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The geopolitics of technology: Evidence from the interaction between the United States and China

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Abstract

Recently researchers performed empirical economic studies to investigate how geopolitical risk impacts diverse economic sectors. We take a fresh perspective by exploring whether advancements in the U.S. IT sector can account for fluctuations in China's geopolitical risk. The conflict between China and the United States regarding semiconductors revolves around technological supremacy, economic dominance, and national security concerns. China has been striving to become self-sufficient in semiconductor production to reduce reliance on foreign suppliers, particularly the United States. However, the United States has imposed restrictions on semiconductor exports to China. Our study constructs a theoretical framework and utilizes the bounds testing approach for cointegration to estimate the parameters of the Autoregressive Distributed Lag model. We use monthly data from January 1993 to November 2023. The findings reveal that the U.S. IT sector significantly and positively influences China's geopolitical risk. From a policy implication perspective, the race to lead the global IT sector may emerge as the primary source of economic and political instability unless rival nations reach a compromise.

Keywords: geopolitical risk, geopolitics of technology, information technology, ARDL model, United States, China.
JEL classification: C22, D83, E02, F51.

1. Introduction

Merriam-Webster dictionary defines Information Technology (IT) as "the technology involving the development, maintenance, and use of computer systems, software, and networks for the processing and distributing data." IT has been widely used in all economic sectors. It helps these sectors to build, grow, and generate maximum output by enhancing total factor productivity (TFP).

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These benefits can be achieved by automating their processes, reducing work inefficiencies, provide accurate information and data about various commercial transactions. Many scholars, i.e., Oliner and Sichel (2000), Jorgenson and Stiroh (2000), Jorgenson (2001), Jorgenson et al. (2004), pointed out the significance of IT's role in boosting the growth of U.S. labor productivity in the second half of the 1990s, and concluded that IT increased U.S. economic growth. On analyzing the firm-level investment in IT sector, Kudyba and Diwan (2002) surveyed 500 U.S. firms using IT during the period (1994–1997) and found that investment in IT enhances the firms' productivity. Likewise, Fueki and Kawamoto (2009) examined the association between IT and TFP on data from Japan industrial-level firms. They found that IT can justify the increase in Japanese industrial productivity. Recently, Goldstein et al. (2023) found that utilizing IT tools increases corporate investment, particularly in firm value. It also enhances equity financing and amplifies managerial incentives. Furthermore, Trieu et al. (2023) concluded that IT boosts the performance of small and medium-sized enterprises (SMEs) and strengthens their organizational resilience. The previous empirical works confirmed the significant influence of IT on economic growth.

Nowadays, the emergence of new technologies, such as artificial intelligence, 5G telecommunications, and big data, is critical to economies, mainly to the financial services industry, supporting new products and services, and changing operational processes. More specifically, these new evolving technologies can help firms promote investment strategies and loan valuation, enhance human capital achievements, improve product development and customer relations via controlling data, strengthen cybersecurity and fraud detection, and expand mobile capabilities and services.

Currently, the IT international market has substantial competition between American companies, i.e., Apple, Alphabet, and Microsoft, and Chinese companies, i.e., Huawei, Tencent, and JD.com, to dominate the international IT market. This kind of rivalry between the two largest economies in the world may increase the geopolitical risk between the two nations. The famous incident of arresting Huawei CFO in Canada on December 1, 2018, is an excellent example of this rivalry and tension between the two countries because of the IT industry. The arrest was based on a legal charge made by the United States authority, who claimed that Huawei's CFO is violating the United States sanctions against Iran and its technology, which is a real threat to U.S. national security. A few days later, China retaliated and arrested two Canadian citizens, a businessman and diplomat.[1]

In the same vein, İşeri (2009) explained that the United States global hegemonic strategy for the 21st century can be attained by utilizing different tools. It includes the intervention in the international oil and foreign exchange markets. This intervention will generate a redistribution income effect, benefiting some nations and penalizing others. Therefore, it is expected to boost geopolitical tensions and conflicts. President Trump's administration launched the trade war against China in 2018 (Blanchard et al., 2024). Zhang and Shi (2020) stated that President Trump's administration intended to break down the U.S.−China economic relationships. They argued that decoupling the policies between the two nations can cause a high

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[1] https://thediplomat.com/2021/08/what-will-happen-in-huawei-cfo-meng-wanzhous-canada-extradition-case/

cost to the United States economy that it cannot bear, and thus, ends in vain. Wong (2021) argued that the IT competition between the two countries is the primary source of their ongoing unsettling rivalry. Technically, there are many reasons behind the geopolitical risk. One reason could be that IT companies face punitive costs or obligations when located in foreign jurisdictions. China and Europe have relatively more rigorous rules. Geopolitical risk also upsurges when competing IT dominant firms seek to extend their standards abroad and tilt international regulations in their favor (Brown, 2019).

The current study is motivated mainly by the fact that there is rivalry between the United States and China. We believe exploring this topic can enrich knowledge of geopolitical risk. There are minimal empirical studies conducted so far on the geopolitics of technology or using the IT sector as a determinant of geopolitics evolution. Thus, the current research aims to contribute to this new research strand and find evidence on whether the development of the U.S. IT sector can explain the fluctuations in China's geopolitical risk. The general aim of the current research is to examine the factors that initiate it. In a recent work, Sweidan (2023d) showed that the United States macroeconomic variables impact international geopolitical risk. He designed a theoretical framework and computed an econometric model utilizing the Autoregressive Distributed Lag methodology and quarterly data over the period 1973–2020. In the same vein, Khan et al. (2022) investigated the causality between global geopolitical risk and technology development using the rolling window approach. Their results showed bidirectional causality between the two variables. They used global research and development expenditures as a proxy for technology development. In contrast to Khan et al. (2022) work, our study is different in many respects, such as the methodology, the nature of the variables or their proxies, and the spatial domain of the work. The rest of our study is organized as follows: Section 2 highlights the roots of the U.S.–China tech war. Section 3 presents a relevant literature review on this topic. Section 4 introduces our study's theoretical framework, data, and methodology. Section 5 displays the empirical results and analysis. Conclusions and policy implications are introduced in Section 6.

2. Roots of the U.S.–China tech war

Throughout the history, scientific and technological collaboration has been vital to the U.S.–China economic relations. Following the Cold War, the process of globalization facilitated the integration of China's abundant low-skilled labor into the operations of the United States and Western firms. Consequently, they shifted the lower and middle segments of industrial value chains to the Chinese mainland while maintaining strict controls over technology exports to China. This strategy facilitated China's integration into the global economic framework and industrial networks to influence its political trajectory according to their preferences (Haiyong, 2019).

