucidates the analytical techniques utilized but also highlights the sources of data that were employed to accurately measure the relationship between these variables.

In the following section, we disclose the results of our study, highlighting the significant discoveries that arise from analyzing the data. This segment of the paper is devoted to elucidating the prominent trends and patterns that have been identified.

In the final section of the paper, we present our conclusions by synthesizing the findings and observations derived from our analysis. Also, this section highlights potential areas for future research.

Literature review

A comprehensive understanding of economic dynamics is essential when examining the intricate connection between technology trade and economic growth in global economies, particularly in the United States, the European Union, and China. The interplay between these factors emphasizes the crucial impact of digital transformation and the exportation of high-tech technologies on economic growth. It underscores the complex relationship between GDP and high-tech exports. Recent studies have placed greater emphasis on understanding the factors that determine high-tech exports. These studies reveal that GDP, trade policies, and technological advancements are key influencers that shape the international trade landscape for technology-intensive goods and services (Navarro Zapata et al., 2023).

The intricate connection between technology, trade, and economic expansion in worldwide economies, particularly in the United States, the European Union, and China, illuminates the need for a nuanced comprehension of economic dynamics. The crucial impact of digital transformation and the exportation of advanced technologies becomes prominent factors that shape economic growth, highlighting the intricate correlation between GDP and high-tech exports (Kheyfets & Chernova, 2021). Research has increasingly concentrated on identifying the drivers behind high-tech exports, uncovering the significant influence of factors such as GDP, trade policies, and technological progress in shaping the framework of international trade in technology-driven goods and services.

Numerous economies have provided evidence of the impact that high-technology exports and intellectual property charges have on economic growth. This evidence indicates a positive connection between the exportation of high-tech goods and the expansion of national economies. Furthermore, studies analyzing the macroeconomic factors of export-driven economies support this correlation, as they demonstrate a direct link between GDP and export volume. Consequently, these findings emphasize the crucial role that export activities play in promoting economic well-being.

Studies comparing the impact of technological factors on economic growth in different countries, including the United States and China, have consistently shown that increased

investment in research and development (R&D) and the exportation of high-tech products have a substantial positive effect on GDP growth. Additionally, the significance of human resources in the fields of science and technology has been recognized as a critical national asset, influencing the proportion of high-tech exports in total exports and emphasizing the interconnectedness between R&D spending, human resources in science and technology, and high-tech exports (Enăchescu & Zaharia, 2014).

While a lot of economies have shown remarkable resilience during times of global economic turmoil, it is important to note that the connection between exports and GDP growth differs among countries. This suggests that exports alone do not solely drive macroeconomic expansion. Additionally, the correlation between the export of high-tech industries and GDP growth in both developing and developed nations underscores the significance of technological progress and high-tech exports in fostering economic advancement (Sojoodi & Baghbanpour, 2023).

The relationship between CO2 emissions, high-tech exports, GDP per capita, and environmental sustainability has been thoroughly examined, revealing the crucial role of high-technology product production in mitigating emissions and fostering economic progress (Daysi et al., 2021). Additionally, the influence of innovation inputs, such as researchers and R&D expenditure, on innovation outputs, including patent grants and high-tech exports, sheds light on how technological advancements impact trade and economic growth. As a result, the economic implications of technology trade in leading global economies are multifaceted, involving a complex interplay between technological innovation, high-tech exports, GDP growth, and environmental sustainability. The findings from numerous studies emphasize the importance of technology trade in shaping the economic trajectories of major global economies, emphasizing the need for policies that support technological advancements and the trade of high-tech goods and services (Gürler, 2022).

The foundation of economic prosperity for countries lies in the exportation of high-tech goods, including advanced manufacturing products, software, and services. These exports are not just simple transactions; they serve as a reflection of a nation's innovation ecosystem, the intensity of research and development (R&D), and their technological capabilities. The connection between a country's GDP and its high-tech exports is based on the belief that technology-driven products bring significant value, command premium prices in the market, and have the potential to greatly enhance a nation's economic performance (Kuzu & Arslan, 2023).

