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Original Paper

Does Geopolitics Affect the Development of China's 5G Industry?

Qingqiao Huang[1], Liushuang Meng[1] & Bin Wang[1*]

[1] College of Science, Guilin University of Technology, Guilin, China

[*] Corresponding author, Bin Wang, College of Science, Guilin University of Technology, Guilin, China

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Abstract

The field of sci-tech innovation, especially the field of emerging technologies, has become an important battlefield in today's geopolitics. Given the unprecedented economic benefits and social changes that 5G technology can bring, 5G has become a major focus of great power competition. This paper uses the bootstrap-rolling-window-causality-test method to investigate the dynamic causal relationship between global geopolitical risk (GPR) and China's 5G industry. The results show that there is a dynamic bidirectional Granger causality between GPR and China's 5G industry with time-varying characteristics. At different times, GPR has impacted China's 5G industry differently. In the early days of the United States' sanctions against China, its sanctions stimulated China's independent innovation capabilities, and GPR had a significant positive impact on China's 5G industry. When the United States strengthens its 5G strategic containment of China, GPR significantly negatively impacts China's 5G industry. During the period of relative stability in the international political situation, China's 5G industry has a significant negative impact on GPR. It can be seen that the strategic suppression of China by the United States has affected the development of China's 5G industry and related industries. These results mean that 5G is integrated into political affairs and becomes a force to defend national sovereignty and enhance geopolitical dominance.

Keywords

geopolitical risk; China's 5G industry; Granger causality test; rolling window

1. Introduction

Caldara and Iacoviello (2022) defined geopolitical risk (GPR) as the threat, realization, and escalation behavior of undesirable events related to war, terrorism, and any tensions between states that affect the peace process in international relations. In recent years, events such as Brexit, the Sino-U.S. trade and technology wars, the Russian-Ukrainian war, and the COVID-19 epidemic have raised GPR, and the impact generated by geopolitics has gradually attracted a great deal of attention. Scientific and technological development has been constantly enriching geopolitical theory and giving new features to geopolitics. With the advent of the fourth technological revolution, emerging technologies represented by artificial intelligence (AI), quantum information technology, and fifth-generation mobile communication technology (5G) are making significant progress, bringing great impact and even revolutionary changes to the world (Liu, 2020). The field of scientific and technological innovation, especially emerging technologies, has become an important battleground in today's geopolitics, and 5G has become the main focus of great power competition. 5G is not a simple upgrade of 4G, which has a maximum rate of about 150 Mbps and an average delay of 50 ms, while 5G can reach aggregated speeds of 10 Gbps with an average delay of 10 ms (Parcu et al., 2022). To consider only the speed of 5G network speed would be a serious underestimation of the role of 5G. 5G can enable the connection of people, things, data, APP, transportation systems, and cities in an intelligent network communication environment, supporting applications such as smart homes and buildings, smart cities, 3D video, cloud-based work and entertainment, telemedicine services, virtual and augmented reality, and large-scale machine-to-machine communication for industrial automation (Note 1).

China attaches great importance to the development of 5G technology given the unprecedented economic benefits and social changes it can bring. As early as 2009, Huawei started research on 5G technology, and at the end of 2012, Huawei decided to invest $600 million in 5G research and development, in addition to investing in actual products (Zhao, 2018). The Chinese government has proposed the strategic decision to vigorously promote 5G industry development in planning platform documents such as "Made in China 2025" and the "13th Five-Year Plan". At the end of 2020, China has built the world's largest 5G network, and the total number of 5G base stations has reached 718,000, accounting for more than 70% of the global proportion (Note 2). In addition, the report released by IPlytics platform shows that as of April 2022, the number of 5G patent families in China accounted for 26.79%, South Korea accounted for 25.94%, the United States accounted for 17.75%, Europe accounted for 15.59%, Japan accounted for 8.52%, and other countries accounted for a total of 5.41%, and China's Huawei enterprise is the largest contributor to the 5G standard, ranking first in the number of 5G patent families and leading the world (Note 3). The global success of Chinese companies such as Huawei has created a sense of strategic anxiety among the United States' strategic decision-makers, who see them as a challenge to their digital hegemony. So the Trump administration has decided to use hegemonic politics and the alliance system to stop the global development of Huawei and other Chinese companies and interfere with the global adoption of 5G technology (Yang, 2021). This has elevated corporate competition to a broader geopolitical confrontation between China and the United States and their allies, known as the "Tech Cold War" (Zhang et al., 2022). In fact, in November 2011, the United States government launched a national security investigation into China's Huawei and ZTE companies (Note 4). In December 2018, the United States joined with Canada to arrest Meng Wanzhou, Huawei's chief financial officer, on suspicion of stealing trade secrets, obstructing criminal investigations, and violating Iranian sanctions. This heralded the intensification of the trade war between China and the United States, which culminated in the designation of Huawei equipment as a national security threat by the United States and its blacklisting and the inability of critical infrastructure providers to use Huawei hardware (ten Oever, 2022). In the same year, the Trump administration took a tough stance against Huawei, citing the risk of espionage from China and deciding to ban the use of Huawei and ZTE equipment in the armed forces (Note 5). In addition, in May 2019, after the United States announced a ban on Huawei products, its Ministry of Commerce included Huawei in the "Entity List" and did not allow Huawei to purchase American products, to suppress Huawei's leading edge in 5G (Friis & Lysne, 2021). At the same time, the United States has engaged in speeches and diplomatic practices among its allies, and NATO members, to carry out the act of "5G securitization" to the end. Pushed by the United States, countries such as Australia, New Zealand, and Japan have taken steps to boycott Huawei's 5G technology (Note 6). In short, the United States government has used national efforts to block a Chinese company, using the Emergency Act, the highest state of war, to impose stricter prohibitions than during the Cold War, including cutting off hardware and software supply chains, using its allied system and even international academic organizations to participate, and finally using hostage-taking to exert pressure (Huang, 2019). All of those reflect the United States' desire to secure its hegemonic position, which leads to the intensification of GPR. Before the United States did not intervene in China's 5G industries development, China's 5G development was particularly rapid and became the "leader" in the global 5G field, but the Sino-U.S. trade technology war initiated by the hegemonic politics of the United States has limited the development of China's 5G industries and hindered the development process of global 5G. Therefore, it is of great practical significance to study the impact relationship between GPR and China's 5G industries.