Against the abovementioned desire, China built a strong economy, including a significant IT sector. It converted China into a geopolitical competitor rather than a partner in the United States hegemonic plan (Mastanduno, 2019). As a result, the two nations went through a geopolitical conflict motivated by the economic rivalry of which the IT sector is a critical title. Danilin (2021) reported that the emergence of the digital economy and the significance of IT as a strategic sector have made traditional geopolitical and economic conflict forming a distinct battleground for tensions between the two nations. Furthermore, he asserted that the tech war had been codified in U.S. official documents, i.e., the United States Department of Defense and the United States Department of State. Arežina (2019) stated that since President Trump took office in January 2017, he had disrupted establishing international norms on various fronts, notably by reorienting the United States policy towards China to emphasize geopolitical rivalry despite their economic interdependence.

Recently, the United States has announced a series of restrictions on tech exports, mainly chips and semiconductors, to China.[2] The rationale for this action is to control the rival power of China by preventing the export of any type of critical defense and advanced technology transfer from the United States and its allied nations.[3] The United States is the leading producer of semiconductors internatinally with a global market share of 48% in 2022.[4] Undoubtedly, China retaliated against these actions and relied on various strategies, such as alternative import sources, loopholes in the United States restrictions, and a focus on domestic innovation (Jiang, 2023). Moreover, China launched a cybersecurity review of Micron, the leading U.S. producer of memory chips. Then, China's regulators banned purchases of Micron chips in China's critical infrastructure sector. After that, China announced restrictions on exporting gallium and germanium, two minerals that are essential critical raw materials for electronics manufacturing.[5] These actions and reactions between the two nations boosted tension and conflict under the title "*threatening national security*." A recent report from Citi researchers shows that China registered a sharp decline in producing and trading chips or integrated circuits in 2022 and 2023.[6]

Critical raw materials are the materials that are vital to economic growth, job creation, and improving quality of life. Besides, there is a high risk associated with their supply because it is concentrated in particular countries. As a subset of critical raw materials, rare earth materials are a relatively abundant group of seventeen elements and are considered substantial to technological advances (Filho et al., 2023). Critical raw materials have unique properties and are used in many significant applications and sectors, such as high-tech applications and industries, renewable energy technologies, and the defense industry. Many scholars (Vakulchuk et al., 2020; Gulley et al., 2019; Habib et al., 2016; Baldi et al., 2014) highlighted the geopolitical implications of critical raw materials because of their expected use and importance for these sectors. For example, those scholars anticipated that the expansion in the usage of renewable energy would reduce reliance on petroleum resources and thus raise the demand for critical raw materials. The expected increase in demand for rare materials will increase dependence on them and intensify international competition. Accordingly, the growing demand for various metals and minerals has profound security implications that could result in geopolitical instability. More importantly, the unequal allocation of these critical raw materials among nations might

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[2] See Jiang (2023) for more details.

[3] Haiyong (2019) documented the United States procedures and actions against China.

[4] The Semiconductor Industry Association Report for 2023. Available at: https://www.semiconductors.org/wp-content/uploads/2023/07/SIA_State-of-Industry-Report_2023_Final_072723.pdf

[5] https://edition.cnn.com/2023/07/04/tech/china-export-controls-semiconductor-war-explainer-intl-hnk/index.html

[6] https://www.citigroup.com/global/insights/global-insights/who-s-winning-the-us-china-chip-war-

be a permanent source of geopolitical tension at the global level. Table 1 introduces the world's rare earth materials production by major international producers. It shows that China is the prominent owner or producer of these strategic materials. Besides, China produced around 70% of the world's rare earth materials production in 2022 compared to 14.3% for the United States. China owned around 97% of the world's rare earth materials in 2009.

Moreover, due to the dynamic feature of the international market on technology advances, some raw materials that are currently not identified as critical might become critical when new data or demand becomes available. Recently, Grohol and Veeh (2023) prepared a study about critical raw materials for the European Union (EU). The study's primary goal is to determine and identify the critical raw materials for the EU's economy and their current available resources. These materials have a high economic importance to the EU combined with a high risk associated with their supply. Grohol and Veeh (2023) presented over 80 critical raw materials that can be used in various manufacturing sectors. Based on Annex 6 of Grohol and Veeh (2023) study, we summarize in Table 2 the critical raw materials that can be used in producing IT equipment and tools, such as computers, electronics, and electrical equipment.

Grohol and Veeh (2023) analyzed the global supply of critical raw materials and found that China is the largest supplier of several critical raw materials, including the raw materials used in the IT sector. Appendix A of the current study displays the countries that have the largest share of critical raw materials. To introduce one of the core issues between the United States and China, Appendix A shows that China has the critical raw materials to produce significant parts of the electronics, such as chips/semiconductors. However, the United States produces cutting-edge chips and the equipment capable of making them.

Table 1
Rare earth mine production (thousand metric tons).

Country	2016	2017	2018	2019	2020	2021	2022
Australia	15.0	19.0	21.0	20.0	21.0	24.0	18.0
Brazil	2.2	1.7	1.1	0.7	0.6	0.5	0.08
Burma	NA	5.0	19.0	25.0	31.0	35.0	12.0
China	105.0	105.0	120.0	132.0	140.0	168.0	210.0
India	1.5	1.8	2.9	2.9	2.9	2.9	2.9
Russia	2.8	2.6	2.7	2.7	2.7	2.6	2.6
United States	NA	NA	18.0	28.0	39.0	42.0	43.0
World production	129.0	132.0	190.0	220.0	240.0	290.0	300.0

Source: United States Geological Survey, National Minerals Information.

Table 2
Critical raw materials utilized in the IT sector.

Arsenic	Beryllium	Borate	Cadmium	Cerium
Cobalt	Cooper	Europium	Fluorspar	Gadolinium
Gallium	Gold	Hafnium	Indium	Iridium
Lanthanum	Lutetium	Manganese	Natural rubber	Neodymium
Palladium	Platinum	Praseodymium	Rhodium	Ruthenium
Samarium	Selenium	Silicon metal	Silver	Terbium
Tin	Tungsten	Vanadium		

Source: Grohol and Veeh (2023).