Creating an atmosphere that promotes the advancement of technology plays a crucial role in boosting a nation's ability to export high-tech products. This requires significant investments in research and development, both from public and private entities, as well as the implementation of policies that foster innovation, safeguard intellectual property, and facilitate the transformation of research into commercial ventures. By cultivating such an ecosystem, not only are domestic technologies nurtured, but international talent and investments are also attracted, thereby strengthening the cycle of innovation and driving economic prosperity.

The economic trajectories of nations are heavily influenced by the exchange of advanced technological goods on a worldwide level. Kheyfets and Chernova (2021) emphasize the cases of the United States and China, illustrating how deliberate investments in research and development and cutting-edge technology can result in substantial increases in GDP. These two countries have successfully utilized their technological prowess to establish dominance in global markets for high-tech exports, encompassing a wide range of products such as semiconductors and renewable energy technologies.

The significance of human resources in the realm of science and technology cannot be emphasized enough. A proficient and inventive workforce serves as the foundation for any prosperous strategy aimed at exporting high-tech products. It is imperative to invest in education, promote lifelong learning, and foster the development of a STEM (Science, Technology, Engineering, and Mathematics) workforce in order to uphold the necessary competitive advantage in the fiercely contested global market for high-tech goods and services.

The significance of the correlation between GDP and high-tech exports in relation to economic development cannot be overstated. Nations that effectively incorporate technology trade into their strategies for economic advancement have the potential to experience long-term growth, generate high-quality employment opportunities, and enhance their trade surpluses. Furthermore, by actively participating in the global technology value chain, countries can diversify their economies, decrease reliance on conventional industries, and fortify themselves against economic recessions (Cheong, 2023).

Methodology

In order to explore the correlation between Gross Domestic Product (GDP) and the exportation of high-tech technologies in three prominent global economies (the United States of America, the European Union, and China), this study employs a quantitative methodology.

The core of the methodology revolves around the implementation of a linear regression analysis with a single factor, which seeks to examine the correlation between a nation's Gross Domestic Product (GDP) and its exports in the high-tech sector. The objective is to measure the extent to which fluctuations in high-tech exports influence the GDP of various economies, with particular emphasis on the United States, European Union, and China.

Accordingly, we will note here the equation of the linear regression model:

$$Y = a + bx + u \quad (1)$$

Y assumes the real values of the dependent variable, respectively of the gross domestic product; *x* assumes the real values of the independent variables, for one of the analyzes it will be high-tech exports; *a* and *b* represent parameters of the model; and *u* assumes the residual variable that signifies the influence of other factors on *Y*.

The parameter *b* is estimated by the following formula:

$$\hat{b} = \frac{n \cdot \sum y_t x_t - \sum x_t \cdot \sum y_t}{n \cdot \sum x_t^2 - \sum x_t \cdot \sum x_t} \quad (2)$$

In the formula (2), *n* implies the number of observations. The analysis we propose has 10 observations because the data collected covers a period of 10 years, namely 2013-2022.

The World Bank Database served as the primary source of data for this study, covering an extensive timeframe from 2013 to 2022. The data gathering process specifically targeted two key economic metrics: Gross Domestic Product (GDP) measured in present-day US dollars, and High-technology exports, also quantified in present-day US dollars. These metrics were chosen to offer a deeper understanding of the worldwide economic panorama, analyzing the progression of individual country economies and the significance of high-technology industries in fostering economic expansion and advancement.

After collecting the necessary data, it has been determined that the most suitable tool for conducting the linear regression analysis is the eViews software. The decision to use eViews is

based on its established proficiency in handling time-series data, as well as its user-friendly interface specifically designed for econometric analysis. This software streamlines the analysis process and effectively addresses the complexities of the data being examined.

To establish the analytical framework, a unifactorial linear regression model is employed. This model seeks to illustrate the relationship between a country's GDP at a particular time and its high-tech exports during that period. It includes variables for the intercept, slope coefficient, and error term, which are crucial in framing the expected association between GDP and high-tech exports.

The estimation of this model involves the utilization of the Ordinary Least Squares (OLS) approach. This particular step holds immense importance as it allows us to ascertain the magnitude and characteristics of the connection between the dependent (GDP) and independent (HT exports) variables. The t-tests are employed to carefully examine the significance of the regression coefficients, providing valuable information regarding the specific effects of high-tech exports on GDP. Additionally, the overall adequacy of the model is assessed using R-squared and F-statistics, which provide a measure of the model's ability to explain the data.