This paper is structured as follows: Section 2 reviews the relevant literature. Section 3 reveals the interaction mechanism between GPR and China's 5G industries. Section 4 introduces the methodological theory. Section 5 provides data description and empirical analysis. Section 6 summarizes the full paper and puts forward policy inference.

2. Literature Review

China's 5G technology is receiving great attention from the world. Some scholars have studied the development of China's 5G technology from the aspects of 5G standards, intellectual property rights (IPR), and semiconductor chips. In terms of technology standardization, countries that have new technologies and set global standards will be well-positioned in the new era of digital transformation. Chen and Kang (2018) mentioned that China was currently responsible for the 5G assessment of the International Telecommunication Union (ITU) and that China had significant contributions to the international communication standards organization 3GPP, with at least one-third of the 5G proposals, reports and standards documents from Chinese companies. Kim et al. (2020) pointed out that Chinese companies, led by China’s Huawei, owned about one-third of the world’s 5G-related standard basic patents (SEPs), and the United States government viewed these companies like Huawei as a threat to their national interests and a challenge to their long-term dominance of global communications networks. Rühlig and Brink (2021) studied the development of 5G standards within formal international standard-setting organizations and the standardization of railroad technology under the Belt and Road Initiative, noting that international technological standardization had been shaped by the externalization of the most technologically advanced countries. China may reshape the international technology standard setting. Buggenhagen and Blind (2022) pointed out that publications, standard essential patents (SEPs), standard contributions, and patents were important indicators of the driving factors of 5G technology development, and found that standardization and patents were dominated by large enterprises in a few countries such as the United States, China, South Korea, Japan, Finland and Sweden, and Huawei of China leads in the number of 5G standard contributions and 5G patent families. Rühlig (2023) analyzed several aspects such as leadership positions in international standards development organizations (SDOs), participation in standards development committees, technical standardization contributions, and standard essential patents (SEPs), and found that China’s footprint in international technical standardization is growing, thus increasing its economic and political influence. In terms of semiconductor chips, semiconductors are a necessary foundation for the digital economy and a key element in the development of 5G technologies. For example, Grimes and Du (2020) elaborated that there was an asymmetric and interdependent relationship between China and the United States in the global semiconductor development model and that the decoupling of the Sino-U.S. semiconductor supply chain under the influence of geopolitical factors may be by far the biggest threat to the further development of the Chinese semiconductor industry and also to the development of 5G in China. However, Peters (2022) noted that despite the current freeze and blacklisting of Chinese electronics by the United States causing temporary disruptions, China’s top chipmaker Semiconductor Manufacturing International Corporation (SMIC) had also achieved a 7nm technology breakthrough comparable to Intel, TSMC, and Samsung. The GPR is intensified by the game between China and the United States over 5G and related technology components such as chips and semiconductors.

The geopolitical issues raised by China’s 5G technology are of great concern. Many scholars have also found that due to the influence of GPR factors, countries maintain mixed attitudes toward China’s 5G. Global infrastructure changes brought about by the 5G transition are increasingly becoming a national security issue, and countries around the world are increasingly emphasizing security issues in their 5G policies. Some countries have banned the use of Huawei’s 5G technology. Tekir et al. (2020) stated that nearly 80% of the global 5G market was dominated by three major companies, with China’s Huawei having a 30% market share, compared to Sweden’s Ericsson’s 26% and Finland’s Nokia’s 22%. Huawei’s dominance of the 5G market is seen as a threat by the United States government, which touts that Huawei may provide intelligence to the Chinese government, leading to a strong boycott of

Huawei's 5G technology in Australia, Japan, and New Zealand; Zhang and Xiao (2022) pointed out that Italy was a supporter of the Belt and Road initiative, but due to the influence of the United States, Italy has currently decided to ban Huawei from supplying 5G equipment to its telecommunications group Fastweb. In addition, the performance of the UK is more dramatic. Zhang et al. (2022) pointed out that the UK's attitude towards China's 5G had taken a 180-degree turn. Initially, Huawei was deeply involved in the UK's 4G development, then the UK government authorized Huawei to play a limited role in non-core elements of its 5G network, and the United States pressed the UK on the grounds of intelligence sharing, and finally, the UK decided to ban the use of Huawei's 5G technology. Cheng et al. (2022) mentioned that the UK could face additional costs of £630 million to £1.19 billion due to geopolitical restrictions and embargoes that restrict major suppliers of 5G infrastructure from helping to build 5G wireless access networks in the UK. Some countries have not explicitly banned Huawei from their networks, but these countries appear to have adopted prudent regulatory measures. Gur (2022) noted that the EU, given the intrinsic link between 5G and statehood, also considered the relatively weak 5G industry to be a security issue, and agreed to support the United States actions through treaties in limited areas to achieve common policy goals. Krolikowski and Hall (2023) noted that although the German government had not formally banned Huawei, it had taken successive steps to restrict its continued participation in German networks. Kewalramani and Kanisetti (2019) mentioned that the vast majority of telecom equipment in India came from imports, and Huawei was a cost-effective partner, and Huawei had a long history of operations in India, so the Indian government should allow Huawei to play a role in the construction and operation of India's 5G network infrastructure, but at the same time impose restrictions and strict supervision on Huawei. In addition to this, some countries have opened up to Chinese companies by allowing them to bid to build their own 5G infrastructure. Jaisal (2020) noted that Huawei had formalized an agreement with the government not to engage in espionage to rebuild its credibility. Many governments have endorsed this agreement. Russian telecom giant MTS and Huawei signed a cooperation agreement, and Swiss telecom giant Sunrise opened its first 5G innovation center in Europe in partnership with Huawei, aiming to build the Swiss 5G ecosystem. Namingit and Haddad (2020) stated that Huawei's customer-centric global strategy had gained market share in neighboring Southeast Asia, where Huawei has helped restore telecom services in disaster-stricken Southeast Asia, providing jobs and contributing to the economy of these countries. In addition to Vietnam, the whole of Southeast Asia has welcomed Huawei, Malaysia's Maxis, the Philippines' Global Telecom, etc. have cooperated with Huawei, and Thailand has established Huawei's first 5G trial platform in Southeast Asia. Sun (2022) noted that since the "Belt and Road" initiative was proposed in 2013, China has gradually become the largest trading partner in the entire Gulf region. Despite the United States' opposition, Huawei has signed 5G commercial contracts with countries such as Saudi Arabia, the United Arab Emirates, Qatar, Kuwait, and Egypt in the Gulf and other parts of the Middle East, which is the world's second-largest market after Europe. In summary, in the process of deploying 5G, the GPR is closely related to it.