3. Literature review

As stated above, the geopolitics of IT is a relatively new research area. There are no solid theoretical or empirical works that extensively cover this topic. This part, therefore, introduces the definition of geopolitical risk, its importance, and why IT can generate such a risk. The available literature stresses the critical role of IT in the future of various nations. Miailhe (2018) pointed out the significant role of IT in the future of various countries, mainly for nations such as the United States and China, by inspiring them to take the lead in the global economy. Likewise, Center and Bates (2020) noted that the growing strategic priority of technology in the various economic sectors would easily enhance the geopolitical tension among nations. Wu (2020) highlighted the critical and intense competition between the United States and China. He discussed whether this rivalry would lead the two nations into a vicious conflict or possibly into two coalitions with different ideologies, political values, and remarkably different economic models. Additionally, Fritsch (2011) found that technology was a significant factor in structuring the international economic system and highly integrated into international political affairs. Further, Fritsch (2017) concluded that technological progress reshaped the foreign policy decision-making mechanism, government behavior, and international conflict. The core of this effect is facilitating the process of gathering and analyzing the required data to speed up the decision-making procedures.

Recently, a growing body of literature has focused on investigating the influence of geopolitical risk on various economic sectors and indicators. For instance, several empirical works concluded that geopolitical risk has a significant impact on the energy sector (Sweidan, 2021a, 2021c; Mei et al., 2020), crude oil security (Wang et al., 2021), environmental degradation (Riti et al., 2022), natural resources rents (Sweidan and Elbargathi, 2022), economic fluctuations (Akadiri et al., 2020), financial stability and stock markets (Abbass et al., 2022; Selmi and Bouoiyour, 2020), bank stability (Phan et al., 2022), trade flows (Gupta et al., 2019), government investment (Bilgin et al., 2020), income inequality (Sweidan, 2023c; Wu et al., 2022), military expenditures (Sweidan, 2023a), and tourism sector (Hailemariam and Ivanovski, 2021). The work of Caldara and Iacoviello (2022) has been motivating all these empirical studies by computing and publishing a monthly geopolitical risk index.

In their work, Caldara and Iacoviello (2022) defined geopolitical risk as the threat, realization, and escalation of adverse events tied to conflicts, terrorism, and strains among nations and political bodies, causing disturbances in the peaceful state of global relations. It represents the international institutional vagueness arising from tensions, wars, military, and military-like actions. According to economic theory, any uncertainty, such as geopolitical risk, will postpone investments, reduce consumption, and wear away capital and foreign direct investment (Bloom, 2014; Wang et al., 2023). The IMF (2023) pointed out that increasing geopolitical tensions would reshape the flow of foreign direct investment across regions and sectors. The rise in geopolitical conflict suggests a reversal of the progress made in international economic integration over the past decades. Nguyen et al. (2023) corroborated that heightened geopolitical tensions could hinder the attainment of sustainable development goals. Nevertheless, many studies verified that geopolitical risk had no exclusive effect. It can encourage some sectors, i.e., renewable energy and energy returns,[7] other studies showed that it could impair other sectors, such as stock markets, trade flows, and tourism.[8] Accordingly, geopolitical risk can be viewed as a motivational tool to improve economic achievements.

Literature shows a critical gap in the current empirical works of understanding the determinants of geopolitical risk. Most of the empirical works in this research area looked at geopolitical risk as an exogenous variable, and focused on exploring its influence on various economic sectors and financial indicators. Very few empirical works explored the opposite research direction. In a recent study, Sweidan (2023d) examined whether the United States major macroeconomic indicators influence international geopolitical risk. He found a statistically significant effect of the United States macroeconomic variables on international geopolitical risk. Khan et al. (2022) inspected the causality between international geopolitical risk and technology growth. They concluded a bidirectional causality between the two variables. Lee et al. (2022) tested the connection between geopolitical uncertainties, oil shocks, and green bond returns. Their outcome stated that an unpredicted positive alteration in oil prices boosts international geopolitical risk. Further, recent empirical research, including studies by Faruk et al. (2022) and Sweidan (2023b), found that the determinants of geopolitical risk had broader implications, transcending borders and causing spillover effects among nations. It indicates that the negative consequences of geopolitical risk can propagate between countries. Further, the geopolitics of technology as a sub-topic is a relatively new strand of research, and the current study aims to contribute to this new and exciting topic. We know that there is a dearth of empirical studies on the intersection between the IT sector and geopolitical risk within the existing literature. Consequently, our objective is to uncover empirical evidence that establishes a concrete relationship in this realm. Further research remains vital to deepen our understanding of this emerging field.

So, why is the IT sector important? Traditional economic theories, i.e., neoclassical growth and endogenous growth theories, explain technology's importance in generating economic growth. Technology and knowledge accumulation are significant components to boost production because they can increase labor skills and productivity, thus enhancing human capital and economic growth. Many well-known studies empirically proved this conclusion, i.e., Barro, 1991; Levine and Renelt, 1992; Barro and Sala-i-Martin, 1995. Economists and politicians are aware of the critical role of IT in the future of controlling the world, either through economic relations or military power. In April 2019, President Trump's statement, "The race for 5G is on, and America must win," reflects IT rivalry among nations.[9] In February 2019, the United States Vice President warned publicly of the threat posed by Chinese technology. He called Europe to step up and support the United States leadership. While talking to the United States partners, he emphasized the imperative of safeguarding their vital telecom infrastructure, urging all security allies to remain alert and steadfastly oppose any endeavor that threatens the integrity of their communication technology and national security.[10] Nevertheless, China is not the only country preparing for the 5G telecommunication and technology era. Many countries, i.e., Germany, Japan, and

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[7] For example, see Sweidan (2021c) and Mei et al. (2020).

[8] For example, see Selmi and Bouoiyour (2020), Gupta et al. (2019), and Hailemariam and Ivanovski (2021).

[9] https://www.washingtonpost.com/politics/2019/04/18/trump-says-america-must-win-g-race-heres-what-you-need-know/

[10] https://www.ft.com/content/76fa4aa6-31e5-11e9-bd3a-8b2a211d90d5

South Korea, plan to digitize their industrial sectors by 2030. It implies that international competition has entered a new era (Wong, 2021). Therefore, the central question of the current study, does IT competition escalate or explain the geopolitical risk among nations? To answer this question, the current research extracts evidence from the limited available statistics by using monthly data covering 01/1993– 11/2023.

The regulatory models of the IT system in the United States and China are different. In the former, the government's role is secondary compared to the leading role of the private sector. Thus, the government's mission is to encourage IT innovations rather than restrict them. In the latter, the IT system works in an environment where *domestic* companies dominate in a silo internet environment, adopt a mass-surveillance policy, and the government serves as the crucial organizing node (Brown, 2019). Sweidan (2021b) showed that state capitalism, as in China and India, is expanding in the world economy, and its central feature is to protect its regime, and it cannot encourage the concept of democracy and the private sector.