Results and discussions

The following table includes data regarding the evolution of the gross domestic product and the evolution of high-tech products export in China, United States of America, and European Union in the period 2013-2022.

Table 1. Evolution of GDP and HT exports in United States of America, European Union and China

Year	United States of America		European Union		China	
	GDP (current mil. $)	***HT exports (current mil. $)***	***GDP (current mil. $)***	***HT exports (current mil. $)***	***GDP (current mil. $)***	***HT exports (current mil. $)***
2013	16.843.190	169.222	15.294.695	642.201	9.570.471	655.897
2014	17.550.680	175.881	15.651.155	666.701	10.475.624	653.847
2015	18.206.020	175.243	13.553.676	607.990	11.061.572	652.212
2016	18.695.110	173.921	13.888.512	631.859	11.233.313	594.520
2017	19.477.336	154.545	14.765.543	631.895	12.310.491	654.156
2918	20.533.057	153.808	15.980.992	682.764	13.894.907	731.318
2019	21.380.976	153.923	15.693.432	692.289	14.279.968	715.302
2020	21.060.473	141.538	15.381.174	643.134	14.687.744	757.458
2021	23.315.080	169.217	17.315.218	760.952	17.820.459	942.314
2022	25.439.700	166.435	16.746.544	837.001	17.963.171	769.699

Source: The World Bank, World Development Indicators [Accessed 10 February 2024].

According to the correlogram in Figure 1, the links between the two variables can be approximated with a straight line, which implies that the model is linear.

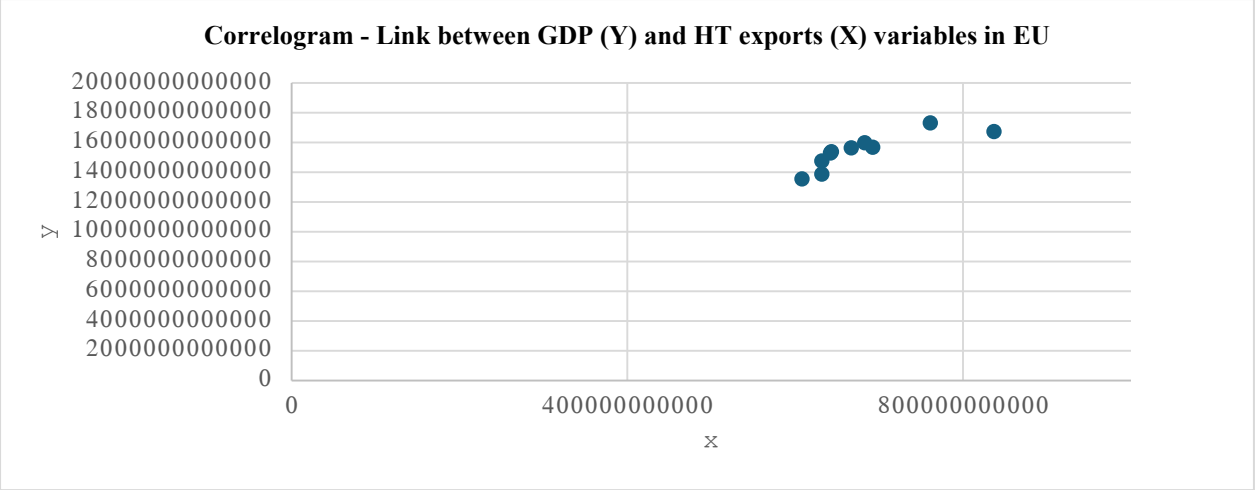

Figure 1. Link between GDP (Y) and HT exports (X) variables in EU

Source: Authors' own data processing in Excel, based on the data from Table 1.

According to Figure 2, the results of parameter b show that when HT export increases by one unit GDP increases by 13.80368 units in the EU.

With an R-squared of 0.69, the model explained 69% of the variation of the variable y, representing an acceptable result. Regarding the independence of the errors, we will consider the Durbin Watson test result which shows a value of 1.56 (d). Taking from the Durbin Watson table the values 0.879 (d1) and 1.32 (d2) for a significance threshold of 0.5, we found that d2<d<4-d2, so the errors are independent.