In summary, many scholars have made important contributions in the field of GPR and 5G, but most of them adopt a qualitative research approach. This paper uses a bootstrap rolling window causality test to investigate the bidirectional causal relationship between GPR and China’s 5G industry. Under the framework of time-varying analysis, this research method not only captures more structural change information but also provides a more comprehensive picture of the dynamic impact of GPR and China’s 5G industry in different time intervals.

3. The Interaction Mechanism between GPR and 5G

3.1 The Influence Mechanism of GPR on 5G

5G technology is rapidly evolving and will play an important role in national critical infrastructure and become a tool for geopolitical power (Miailhe, 2018). GPR will influence the development of 5G technology through foreign direct investment (FDI), technology, and government investments.

GPR significantly affects FDI (Nguyen et al., 2022; Feng et al., 2023). Next-generation 5G networks are widely perceived as technology game changers, with Chinese telecom giant Huawei as the world’s leading 5G provider. Geopolitical concerns and the United States’ suppression of Chinese 5G-related companies represented by Huawei and China’s Semiconductor Manufacturing International Corporation (SMIC) have made foreign capital cautious about investing in 5G-related companies in China, including SMIC. Foreign investors are gradually reducing their investments in China’s 5G sector as the broader Sino-U.S. GPR rises (Brennan & Vecchi, 2021).

GPR is significantly related to technological security, and an increase in GPR hinders technological development (Habiba, 2021; Yu & Wang, 2023). Semiconductor technology is a necessary foundation for the digital economy and is critical to the development of 5G technology. The United States invented semiconductors and led the global market, accounting for 46% of global chip sales (Note 7). The severe sanctions imposed by the United States on Huawei mean that Huawei’s 5G equipment cannot use the United States chips, hindering the development of Chinese 5G technology. However, GPR has both negative and positive effects on the technology (Wang et al., 2021; Khan et al., 2022). Continued crises and geopolitical competition will promote scientific and technological competition and accelerate its development (Diniz, 2019). Influenced by geopolitics, China has been aiming for autonomous innovation in important areas. Although SMIC was blacklisted by the United States with additional restrictions on the import of advanced equipment, it took just two years to jump from the 14nm process to the 7nm process to produce semiconductors (Note 8). China currently produces 25% of the world’s semiconductors and is growing rapidly (Triolo, 2020).

China attaches great importance to the development of 5G technology, and Chinese companies receive relevant government incentives for 5G investment. Government support provides significant cost advantages, a well-established local supply chain, and lower licensing costs (Bartholomew, 2020). GPR is a boost to government investment, which increases investment to compensate for the negative impact of geopolitical events (Bilgin et al., 2020).

Many econometric models are multiplier models (Alfaro et al., 2018; Ren et al., 2022), and this paper draws on Su et al. (2022) to hypothesize the following mechanism for the impact of GPR on China's 5G industry.

$$5G = F * T * G$$

Here 5G represents China's 5G industry, F denotes FDI in China's 5G, T denotes Technology, and G denotes Government Investment.

3.2 The Influence Mechanism of 5G on GPR

5G technology delivers significant socio-economic benefits by increasing productivity, increasing cost competitiveness, and improving health and safety. First, 5G will directly promote economic growth through network infrastructure deployment and will generate indirect economic benefits as 5G is applied to various industries. From 2020 to 2030, 5G deployments are expected to contribute $1.4 trillion to $1.7 trillion to the United States' GDP and create 3.8 million to 4.6 million jobs. The indirect 5G benefits add $1.0 trillion to $1.2 trillion to the United States' GDP and create 3 million to 3.6 million new jobs, with this indirect impact accounting for approximately 70% of the total potential value of 5G (Note 9). However, China's current leadership in 5G technology facilitates China's international dominance and will greatly contribute to the development of the Chinese economy. The China Academy of Information and Communications Technology pointed out that it is expected that 5G will directly drive total economic output of 1.45 trillion RMB and direct economic value added of about 392.9 billion RMB in 2022, up 12% and 31%, respectively, from 2021, and indirectly drive total output of about 3.49 trillion RMB and indirect economic value added of about 1.27 trillion RMB (Note 10). These economic benefits have caused fierce competition among major countries for dominance of 5G technology, which will increase the GPR.

Standard necessary patents (SEPs), standard contributions, and patents are important indicators of driving factors of 5G technology development, and the number and quality of patents are important strategic indicators for comparing organizational technology portfolios. Currently, Huawei's 5G standard contributions and the number of 5G patent families both lead the world (Buggenhagen & Blind, 2022). As a result, countries such as the United States want to compete with China for 5G dominance and compete fiercely for 5G patents, raising geopolitical issues between major powers.

So, China's leading position in 5G technology has strained the global geopolitical situation, and China's 5G technology can affect GPR through economic effects and the number of 5G patents.

In summary, the interaction mechanism between GPR and China's 5G can be obtained (see Figure 1).