According to Abishur Prakash,[11] the founder and chief executive of the Center for Innovating the Future, IT is generating geopolitical risk for many different reasons. The expected progress in the IT field can generate enormous improvements in the performance of the various economic sectors because of the expected high labor productivity and the availability of massive data. Besides, it will increase network speed and capacity and allow more data to be transmitted than current networks. It will also open opportunities for a new era of competition among nations because the legislation of the Outer Space Treaty, ratified by the United Nations in 1967, is outdated. It means that competing nations can control the earth's atmosphere. Moreover, the current IT types allow using and developing a new generation of artificial intelligence, robotics, and drones by military power. Additionally, the new generations of IT can collect big data, which includes detailed information about the population preferences in all aspects, including political ones. These data collections are strategic for a particular nation and can be used by a third party, which can generate economic and political instability.

Within these significant functions of IT and its new generations, governments are expected to launch new lines and public policies to enable data sovereignty. Alternatively, information gathered online by IT companies will be subject to the country's laws where it is collected or processed and remains within its borders. Undoubtedly, those who own the advanced technology and can develop new generations of this technology, will dominate the world's economic and military powers and the earth's atmosphere. Based on these facts, we expect fierce rivalry among nations leading the world of technology, generating permanent geopolitical risks among the competing nations.

4. Theoretical framework, data and methodology

4.1. Theoretical framework

The current study's empirical model assumes that there are four factors that can influence China's geopolitical risk index ($GPRC_t$). These four explanatory

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[11] https://www.thenationalnews.com/world/the-risk-is-on-7-ways-technology-will-impact-geopolitics-in-2021-1.1136399

factors cannot be controlled by the Chinese government, implying that they are exogenous to the Chinese economy. The first and core independent variable is S&P U.S. Information Technology Index ($USIT_t$). It tracks the stock performance of the largest 500 companies listed in the United States stock exchanges. Alternatively, it shows the investments in the United States information technology sector. We think that $USIT_t$ is a relevant and significant indictor to the Chinese, as rivals, and also to the rest of the world to know more about progress in the U. S. IT sector, and hence react to these developments accordingly. The other three determinants are extracted from the literature and previous studies as potential determinants of China's geopolitical risk and are as follows: crude oil prices (OP_t), the international geopolitical risk index ($IGPR_t$) and the relative importance of the United States' competitiveness index to China's competitiveness index (CIR_t).[12] If CIR_t is increasing and becomes greater than 100, it implies that U.S. competitiveness is deteriorating compared to China. However, if it is decreasing and turns out to be less than 100, then the opposite is true. The crude oil price is measured by oil prices of West Texas Intermediate, while the real effective exchange rates ($REER_t$) are used to estimate CIR_t.[13] All the variables in this research are transformed by using the natural logarithm. Accordingly, the general functional form of the current study's empirical model is as follows:

$$GPRC_t = F(USIT_t, OP_t, CIR_t, IGPR_t). \tag{1}$$

Equation (1) can be written in a linear regression form as follows:

$$GPRC_t = \alpha_0 + \alpha_1 USIT_t + \alpha_2 OP_t + \alpha_3 CIR_t + \alpha_4 IGPR_t + U_t, \tag{2}$$

where α_0, α_1, α_2, α_3 and α_4 are the model's coefficients; U_t is a white noise error term. Logically, the signs of the three parameters (α_0, α_1, α_2, α_3, α_4) are expected to be positive. Fig. 1 displays the $GPRC_t$ monthly index during the period 01/1993–11/2023. The index fluctuates permanently over the whole sample, and has a clear upward trend. Recall that the $GPRC_t$ index represents China institutional ambiguity that arises because of tensions, wars, military, and military-like actions.

4.2. Data

Our study extracts the data from four primary sources. $GPRC_t$ is used from Caldara and Iacoviello (2022). $USIT_t$ is obtained from DataStream, OP_t is extracted from the Federal Reserve Bank of Saint Louis website,[14] while $REER_t$ is mined from Darvas (2012). This study uses monthly data covering the period 01/1993–11/2023, and thus, it has 371 observations. Table 3 displays the descriptive statistics and the correlation coefficients of the current study's data sample.

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[12] The competitiveness index for each country is represented by the real effective exchange rate for each one ($REER_t$). $REER_t$ is estimated based on a basket consists of 120 countries of trading partners.

[13] $REER_t = (NEER_t \times CPI_t^{under\_study})/CPI_t^{foreign}$, where $REER_t$ is the real effective exchange rate of the country under study. $NEER_t$ denotes the nominal effective exchange rate of the country under study. CPI_t stands for the consumer price index. An increase in the country's $REER_t$ indicates appreciation of the home currency against the basket of trading partners' currencies. Thus, its exports are becoming more expensive and its imports are becoming cheaper. It is losing its trade competitiveness.

[14] Available at: https://www.stlouisfed.org

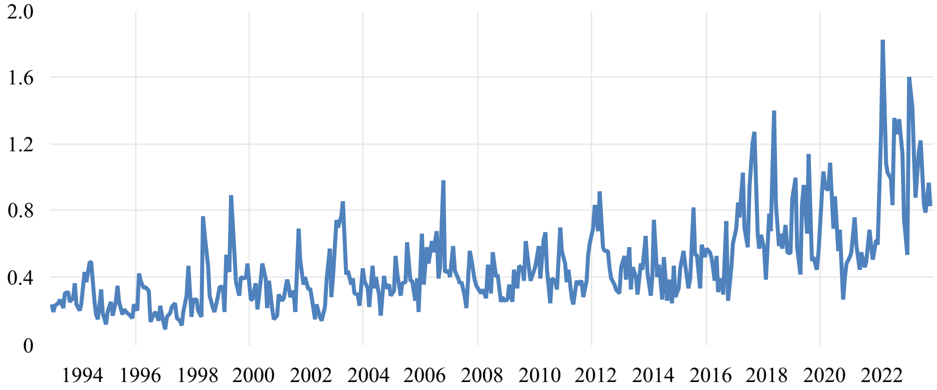

Fig. 1. The *GPRC* monthly index, 01/1993–11/2023.

Source: Caldara and Iacoviello (2022).

Table 3
The variables' descriptive statistics and correlation coefficients ($N = 371$).

Variable	$\text{Ln}\,GPRC_t$	$\text{Ln}\,USIT_t$	$\text{Ln}\,OP_t$	$\text{Ln}\,CIR_t$	$\text{Ln}\,IGPR_t$
Mean	–0.89	6.16	3.79	100.22	4.53
Std. dev.	0.53	0.90	0.63	3.17	0.35
Min	–2.47	4.30	2.42	94.89	3.67
Max	0.60	8.07	4.90	108.91	6.24
$\text{Ln}\,GPRC_t$	1.00				
$\text{Ln}\,USIT_t$	0.65	1.00			
$\text{Ln}\,OP_t$	0.48	0.52	1.00		
$\text{Ln}\,CIR_t$	–0.36	–0.52	–0.66	1.00	
$\text{Ln}\,IGPR_t$	0.38	0.04	0.14	0.12	1.00

Source: Author's calculations.