Dependent Variable: GDP
Method: Least Squares
Date: 02/23/24 Time: 21:52
Sample: 2013 2022
Included observations: 10

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	6.05E+12	2.20E+12	2.750571	0.0250
HTE	13.80368	3.218148	4.289326	0.0027

R-squared	0.696950	Mean dependent var	1.54E+13
Adjusted R-squared	0.659069	S.D. dependent var	1.16E+12
S.E. of regression	6.76E+11	Akaike info criterion	57.49404
Sum squared resid	3.66E+24	Schwarz criterion	57.55456
Log likelihood	-285.4702	Hannan-Quinn criter.	57.42766
F-statistic	18.39832	Durbin-Watson stat	1.561930
Prob(F-statistic)	0.002654		

Figure 2. Estimation of the impact of HT exports (X) on GDP (Y) in EU

Source: Authors' own data processing in eViews, based on the data from Table 1.

In order to test the hypothesis of homoscedasticity, on the basis of which it can be admitted that the connection between Y and X is relatively stable, we chose the graphical method for which we made a correlogram between the variables x and u.

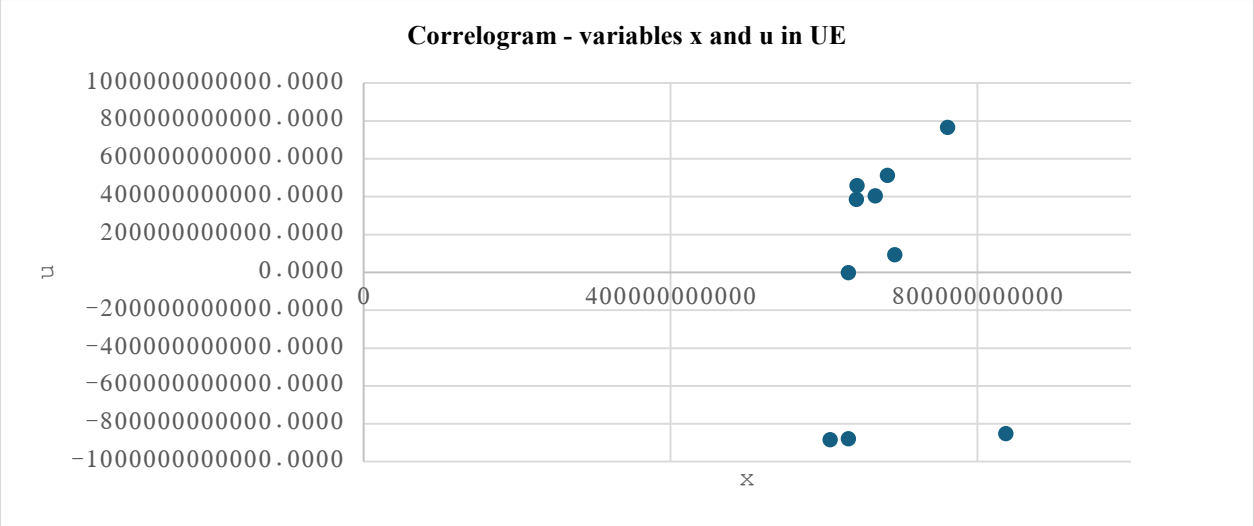

Figure 3. Link between variables x and u in EU

Source: Authors' own data processing in Excel, based on the data from Table 1.

Since the plot of empirical points shows an oscillating distribution, the hypothesis that the two variables are independent and not correlated can be accepted.

For the USA, the analysis is as follows:

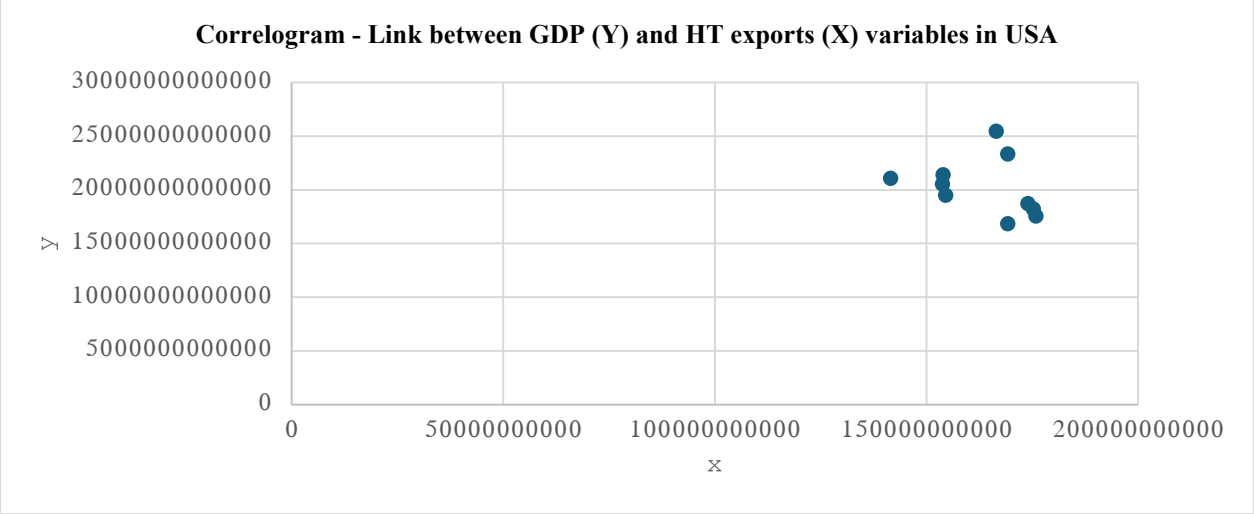

Figure 4. Link between GDP (Y) and HT exports (X) variables in USA

Source: Authors' own data processing in Excel, based on the data from Table 1.

According to the correlogram in figure 4, the links between the two variables cannot be approximated by a straight line, which implies that the model is not linear.

Dependent Variable: GDP
Method: Least Squares
Date: 02/23/24 Time: 22:35
Sample: 2013 2022
Included observations: 10

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.16E+13	1.27E+13	2.492981	0.0373
HTE	-69.41940	77.38856	-0.897024	0.3959

R-squared	0.091389	Mean dependent var	2.03E+13
Adjusted R-squared	-0.022187	S.D. dependent var	2.68E+12
S.E. of regression	2.71E+12	Akaike info criterion	60.26706
Sum squared resid	5.85E+25	Schwarz criterion	60.32758
Log likelihood	-299.3353	Hannan-Quinn criter.	60.20067
F-statistic	0.804652	Durbin-Watson stat	0.453039
Prob(F-statistic)	0.395897		

Figure 5. Estimation of the impact of HT exports (X) on GDP (Y) in USA
Source: Authors' own data processing in eViews, based on the data from Table 1.

According to Figure 5, the results of parameter b show that when HT export increases by one unit GDP increases by -69.41940 units in the USA.

With an R-squared of 0.09, the model explained 9% of the variation in the variable y, therefore, in the case of the USA, the results are not relevant.

For the China, the analysis is as follows:

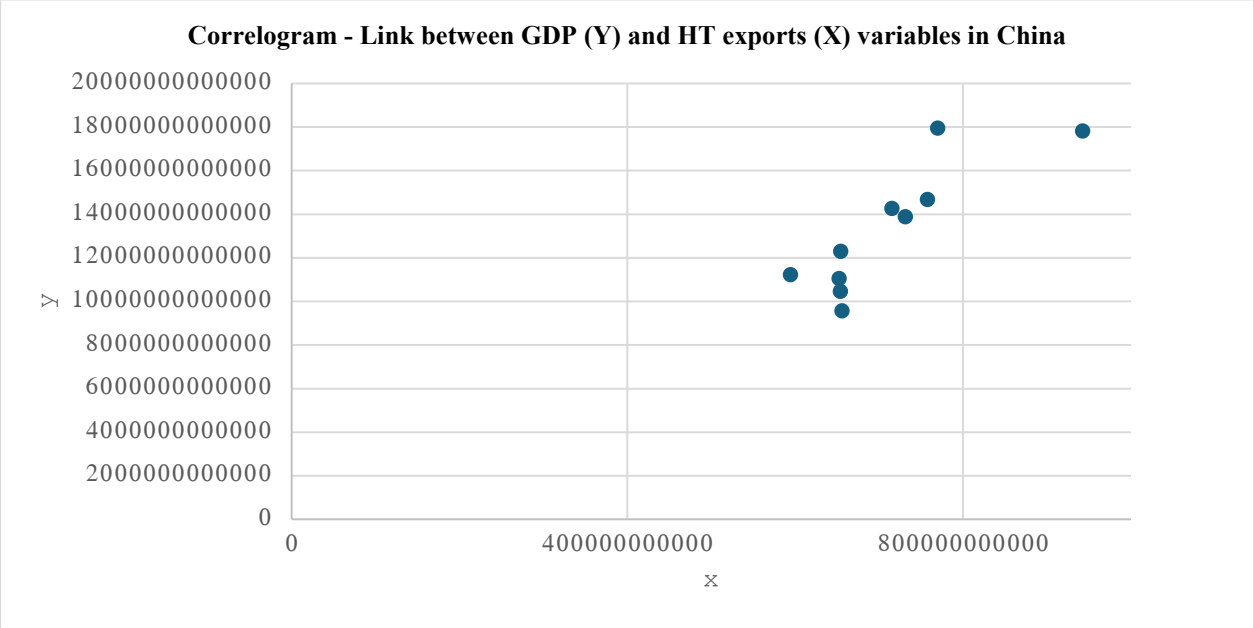

Figure 6. Link between GDP (Y) and HT exports (X) variables in China
Source: Authors' own data processing in Excel, based on the data from Table 1.

According to the correlogram in Figure 6, the links between the two variables can be approximated with a straight line, which implies that the model is linear.

Dependent Variable: GDP
Method: Least Squares
Date: 02/23/24 Time: 22:48
Sample: 2013 2022
Included observations: 10

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-4.85E+12	4.02E+12	-1.204665	0.2628
HTE	25.50383	5.597427	4.556349	0.0019

R-squared	0.721839	Mean dependent var	1.33E+13
Adjusted R-squared	0.687069	S.D. dependent var	2.94E+12
S.E. of regression	1.64E+12	Akaike info criterion	59.26881
Sum squared resid	2.16E+25	Schwarz criterion	59.32933
Log likelihood	-294.3440	Hannan-Quinn criter.	59.20242
F-statistic	20.76032	Durbin-Watson stat	1.325190
Prob(F-statistic)	0.001859		

Figure 7. Estimation of the impact of HT exports (X) on GDP (Y) in China
Source: Authors' own data processing in eViews, based on the data from Table 1.

According to Figure 7, the results of parameter b show that when HT export increases by one unit GDP increases by 25.50383 units in China.

With an R-squared of 0.72, the model explained 72% of the variation of the variable y, representing an acceptable result. Regarding the independence of the errors, we will consider the Durbin Watson test result which shows a value of 1.32 (d). Taking from the Durbin Watson table the values 0.879 (d1) and 1.32 (d2) for a significance threshold of 0.5, we found that d2<d<4-d2, so the errors are independent.

In order to test the hypothesis of homoscedasticity, on the basis of which it can be admitted that the connection between Y and X is relatively stable, we chose the graphical method for which we made a correlogram between the variables x and u.