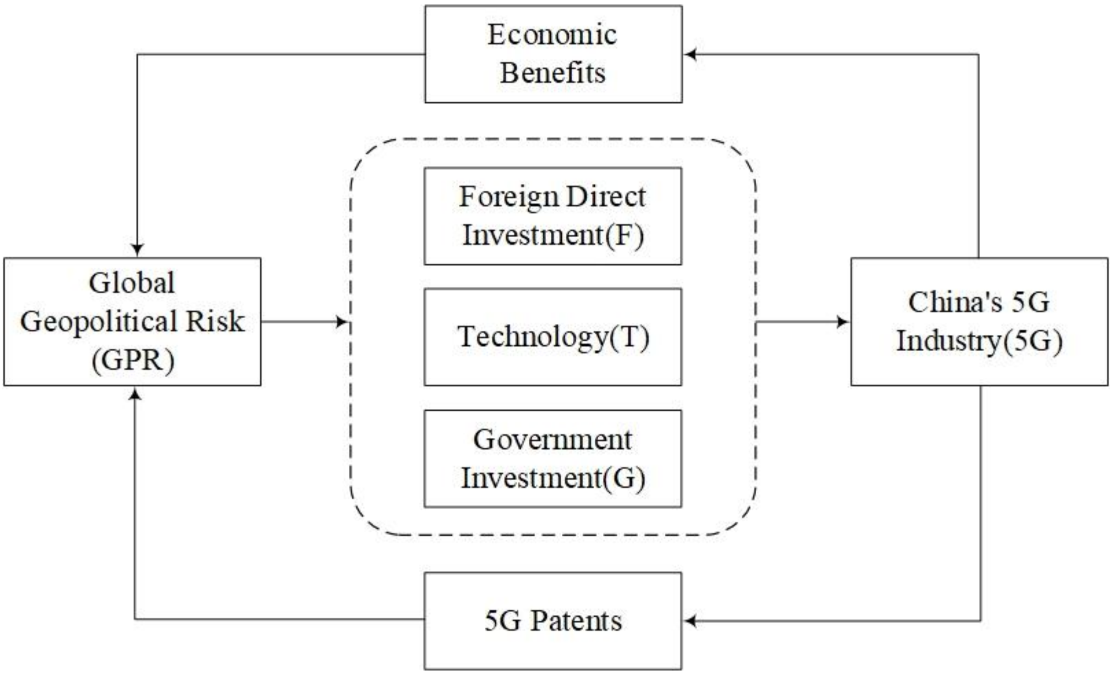

Figure 1. Interaction Mechanism between GPR and 5G

4. Methodology

This paper uses the bootstrap rolling window causality test to analyze the causal relationship between GPR and China's 5G industry. This method is based on the traditional Granger causality test, and the final test results are obtained by using a rolling window to test the causality of the full sample data and sub-sample data separately. The prerequisite of the traditional Granger causality test is that the time series is stationary, and after that, the VAR model is used to calculate Wald, likelihood ratio (LR), and Lagrange multiplier (LM) three statistics, which obey the standard asymptotic distribution, and then determine the causality of the study object and its significance. However, the use of the Granger causality test in the case of small samples is likely to affect the test precision (Mantals & Shukur, 1998). To address this issue, Shukur and Mantalos (2000, 2004) analyzed the effectiveness of various Granger test methods and found that the residual-based bootstrap technique (RB) and the modified LR statistic based on the bootstrap technique had the best test strength and adaptability. Therefore, in this paper, we choose the modified LR statistic based on the RB method and combine it with 10,000 simulations of the bootstrap method to test the dynamic bidirectional causality between the GPR and China's 5G industry.

4.1 Bootstrap Full-sample Causality Test

This paper uses the binary VAR (p) model to conduct a causality test of LR statistics modified by RB. The binary VAR (p) model is constructed as follows:

$$y_t = \Phi_0 + \Phi_1 y_{t-1} + \cdots + \Phi_p y_{t-p} + \varepsilon_t, \qquad t = 1, 2, 3, \ldots, T \tag{1}$$

where y_t is the k dimensional endogenous variable, T refers to the number of samples, ε_t is a white noise process with zero means, and p is the optimal lag order determined by the deficit information criterion (AIC) or the Schwartz criterion (SC). Variable y_t is divided into two sub-vectors $y_t = (y_{1t}, y_{2t})'$, then equation (1) can be rewritten as:

$$\begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix} = \begin{bmatrix} \Phi_{10} \\ \Phi_{20} \end{bmatrix} + \begin{bmatrix} \Phi_{11}(L) & \Phi_{12}(L) \\ \Phi_{21}(L) & \Phi_{22}(L) \end{bmatrix} \begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} \tag{2}$$

Here y_{1t} and y_{2t} respectively represent the variables of GPR and China's 5G industry. $\Phi_{ij}(L) = \sum_{k=1}^{p} \Phi_{ij,k} L^k, i, j = 1,2$, L is the lag operator and $L^k y_t = y_{t-k}$. If the constraint $\Phi_{21,k} = 0 \ (k = 1, 2, \cdots, p)$ is applied to equation (2), the original hypothesis can be tested: GPR is not the Granger reason of China's 5G industry; Similarly, if constraint $\Phi_{12,k} = 0 \ (k = 1, 2, \cdots, p)$ is applied, the null hypothesis can be tested: China's 5G industry is not the Granger reason of GPR.

4.2 Parameter Stability Test

The full-sample Granger causality test generally assumes that the parameters of the VAR model do not have structural changes. Nevertheless, in practice, with the increase in the sample size, the time series is likely to have structural change during the whole sample period (Balcilar & Ozdemir, 2013). Structural change would lead to parameter changes, thus making Granger causality test results invalid (Salman & Shukur, 2004). Andrews (1993) and Andrews and Ploberger (1994) proposed three statistics, Sup-F, Ave-F, and Exp-F to test the stability of model parameters in the short run. Sup-F statistic is used to test for structural changes in the parameters, and Ave-F and Exp-F statistics are used to test for changes in the parameters over time. In addition, the three statistics Sup-F, Ave-F and Exp-F require a bilateral 15% correction to the test sample. Therefore, the actual sample interval for the parameter stability test is (0.15, 0.85). In addition, this paper uses the L_c statistic proposed by Nyblom (1989) and Hansen (1992) to perform the long-term stability test of the parameters, which is used to test whether the parameters follow a random walk process. If the model parameters are unstable, it indicates a time-varying correlation between the GPR and China's 5G industry, which needs to be further tested by applying the bootstrap subsample rolling window causality test.