Table 4
The variance inflation factors.

Variable	$\text{Ln}USIT_t$	$\text{Ln}OP_t$	$\text{Ln}CIR_t$	$\text{Ln}IGPR_t$
VIF	1.49	2.06	2.06	1.11

Source: Author's calculations.

The correlation coefficients among the independent variables are low or within the acceptable range. It is a good indicator that the data of our research does not have the symptoms of multicollinearity. To validate the absence of multicollinearity, this research computed the Variance Inflation Factors (VIF). Table 4 illustrates that the VIF value is notably minimal, remaining below four.

At this point, this study began estimating the ARDL model by investigating potential structural breaks within China's geopolitical risk, visually represented in Fig. 1. Subsequently, a standard Vector Autoregressive (VAR) model was constructed, and the optimal lag length was determined using the Akaike Information Criterion (AIC), which recommended a lag length of 12. Thus, our study proceeded to estimate a VAR model utilizing 12 lags and conducted numerous multiple breakpoint tests. As a sample example, Table 5 presents the outcomes of the Bai–Perron test (Bai and Perron, 2003), revealing no structural breaks in China's geopolitical risk index.

Table 5
The results of the Bai–Perron test ($L + 1$ breaks vs. global L).

Sequential F-statistic determined breaks:	0		
Significant F-statistic largest breaks:	0		
Break test	F-statistic	Scaled F-statistic	Critical value**
0 vs. 1*	2.08	27.01	27.03
1 vs. 2	2.01	26.01	29.24
2 vs. 3	1.04	13.54	30.45
3 vs. 4	1.20	15.54	31.45
4 vs. 5	0.00	0.00	32.12

Estimated break dates:
1: 2001M09
2: 2001M09, 2016M11
3: 1998M06, 2003M12, 2016M12
4: 2001M09, 2006M10, 2011M07, 2016M12
5: 1998M06, 2002M11, 2007M06, 2011M11, 2016M12

Note: * Significant at the 5% level; ** Bai and Perron (2003) critical values.
Source: Author's calculations.

4.3. Methodology

The current work uses the bounds testing technique for cointegration as an instrument to approximate the Autoregressive Distributed Lag (ARDL) model parameters. This approximation process was developed by Pesaran et al. (2001). It inspects the presence of a long-run relationship among the model's variables. It estimates short-run and long-run coefficients, and the speed of adjustment or the error correction term (ECM_t) toward the long-run equilibrium. This estimation method can be applied regardless of the variables' integration orders. It is applicable if the variables of I (0) or I (1) or a grouping of them, but not I (2). In addition, the ARDL technique performs well on small sample size.

The general specification form of the ARDL (p, q) is as follows:

$$Q_t = \delta + \sum\nolimits_{k=1}^{p} \alpha Q_{t-k} + \sum\nolimits_{j=0}^{q} \beta R_{t-j} + \varepsilon_t, \tag{3}$$

where Q_t denotes the dependent variable; R_t represents a list of independent or explanatory variables; δ, α, and β are the model's assessed parameters; ε_t is the random disturbance. Equation (2) can be re-written to match the ARDL model in Equation (3) and as follows:

$$\begin{aligned} \Delta\ln GPRC_t = \alpha_0 + \sum_{k=1}^{12} \alpha_1 \Delta\ln GPRC_{t-k} + \sum_{k=0}^{12} \alpha_2 \Delta\ln OP_{t-k} + \sum_{k=0}^{12} \alpha_3 \Delta\ln CIR_{t-k} + \\ + \sum_{k=0}^{12} \alpha_4 \Delta\ln USIT_{t-k} + \sum_{k=0}^{12} \alpha_5 \Delta\ln IGPR_{t-k} + \beta_1 \ln GPRC_{t-1} + \\ + \beta_2 \ln OP_{t-1} + \beta_3 \ln CIR_{t-1} + \beta_4 \ln USIT_{t-1} + \beta_5 \ln IGPR_{t-1} + \varepsilon_t, \end{aligned} \tag{4}$$

where Δ stands for the first difference operator. The coefficients α_1 to α_5 indicate the short-run parameters in Equation (4), while the long-run coefficients are denoted by the coefficients β_2 and β_5 normalized by the parameter β_1. Through the process of estimating Equation (4) parameters, this study imposes a maximum of 12 lags via the automatic selection option. Besides, it conducts diagnostic and stability tests to inspect the robustness of the results. It also employs two methods of the ARDL methodology to investigate the existence of a cointegration relationship among the variables. First, it computes and compares the upper and lower critical F-values of Pesaran et al. (2001). If the computed F-statistic is less than the lower bound critical values, the null hypothesis of no cointegration cannot be rejected. On the contrary, if the calculated F-statistic is higher than the upper bound critical values, the null hypothesis can be rejected, and the long-run relationship exists. The results are indecisive if the computed F-statistic is in-between the upper and lower bound critical values. Second, ECM_t is estimated and placed in the model instead of the long-run variables. If the computed coefficient of ECM_t is statistically significant, negative, and less than one, then the long-run relationship among the model's variables exists.

5. Results

5.1. Preliminary estimates

The prevalence of unit root challenges in economic time series data is widely acknowledged. To ensure precision, we precisely scrutinized our data for any indication of unit root presence before employing the ARDL bounds testing method for cointegration. This crucial step aids in selecting the appropriate time series model and diminishes the likelihood of erroneous regression. Our examination involved four unit root tests—two standard tests: Augmented Dickey–Fuller (ADF; Dickey, Fuller, 1981) and Phillips–Perron (PP; Phillips, Perron, 1988), and two tests designed for accommodating structural breaks (ADF and PP). Across all tests, the null hypothesis implies that a unit root impacts the series. The findings in Table 6 illustrate that the variables in this research display either data-level or first-difference stationarity. Consequently, it asserts that utilizing the ARDL bounds testing method for co-integration is the apt approach for estimating our model's coefficients.

The current study estimates an ARDL model over the main sample (01/1993–11/2023) and two sub-samples (01/2000–11/2023 and 01/1993–11/2017).[15] The purpose of the sub-sample estimates is to guarantee robust results. This research starts the empirical estimate by exploring the existence of a cointegration relationship among the model variables over the two samples by utilizing the F-test statistics. The cointegration tests of the different samples are reported in Table 7. The estimated F-statistics are larger than the upper critical values (4.370) at 1% significant level for all the samples. This indicates that the null hypothesis of no cointegration can be rejected.