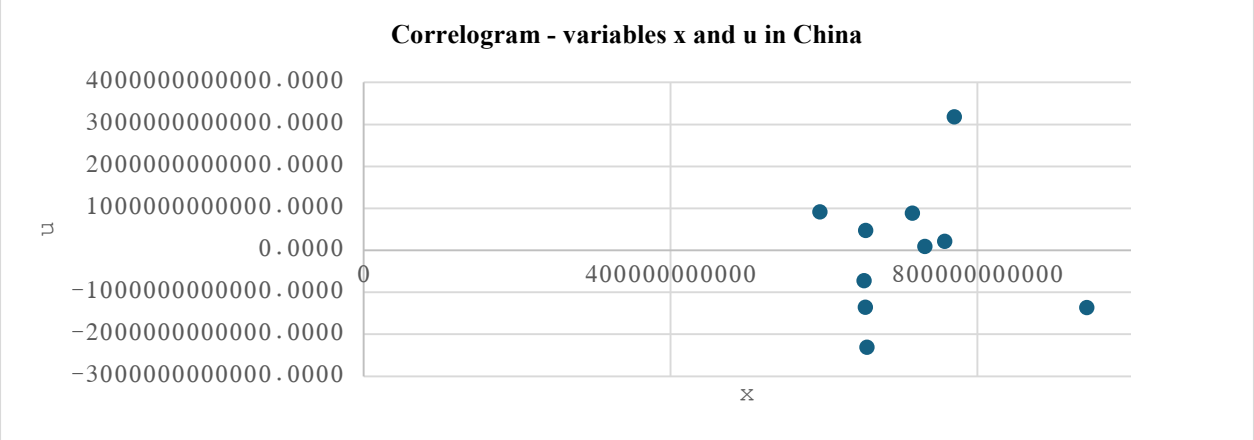

Figure 8. Link between variables x and u in China
Source: Authors' own data processing in Excel, based on the data from Table 1.

Since the plot of empirical points shows an oscillating distribution, the hypothesis that the two variables are independent and not correlated can be accepted.

Therefore, in the EU, the strong and significant association between high-tech exports and GDP expansion emphasizes the crucial significance of the technology sector in driving economic progress. The statistical findings, which demonstrate a substantial impact of high-tech exports on GDP, accounting for approximately 69% of the variation, indicate that the EU's economic well-being increasingly hinges on its capacity to innovate and compete effectively in the global high-tech market.

On the other hand, the situation in the United States is quite intricate, as the expected positive impact of high-tech exports on GDP growth does not unfold in a straightforward manner. The complexity arises from the absence of a significant linear relationship and a model that only explains less than 10% of the variability in GDP.

During this period, China's economic tale unfolds as one of swift advancement, encompassing not only GDP growth but also the surge in high-tech exports. The nation's ever-growing supremacy in the global high-tech sector, coupled with its significant economic expansion, indicates a mutually advantageous association between the two.

Conclusion

The significance of the tech sector in driving economic progress is highlighted by a strong connection between high-tech exports and GDP growth in the EU. Approximately 69% of the variation in GDP can be attributed to high-tech exports. In contrast, the relationship between high-tech exports and GDP growth in the U.S. is more intricate, indicating a diverse economy where high-tech exports do not have a direct impact on growth. China, on the other hand, showcases a narrative of rapid advancement, with a clear positive correlation between increasing high-tech exports and GDP growth. This further emphasizes the crucial role of technology and innovation in their economic development strategies.

Therefore, this study illuminates the transformative role of high-tech trade in economic development, demonstrating empirically how technological exports are pivotal for GDP growth in major economies like China, the USA, and the EU. This novel insight into the economic benefits of high-tech trade enriches the discourse on technology's impact on global economic dynamics.

There are multiple avenues for future discussions and research directions that arise from the divergent situations observed in the EU, USA, and China. In the case of the EU and China, it would be beneficial to conduct further analysis on the specific sectors that are propelling the growth of high-tech exports and their broader impacts on the economy, both direct and indirect. Exploring the influence of government policies, education systems, and international trade agreements in creating an environment that fosters innovation and promotes high-tech exports would provide valuable insights. As for the USA, a multidimensional analysis is required to understand the reasons behind the complex relationship between high-tech exports and GDP growth. This analysis could potentially investigate the role of service sectors, intellectual property, and the characteristics and size of the domestic market. Furthermore, the possible reason behind the lack of a notable connection between the growth of the United States' GDP and the export of high-tech products can be attributed to the country's diverse economy and the significant importance of domestic consumption. The U.S. economy thrives on various sectors such as finance, healthcare, services, and technology, which may diminish the impact of high-tech exports on overall GDP growth. Additionally, the substantial domestic market for high-tech goods and services, characterized by

strong consumer spending, could overshadow the contributions made by exports to economic expansion. This implies that the production and consumption of high-tech goods and services within the country play a more crucial role in driving the U.S. economy than exports alone.

The intricate global value chains and the U.S.'s prominent role in technological innovation add complexity to this correlation. The economic benefits of high-tech industries in the U.S. are not solely reliant on exports but also stem from domestic activities and global operations. Additionally, statistical limitations, economic policies, trade agreements, and regulations further complicate this relationship. To fully understand the impact of high-tech exports on GDP growth, it is crucial to develop more nuanced economic models that consider indirect effects, feedback loops, and the multifaceted nature of high-tech industries.

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