4.3 Bootstrap Sub-sample Rolling-window Causality Test

To overcome the problem of parameter instability and avoid a priori bias, this paper further tests the dynamic causality between two-time series by combining the rolling window method proposed by

Bilcilar et al. (2010). The bootstrap subsample rolling window causality test method is to split the full sample into many subsamples according to a fixed window width, and then let the subsamples roll from the beginning to the end of the full-sample sequence. Specifically, let the length of the time series be T, the length of the subsample be l, and the sample period of any subsample be $\tau - l + 1, \tau - l, \cdots, T,\ (\tau = l, l+1, \cdots, T)$, then the full sample becomes a sequence of $T - l$ subsamples. The LR causality test based on RB correction is applied to each subsample, instead of conducting one causality test for the full sample. Through this method, possible time-varying features in the causal relationship between the GPR and China's 5G industry can be visually identified. In addition, the method can quantify the degree of interaction between the GPR and China's 5G industry. Let N_b denote the number of bootstrap repetitions, $\overset{*}{\Phi}_{12,k}$ and $\overset{*}{\Phi}_{21,k}$ be the bootstrap estimates of the VAR model in Equation (2). Then $N_b^{-1}\sum_{k=1}^{p}\overset{*}{\Phi}_{21,k}$ is the degree of influence of the GPR on China's 5G, and $N_b^{-1}\sum_{k=1}^{p}\overset{*}{\Phi}_{12,k}$ is the degree of influence of China's 5G on the GPR. In this paper, a 90% confidence interval is used, and the upper and lower bounds of the impact coefficients are the 95th quantile and 5th quantile in $\overset{*}{\Phi}_{12,k}$ and $\overset{*}{\Phi}_{21,k}$, respectively, with the 5% extreme values at the first and last ends removed to ensure accuracy.

The selection of the width of the scroll window is more complicated, which requires not only the accuracy of the test but also the representativeness of the test statistics. Bilcilar et al. (2010) pointed out that the accuracy of the rolling window test mainly depends on the window width l. The larger window width can improve the test accuracy, but the heteroscedasticity may result in errors, thus reducing the representativeness of the test statistics; the smaller window width can improve the representativeness of the test statistics but also reduce the test accuracy. When structural changes occur, Pesaran and Timmerman (2005) proved that the choice of the optimal window size depends on the durability and size of the break. They found that the minimum window size limit is 20 when there are multiple structural change points. In this paper, a window width of 20-50 was set for simulation, and the window width was finally selected to be 20.

5. Empirical Data and Analysis

Caldara and Iacoviello (2022) collected information related to threats, tensions, and wars to quantify geopolitical risks and construct the GPR index. In 2015, "Made in China 2025" put forward the strategic requirement to make a comprehensive breakthrough in 5G technology, and in 2016, China's 5G technology was steadily developed, which has caused geopolitical risks around the world. Therefore, this paper selects monthly data from January 2016 to December 2022 to study the impact relationship between world geopolitical risk and China's 5G industry. To eliminate potential heteroskedasticity in the time series, the natural logarithm form is used, and the $r_t = \ln(p_t / p_{t-1})$ formula is applied. The world geopolitical risk variable (GPR) is derived from (https://www.matteoiacoviello.com/gpr.htm), and the China 5G variable (5G) is represented by the CSI 5G Communication Index. The CSI 5G Communication Index selects the securities of listed companies whose business is related to 5G construction or application from the Shanghai and Shenzhen markets as the index sample, including but not limited to 5G infrastructure, terminal equipment, and application scenarios, and aims to reflect the overall performance of China's listed securities with 5G communication themes. Data is obtained from the Wind database.

5.1 Descriptive Statistical Analysis

Table 1. Descriptive Statistics

	GPR	5G
Mean	-0.003151	-0.004595
Median	-0.002818	-0.000586
Maximum	0.622459	0.253509
Minimum	-0.600151	-0.295037
Standard Deviation	0.213155	0.086434
Skewness	0.203983	-0.407938
Kurtosis	3.873482	4.614797
Jarque-Bera	3.252925	11.45628***
ADF	-10.07695***	-11.67863***

Note. *** indicates significance at the 1% level.

This paper uses descriptive analysis to explore the data structure of the GPR and 5G variables. Table 1 shows the descriptive statistics of GPR and 5G variables; the skewness of GPR is greater than 0 and is right skewed, while the skewness of 5G is less than 0 and is left skewed; the kurtosis of both GPR and 5G is greater than 3 and is spiky, indicating that both GPR and 5G have typical "spikes and thick tails" characteristics. In addition, the Jarque-Bera test results show that GPR obeys normal distribution and 5G obeys non-normal distribution at a 1% significance level. To conduct the bootstrap rolling window causality test, the stationarity of the time series must first be tested, and the ADF method (Dickey & Fuller, 1979) is used in this paper to conduct the unit root test. From the results of the ADF test, it can be seen that both GPR and 5G reject the original hypothesis of the existence of unit root at the 1% significance level, indicating that both time series are stable.

5.2 Bootstrap Full-sample Causality Test

Both GPR and 5G sequences are stable, so the full-sample bootstrap rolling window causality test can be conducted. The results of both the AIC test and SIC test show 1. Therefore, 1 is chosen as the optimal lag order. In this paper, the bivariate VAR(1) model of GPR and 5G is established, and LR statistics modified based on RB are used for testing. The LR statistics and bootstrap-p values after testing are shown in Table 2.

Table 2. Full-sample Test Result

Tests	H_0: GPR is not the Granger reason for 5G		H_0: 5G is not the Granger reason for GPR	
	Statistics	p-values	Statistics	p-values
Bootstrap LR test	0.2972	0.5852	0.0323	0.8533

Note. To calculate p-values using 10,000 bootstrap repetitions.