Throughout estimating the ARDL models and the cointegration tests, this study imposes a maximum of 12 lags. The ARDL model's results of the main sample are presented in Table 8. This table has three panels: the short-run parameters, the long-run coefficients normalized by the coefficient of the lagged dependent variable ($\Delta \ln GPRC_{t-1}$), and the diagnostic and stability tests. These diagnostic evaluations assess different elements: the normality of the error term, the presence of serial correlation, heteroscedasticity, autoregressive conditional heteroscedasticity, the suitability of the model's functional form, and tests for stability.[16]

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[15] The sub-samples are chosen randomly.

[16] This set of diagnostic evaluations encompasses seven tests: Jarque–Bera, Breusch–Godfrey (BG) serial correlation LM, Breusch–Pagan–Godfrey (BPG), ARCH–LM, Ramsey RESET, the Cumulative Sum of the Recursive Residuals (CUSUM), and the Cumulative Sum of the Squared Recursive Residuals (CUSUMSQ).

Table 6
Unit root test.

Variable	Standard				Structural Breaks			
	ADF		PP		ADF		PP	
	Level	1st diff.	Level	1st diff.	Level	1st diff.	Level	1st diff.
$\text{Ln}\,GPRC_t$	-8.03^{***}	–	-12.24^{***}	–	-12.34^{***}	–	-12.22^{***}	–
$\text{Ln}\,USIT_t$	-1.54	-15.04^{***}	-1.65	-15.18^{***}	-3.41	-15.71^{***}	-3.41	-7.15^{***}
$\text{Ln}\,OP_t$	-2.89	-14.82^{***}	-2.52	-14.37^{***}	-5.48^{***}	–	-5.48^{**}	–
$\text{Ln}\,CIR_t$	-1.74	-18.39^{***}	-1.71	-18.38^{***}	-3.62	-41.25^{***}	-3.68	-18.46^{***}
$\text{Ln}\,IGPR_t$	-6.60^{***}	–	-6.26^{***}	–	-7.90^{***}	–	-5.93^{***}	–

Note: $^{***}\,p < 0.01$, $^{**}\,p < 0.05$, $^{*}\,p < 0.10$.
Source: Author's calculations.

Table 7
The ARDL cointegration tests.

Cointegration hypotheses	Time interval	F-statistics
$\text{Ln}\,GPRC_t = F(\text{Ln}\,USIT_t, \text{Ln}\,OP_t, \text{Ln}\,CIR_t, \text{Ln}\,IGPR_t)$	01/1993–11/2023	13.139^{***}
$\text{Ln}\,GPRC_t = F(\text{Ln}\,USIT_t, \text{Ln}\,OP_t, \text{Ln}\,CIR_t, \text{Ln}\,IGPR_t)$	01/2000–11/2023	9.379^{***}
$\text{Ln}\,GPRC_t = F(\text{Ln}\,USIT_t, \text{Ln}\,OP_t, \text{Ln}\,CIR_t, \text{Ln}\,IGPR_t)$	01/1993–11/2017	7.473^{***}

Note: $^{***}\,p < 0.01$, $^{**}\,p < 0.05$, $^{*}\,p < 0.10$. The critical values of the upper bound for Pesaran and Shin (2001) test is 4.370 at 1% significant levels.
Source: Author's calculations.

Table 8
ARDL model estimation. Main sample: period 01/1993–11/2023.

Variable	Coefficients	Standard errors
(A) Short-run parameters		
Constant	-2.302^{**}	0.931
$\Delta\text{Ln}\,GPRC_{t-1}$	-0.120^{**}	0.048
$\Delta\text{Ln}\,USIT_t$	0.865^{***}	0.298
$\Delta\text{Ln}\,OP_t$	0.082^{**}	0.040
$\Delta\text{Ln}\,CIR_{t-2}$	0.081^{***}	0.031
$\Delta\text{Ln}\,CIR_{t-4}$	0.059^{*}	0.031
$\Delta\text{Ln}\,CIR_{t-9}$	0.091^{***}	0.031
$\Delta\text{Ln}\,IGPR_t$	0.680^{***}	0.078
(B) Long-run parameters		
Constant	-4.693^{***}	1.800
$\text{Ln}\,USIT_{t-1}$	0.293^{***}	0.050
$\text{Ln}\,OP_{t-1}$	0.167^{**}	0.080
$\text{Ln}\,CIR_{t-1}$	-0.009	0.016
$\text{Ln}\,IGPR_{t-1}$	0.495^{***}	0.110
ECM_{t-1}	-0.491^{***}	0.060
(C) Diagnostics tests		Probability
Adj. R^2	0.421	
Jarque–Bera	1.291	0.616
LM – Stat. (BG-test), F (12, 330)	0.834	0.939
Heteroskedasticity (BPG-test), F (18, 342)	0.675	0.836
Heteroskedasticity (ARCH-test), F (1, 358)	0.300	0.584
Ramsey RESET (F-test), F (5, 337)	1.099	0.361
CUSUM	Stable	
CUCUMSQ	Stable	

Note: $^{***}\,p < 0.01$, $^{**}\,p < 0.05$, $^{*}\,p < 0.10$. For the short-run parameters with long lags, the author reports the statistically significant coefficients only.
Source: Author's calculations.

Figs. 2, 3, and 4 showcase a sample of the two stability (CUSUM and CUCUMSQ) tests relevant to our study's estimations. All these preliminary tests confirm that the assumptions of the classical linear regression model have been

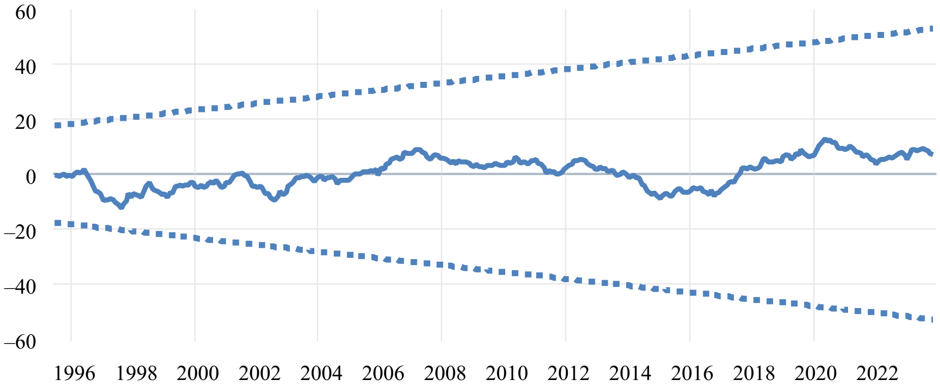

Fig. 2. A sample of the CUSUM test from the main sample, 01/1993–11/2023.