The results of the full-sample Granger causality test show that GPR is not the Granger cause of 5G, and at the same time, 5G is not the Granger cause of GPR, there is no bidirectional causality between GPR and 5G. However, since China is currently leading the world in 5G technology, the United States government considers China as a dual threat to the United States geopolitical and economic power, claiming that Chinese companies such as Huawei and ZTE may spy through 5G networks and join its allies to boycott China's 5G (Tang, 2020). This incident suggests an interactive relationship between geopolitics and 5G, which is inconsistent with the results of the full-sample Granger causality test. In practice, there may be structural changes in the parameters of the VAR model, which may affect the accuracy of the full-sample Granger causality test. Therefore, the stability of the model parameters needs to be tested.

5.3 Parameter Stability Test

In this paper, Sup-F, Ave-F, and Exp-F are used to test the short-term stability of the model parameters. Table 3 shows the parameter test results of GPR, 5G, and VAR systems composed of GPR and 5G.

Table 3. Parameter Stability Test Result

Tests	GPR		5G		VAR system	
	Statistics	p-values	Statistics	p-values	Statistics	p-values
Sup-F	27.1114^{***}	0.0001	30.8890^{***}	0.0000	28.1327^{***}	0.0024
Ave-F	5.2285^{*}	0.0925	5.9315^{*}	0.0560	8.9453	0.1027
Exp-F	10.5593^{***}	0.0005	11.4101^{***}	0.0004	10.9705^{***}	0.0017
L_c					1.6840^{*}	0.0503

Note. To calculate p-values using 10,000 bootstrap repetitions.

*** and * indicate significance at the 1% and 10% levels, respectively.

The results of the Sup-F test show that the parameters of GPR, 5G, and VAR systems all reject the original hypothesis at a 1% significance level, which indicates that there is a structural change in the parameters. The results of the Ave-F test show that the parameters of GPR and 5G are significant at a 10% significance level, which means that the parameters of GPR and 5G have been significantly shifted with time. Meanwhile, the results of the Exp-F test show that the parameters of GPR, 5G, and VAR systems are significant at a 1% significance level, which means that the parameters change over time. The results of Sup-F, Ave-F, and Exp-F tests indicate that the parameters of GPR, 5G, and VAR systems do not have short-term stability. In addition, the L_c test results show that the parameters of the VAR system reject the original hypothesis at the 10% significance level, indicating that the parameters do not have long-term stability.

5.4 Sub-sample Rolling Window Causality Test

From the results of the parameter stability test, it is clear that the Granger causality between GPR and 5G is not constant, and there are structural changes in the two-time series data that lead to parameter instability. Based on this, this paper uses the bootstrap sub-sample rolling window causality test to investigate the time-varying Granger causality between GPR and 5G.

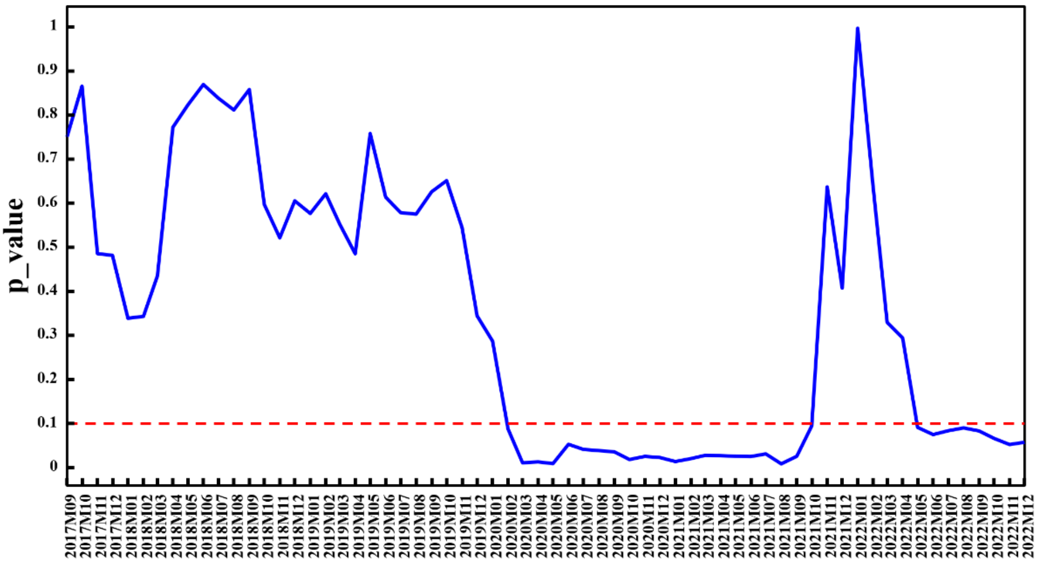

Figure 2. The Rolling Window Test p-value of GPR is not Granger Cause for 5G

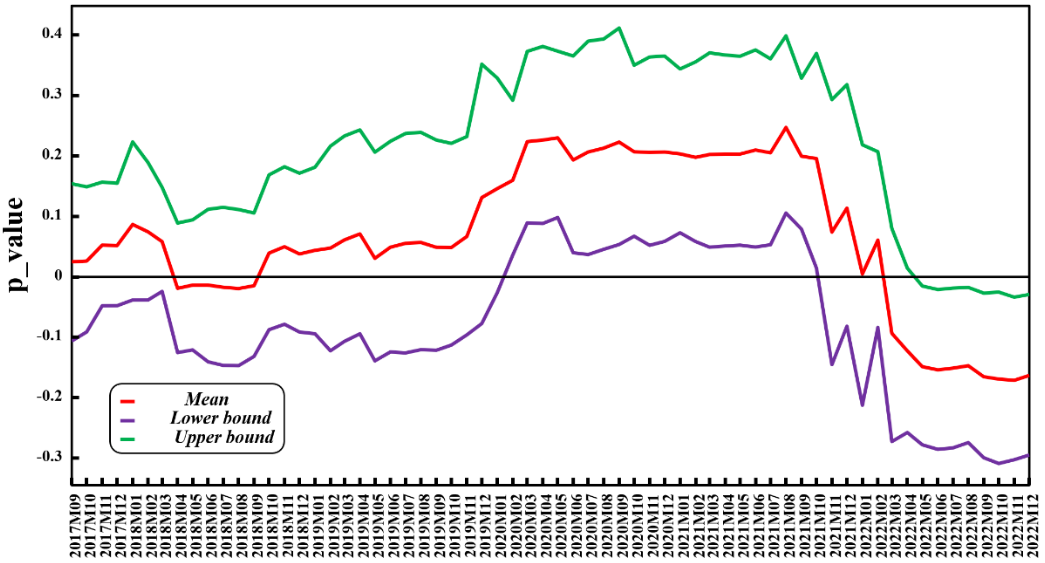

Figure 3. The Rolling Window Influence Coefficient of GPR on 5G

Figure 2 shows the bootstrap-p values for the original hypothesis that GPR is not the Granger cause of 5G. The time intervals with p-values less than 0.1 indicate rejection of the original hypothesis, indicating that GPR is the Granger cause of 5G. The sub-sample intervals that are significant at the 10% significance level are 2020M02-2021M10 and 2022M05-2022M12. Figure 3 shows the mean and upper and lower bounds of the coefficient of the effect of GPR on 5G, depicting the magnitude of the effect of GPR on 5G with the positive and negative direction of the effect. With the zero scale line as the dividing line, if the mean value of the bootstrap rolling window impact coefficient is greater than 0, it indicates a positive impact, and vice versa, it indicates a negative impact. If the mean value and upper and lower limits of the impact coefficient are greater than 0 or less than 0, the impact is highly significant. In the sub-sample interval 2020M02-2021M10, the mean value of the bootstrap rolling window impact coefficient is greater than 0, and the upper and lower bounds of the impact coefficient are also greater than 0, indicating that GPR has a very significant positive impact on 5G. This is because even the United States government imposed new restrictions on Huawei in 2020, prohibiting third-party companies outside the United States from using the United States' technology and software to design and produce chips for Huawei (Yang, 2021) and China's SMIC achieves a 7 nm technology breakthrough comparable to Intel, TSMC, and Samsung (Peters, 2022), and China's semiconductor sales are growing rapidly. In addition, to some extent, competition among countries in the 5G will facilitate the development of 5G technology. In the sub-sample interval 2022M05-2022M12, the mean and upper and lower bounds of the bootstrap rolling window impact coefficient are less than 0, indicating that GPR has a very significant negative impact on 5G. With the rise of China, the United States is worried about China surpassing it and constantly take a series of measures to try to limit China's development. China's achievements in the field of 5G have made the United States government more worried, and the United States has tried to persuade other countries, especially its allies, to boycott China’s 5G equipment, resulting in a rise in GPR and hindering China’s 5G industry development.