Source: Author's calculations.

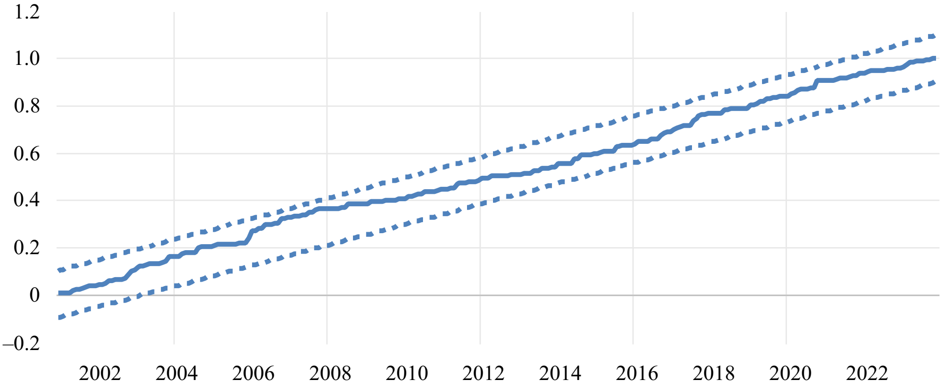

Fig. 3. A sample of the CUSUMSQ test from the sub-sample, 01/2000–11/2023.

Source: Author's calculations.

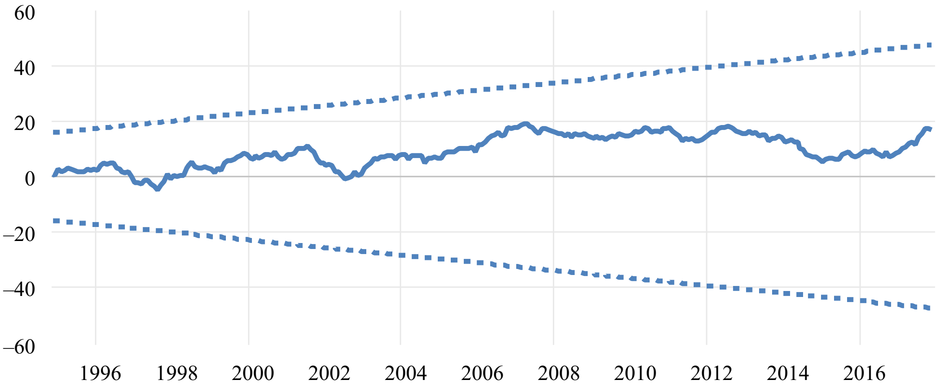

Fig. 4. A sample of the CUSUM test from the sub-sample, 01/1993–11/2017.

Source: Author's calculations.

satisfied. The samples of the stability tests in the abovementioned figures do not cross the 5% critical lines, which indicates that the model's parameters are stable.

5.2. Analyzing the results

In the short run, the results of Table 8 reveal that the influence of the four explanatory variables on China's geopolitical risk is statistically significantly different from zero and positive. Implicitly, it shows that the development of the U.S. IT sector boosts China's geopolitical risk. Besides, it indicates the importance of this sector in the international relations between the two nations. Further, China's geopolitical tension surges when oil prices increase, the level of international geopolitical tension elevates, and the United States economy loses its economic competitiveness with China's economy. The latest finding explains the high tension between the two nations due to international trade competition. Geopolitical tension might also be valuable for achieving economic gains and balance. The short-run results continue exactly to the long-run, except for the relative competitiveness index effect, which becomes statistically insignificant. The long-run results prove that the progress of the U.S. IT sector, the oil prices, and the international geopolitical risk level determine China's geopolitical risk. In the robustness check part, Tables 9 and 10 present the results for the sub-samples, namely (01/2000–11/2023) and (01/1993–11/2017), respectively. Those two tables indicate comparable findings to those in Table 8 for short- and long-term analyses.

In summary, our study demonstrates that the evolution of the U.S. IT sector poses a geopolitical risk for China. This result particularly aligns with the findings of the limited empirical works in this research strand. For instance, Wong (2021) confirmed that the competition in the IT sector between the United States and China is the key instigator of their ongoing contentious rivalry. Furthermore, the current study's results align with previous empirical studies using related explanatory variables. Lee (2022) and Sweidan (2023d) observed an upsurge in oil prices amplifies global geopolitical risk. Khan et al. (2022) indicated that the IT sector's competition drives geopolitical risk, influencing nations' pursuit of economic supremacy and security. Additionally, Faruk et al. (2022) and Sweidan (2023b) noted that geopolitical risk extends beyond borders, generating spillover effects among nations. The outcomes of the current study provide evidence on the sensitivity of China's geopolitical risk to the various variables under investigation. These variables are volatile by nature and not under the control of China's policymakers. Thus, they make China's geopolitical risk volatile, which will adversely influence the Chinese economy.

Moreover, Tables 8, 9, and 10 show that the ECT coefficients, being negative and statistically significant, validate the presence of a long-term connection among the variables in the models. It suggests a consistent Granger causality from the explanatory variables to China's geopolitical risk. On average, the absolute value of the ECT stands at 0.485. As a result, the current adjustment towards long-term equilibrium is corrected by around 48.5% of the past year's error.

6. Conclusions and policy implication

A large body of growing empirical works investigated the effect of geopolitical risk on various economic sectors and financial variables over the past six years.

Table 9

ARDL model estimation. Sub-sample 1: period 01/2000–11/2023.

Variable	Coefficients	Standard errors
(A) Short-run parameters		
Constant	-2.783^{***}	1.020
$\Delta \text{Ln}\, GPRC_{t-1}$	-0.175^{***}	0.052
$\Delta \text{Ln}\, USIT_{t}$	1.158^{***}	0.342
$\Delta \text{Ln}\, OP_{t}$	0.102^{**}	0.051
$\Delta \text{Ln}\, CIR_{t}$	0.266^{***}	0.084
$\Delta \text{Ln}\, CIR_{t-1}$	-0.164^{**}	0.083
$\Delta \text{Ln}\, IGPR_{t}$	0.690^{***}	0.081
(B) Long-run parameters		
Constant	-6.194^{***}	2.113
$\text{Ln}\, USIT_{t-1}$	0.318^{***}	0.058
$\text{Ln}\, OP_{t-1}$	0.227^{**}	0.109
$\text{Ln}\, CIR_{t-1}$	0.001	0.017
$\text{Ln}\, IGPR_{t-1}$	0.512^{***}	0.127
ECM_{t-1}	-0.449^{***}	0.059
(C) Diagnostics tests		Probability
Adj. R^2	0.451	
Jarque–Bera	0.647	0.724
LM – Stat. (BG-test), F (12, 264)	0.781	0.670
Heteroskedasticity (BPG-test), F (10, 276)	0.871	0.561
Heteroskedasticity (ARCH-test), F (1, 284)	0.105	0.747
Ramsey RESET (F-test), F (5, 271)	0.510	0.769
CUSUM	Stable	
CUCUMSQ	Stable	

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.
Source: Author's calculations.