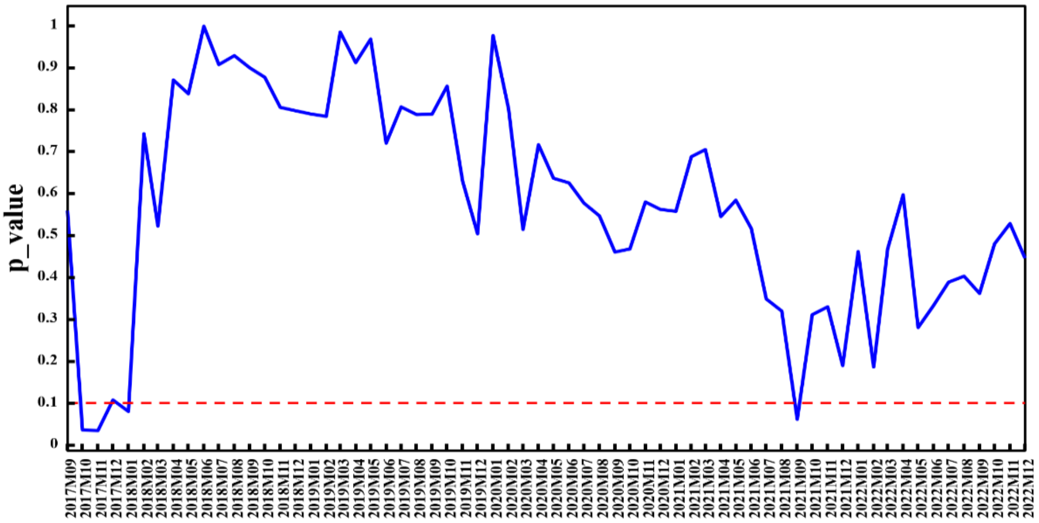

Figure 4. The Rolling Window Test p-value of 5G is not Granger Cause for GPR

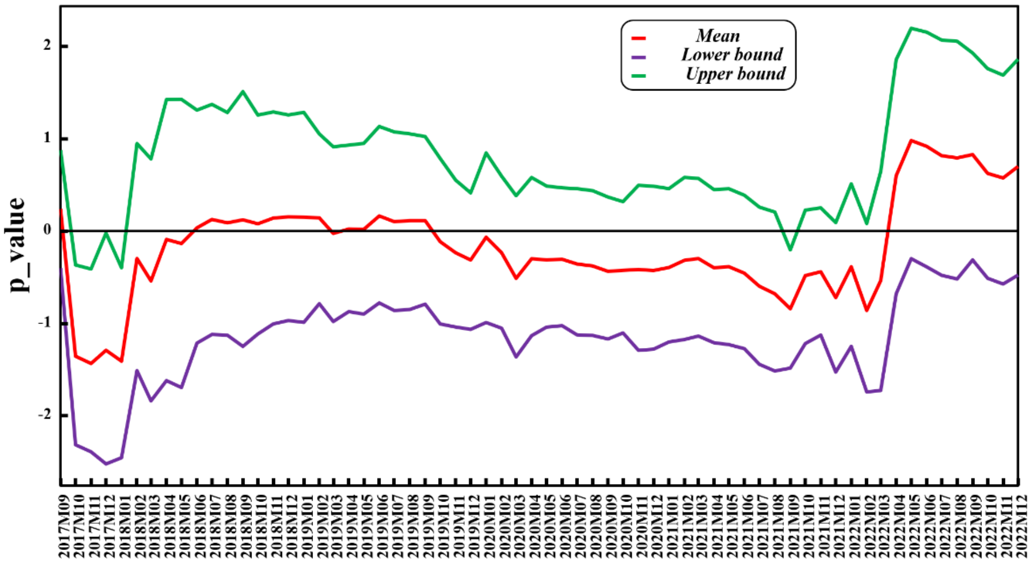

Figure 5. The Rolling Window Influence Coefficient of 5G on GPR

Figure 4 shows the bootstrap-p values for the original hypothesis that 5G is not the Granger cause of GPR. The time intervals with p-values less than 0.1 indicate rejection of the original hypothesis, indicating that 5G is the Granger cause of GPR. The sub-sample intervals that are significant at the 10% significance level are 2017M10-2018M01 and 2021M09. Figure 5 shows the mean and upper and lower bounds of the coefficient of the effect of 5G on GPR, depicting the magnitude of the effect of 5G on GPR with the positive and negative direction of the effect. In the sub-sample interval 2017M10-2018M01, the mean value of the bootstrap rolling window impact coefficient is less than 0, and both the upper and lower bounds of the impact coefficient are also less than 0, indicating that there is a very significant negative impact of 5G on GPR. The GPR was low and the international political situation was relatively stable during this period. In October 2017, Qualcomm and Intel launched 5G modem chips and successfully achieved the world's first 5G data implementation connection; in November, Huawei launched the world's first miniaturized 5G CPE terminal; in December, China Mobile led the completion of the 5G network system architecture standard and received strong support from more than 67 partners worldwide (Note 11). During 2021M09, the mean value of the bootstrap rolling window impact coefficient is less than 0, and the upper and lower bounds of the impact coefficient are also less than 0, indicating that 5G has a very significant negative impact on GPR. Although the United States and other countries are boycotting China's 5G technology, they cannot hide the fact that China's 5G technology is leading the world. Given the unprecedented impact that 5G technology will have, many countries have expressed their desire to apply China's advanced and inexpensive 5G equipment, and some US allies are looking for ways to cooperate with China without offending the US, which makes GPR decrease. In addition, China's close trade with ASEAN countries has also eased GPR during this period (Zhang & Xiao, 2022).

6. Conclusion and Policy Inference

The purpose of this paper is to investigate whether the world GPR affects the development of China's 5G industry. First, the bootstrap full-sample Granger causality test is used for analysis, and the results show that GPR is not a Granger cause of 5G and 5G is not a Granger cause of GPR. However, the results of the parameter stability test reveal that there are structural changes in the parameters of GPR, 5G, and the VAR system, which can affect the accuracy of the test. Therefore, the dynamic causal relationship between GPR and 5G is further analyzed using the bootstrap subsample rolling window causality test, and the following conclusions are finally obtained. Firstly, at different times, GPR has had different impacts on China's 5G industry. In the early days of the United States sanctions against China, e.g. during the period 2020M02-2021M10, China's semiconductor chip technology kept improving because the United States restricted China from using its chips and China could only develop them independently, thus promoting the continuous improvement of 5G technology. Its sanctions stimulate China's independent innovation capabilities, and GPR has a significant positive impact on China's 5G industry. When the United States strengthens its 5G strategic containment of China, GPR has a significant negative impact on China's 5G industry, e.g. During the period 2022M05-2022M12, the United States strengthens its 5G strategic containment on China, and GPR has a very significant negative impact on China's 5G industry. The results show both positive and negative impacts from GPR to 5G, which is similar to previous studies (Fritsch, 2011; Bonciu, 2017; Center and Bates, 2020; Khan et al. 2022). Secondly, during the period 2017M10-2018M01, China's 5G industry had a very significant negative impact on GPR. The international political situation is relatively stable during this period, and 5G technology is rapidly developing. During 2021M09, there was a very significant negative impact of China’s 5G industry on GPR. China is leading in 5G and many countries, including the United States allies, want to cooperate with China, thus easing geopolitical tensions. In conclusion, there is a bidirectional Granger causality between GPR and China’s 5G industry and it has time-varying characteristics.

How to resolve geopolitical tensions regarding 5G will affect the future of the world’s cybersecurity and national economies. Based on the results of the study, the following insights were obtained: First, GPR has had different impacts on 5G in China at different times, both promoting and inhibiting effects, which suggests that GPR has a very important impact on the development of China’s 5G industry. During periods when GPR inhibits 5G development, governments can build new strategic partnerships, promote a more moderate, evidence-based policy dialogue around 5G, promote best practices in cybersecurity, and raise overall awareness of issues such as national security and the human rights encompassed by 5G. China can mitigate the negative impact of GPR on 5G by issuing security guidance to strengthen security in the 5G space, enhancing risk assessment and management processes, and also seeking to improve risk mitigation through national responses. In the period when GPR promotes the development of 5G, the government should introduce more industrial policies to provide clear and broad market prospects for the development of the 5G industry and provide a good production and operation environment for enterprises. At the same time, the government and enterprises should increase investment in the 5G industry, actively absorb foreign direct investment, focus on promoting the research and development and application of 5G industrial chips, Internet of Things, industrial terminals, and other products and equipment, and making efforts to reduce the construction costs of 5G fully connected factories. Second, China’s 5G industry hurts GPR. Relevant departments should objectively and comprehensively assess the impact of 5G on GPR. With China’s increasing influence in the world and its current leading position in 5G technology, the world is impressed by this rising country and most countries in the world want to cooperate with China, thus reducing GPR. However, China cannot let down its guard and should seize the opportunity to strengthen the optimization and promotion of 5G technology. At the same time, China should proactively carry out cooperation with other countries in the field of 5G, jointly promote the realization of the maximum value of 5G technology, and cooperate to win together.

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