Table 10

ARDL model estimation. Sub-sample 2: period 01/1993–11/2017.

Variable	Coefficients	Standard errors
A) Short-run parameters		
Constant	-2.150^{**}	1.050
$\Delta \text{Ln}\, GPRC_{t-4}$	-0.090^{*}	0.054
$\Delta \text{Ln}\, USIT_{t}$	0.926^{***}	0.329
$\Delta \text{Ln}\, OP_{t}$	0.089^{**}	0.043
$\Delta \text{Ln}\, CIR_{t-2}$	0.078^{**}	0.032
$\Delta \text{Ln}\, CIR_{t-4}$	0.066^{**}	0.032
$\Delta \text{Ln}\, IGPR_{t}$	0.686^{***}	0.087
(B) Long-run parameters		
Constant	-4.176^{***}	2.113
$\text{Ln}\, USIT_{t-1}$	0.237^{***}	0.074
$\text{Ln}\, OP_{t-1}$	0.173^{**}	0.079
$\text{Ln}\, CIR_{t-1}$	-0.009	0.016
$\text{Ln}\, IGPR_{t-1}$	0.445^{***}	0.111
ECM_{t-1}	-0.515^{***}	0.076
(C) Diagnostics tests		Probability
Adj. R^2	0.426	
Jarque–Bera	0.1.271	0.530
LM – Stat. (BG-test), F (12, 265)	0.722	0.730
Heteroskedasticity (BPG-test), F (16, 277)	0.800	0.686
Heteroskedasticity (ARCH-test), F (1, 291)	0.026	0.873
Ramsey RESET (F-test), F (5, 272)	1.354	0.242
CUSUM	Stable	
CUCUMSQ	Stable	

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. For the short-run parameters with long lags, the author reports the statistically significant coefficients only.
Source: Author's calculations.

These empirical studies are motivated by the geopolitical risk index established by Caldara and Iacoviello (2022). The present study concentrates on a new dimension and explores the determinants of geopolitical tension. Technically, it investigates evidence regarding the geopolitics of technology. More precisely, it seeks to answer whether progress in the U.S. IT sector can justify China's geopolitical risk movement. The design of the question is related to the nature of data and its availability.

The preliminary indicators and theoretical background show that some superpower countries, mainly the United States and China, have a severe rivalry in the IT sector. Over the past three decades, the Chinese economy has experienced remarkable real economic growth, reaching a rate of 8.75%, compared to 2.45% for the United States economy. These figures underscore China's rapid progress and potential to emerge as a major competitor to the United States economy. Additionally, China has made significant strides in accessing and excelling in the IT sector. Strategically, China is the largest supplier of critical raw materials essential for electronics manufacturing. Data reveals that China possesses five times more rare earth materials than the United States, which are crucial for producing essential electronic components like chips. However, while the United States leads in the production of these components, commanding a 48% international market share compared to China's 8%, this gap might be more significant if we consider the United States allies, such as South Korea, Taiwan, and Europe. This economic dynamic has generated geopolitical tensions and economic rivalry as both nations vie for control over the international IT sector and the global economy.

Technology is a significant core component of the supply-side economy (production functions), as explained in the various economic growth theories. Nowadays, the nation that owns, produces, and innovates new generations of IT will dominate the international economy and military power, and control the earth's atmosphere. Undoubtedly, our traditional life has become dependent on technology, mainly with the COVID-19 pandemic. These changes generate the concept of Big Data as another new strategic element that the superpower countries have control over.

The current study estimates an ARDL model over three samples to guarantee robust results. The current study successfully extracts empirical proof of the geopolitics of technology between the United States and China. It confirms that the progress in the U.S. IT sector can explain the movement of China's geopolitical risk. The three estimated ARDL models show that this effect is statistically significant and positive either in the short or long run. This conclusion bears a crucial policy implication: the arena of global geopolitics among superpowers is influenced by the IT sector and other macroeconomic indicators. Cultivating a robust IT sector is pivotal for asserting dominance in the global atmosphere and economy. Undoubtedly, there is fierce competition among global superpowers to lead the next wave of IT advancements. It could become a significant source of economic and political instability if compromises are not reached. Our study anticipates a substantial surge in global geopolitical risk due to the heightened tensions among nations worldwide. It is motivated by the resurrection of an international multipolar system and the intensified race in the IT sector.

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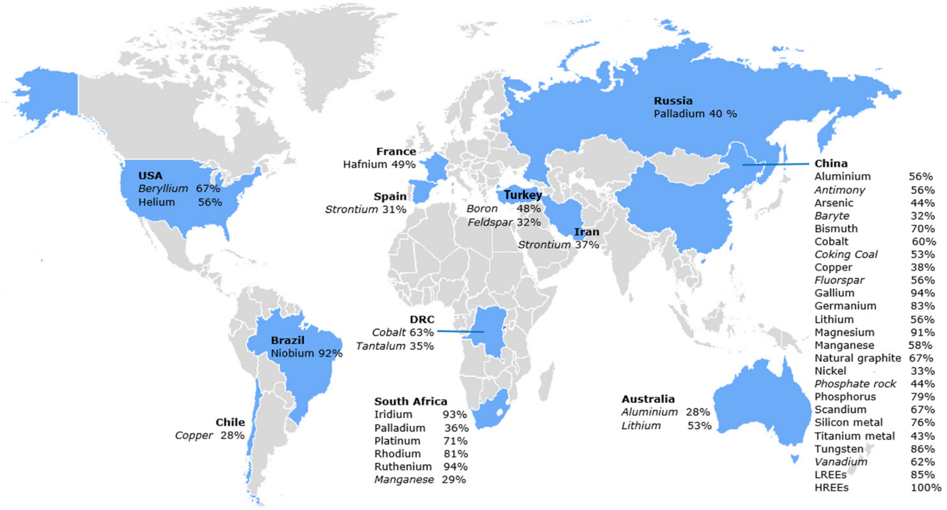
Appendix A. Countries accounting for largest share of global supply of critical raw materials



Note: Italic — extraction stage, regular — processing stage.
Source: Grohol and Veeh (2023).

Supplementary material

The geopolitics of technology
Author: Osama D. Sweidan
Data type: Table
Explanation note: This data is used to conduct the study. A description of the data exists in the study.

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