Time-Varying Influence of Policy Risk on Carbon Emissions Analysis

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ABSTRACT

The proposed carbon-neutral and carbon-peak targets will help China achieve a low-carbon economic transition and embark on a high-quality development path. As the developing country with the highest carbon emissions, the path to energy conservation and emission reduction will be long and difficult. Given the current complex international situation, which includes high geopolitical risks and frequent internal policy adjustments, this paper empirically investigates the time-varying effects of political uncertainty risks on China's carbon emission intensity over time and at equal intervals from 1995 to 2020 using the TVP-VAR model and the research objects of geopolitical risks, economic policy uncertainty risks, and carbon emission intensity. The empirical findings show that both geopolitical risk and economic policy uncertainty significantly increase carbon emission intensity, and the impact of geopolitical risk tends to expand gradually, despite abrupt structural changes in different time periods, which should be emphasized. Meanwhile, the article investigates the possible paths of political risks impeding the achievement of the dual-carbon target from the perspectives of R&D investment and science and technology innovation and makes a series of policy recommendations as a result.

Keywords: Geopolitical risk; Policy uncertainty; Carbon emissions; TVP-VAR model

1 Introduction

Global warming is the result of the Earth's climate change caused by human behavior. Carbon is consumed more, and carbon dioxide, the cause of global warming, is also produced much more. With human activities, global warming is also changing people's lifestyles, bringing increasingly more problems. In October 2018, the United Nations Intergovernmental Panel on Climate Change issued a report calling on all countries to take actions to control the temperature rise within 1.5 degrees Celsius. To achieve this goal, rapid and far-reaching reforms are needed in the fields of land, energy, industry, construction, transportation and cities. The proposed carbon-neutral and carbon-peak targets fully demonstrate China's responsibility and commitment to address the climate crisis as a superpower in terms of population and economic volume. As the country with the highest carbon emissions, China's proposed dual carbon target reflects its determination and motivation to save energy and reduce emissions and has the advantages of reducing global carbon emissions. The year 2021 is the start of the 14th Five-Year Plan, and the whole country has indicated that it will commit to make progress in energy conservation and emission reduction, promote environmental protection and low-carbon production, and change the lifestyles of enterprises and the people. All industries are committed to improving the efficiency of resource utilization through a series of technologies and applications. At present, in the fields of science and technology and the chemical industry, environmental protection measures have been vigorously developed, but the side effects of internal and external policy risks on environmental protection have been ignored.

"Carbon peak" means that by 2030, China's carbon dioxide emissions will reach its peak level and then gradually decline, which entails carbon emissions being decoupled from economic development. The peak target includes the peak year and peak value. "Carbon neutral" refers to the total amount of carbon dioxide or greenhouse gas emissions directly or indirectly produced by Chinese enterprises, products, activities and individuals in a certain period of time in 2060, which can be offset by afforestation, energy conservation and emission reduction to achieve positive and negative offset and achieve "zero emissions".

Subject to the current complicated and changeable domestic and international situation, macrolevel political uncertainty has a great impact on the economic and social development of the country. Therefore, we must be alert that political risks may also play a negative role in the reduction of carbon emissions. Local conflicts continue, and the Russian-Ukrainian war have pushed the geopolitical risks around China to a high point. This is not only a critical period for the transformation of China's economic structure, the accumulation and release of deep-seated problems, and the implementation of a new round of major reforms in China but also a period when the world economic structure and order are broken. To cope with the complicated domestic and international environment and eliminate sluggish economic development, the government must implement various regulatory policies in various fields. The frequent introduction of regulatory policies makes the uncertainty of economic policies constantly increase. Among these uncertainties, international geopolitical risks may lead to an energy crisis and technical blockade, while domestic economic policy uncertainties may lead to insufficient innovation and policy interruption, which will have a far-reaching impact on China's economic and social development.

Although China is making efforts to promote energy conservation and emission reduction through various means, it is still a serious challenge for China to maintain steady economic growth while achieving the double-carbon target at the current level of technology. The current research on the factors influencing carbon emissions is mainly focused on the micro level, such as energy structure and economic growth, but few studies have considered the impact of political uncertainties arising from geopolitical risks and economic policy uncertainties on the achievement of the double-carbon target. Therefore, this paper focuses on the high geopolitical risk caused by the complicated international environment after the international tension and the U.S.–China trade war and the high uncertainty of economic policy caused by frequent domestic policy regulation and investigates whether the two macro political uncertainties will hinder the achievement of China's dual carbon goal, which has important practical significance and theoretical value.

In this empirical study, we use a more realistic time-varying parametric stochastic fluctuation vector autoregressive model to analyze the time-varying effects of geopolitical risk (GPR) and economic policy uncertainty (EPU) on China's carbon emission intensity during 1995–2020 while taking into account the positive effects of R&D investment and the science and technology innovation brought by R&D investment on energy conservation and emission reduction and carbon emission intensity reduction. R&D input and science and technology innovation are incorporated into the empirical analysis system. This paper aims to answer the following three questions. First, does GPR impede the reduction of carbon emission intensity in China? Second, does EPU increase China's carbon emission intensity? Third, we examine whether R&D inputs and innovation are effective at reducing carbon emission intensity and what role GPR and EPU play in the middle. The research goal of this paper is to find the time-varying relationship between political risks and carbon emission intensity through theoretical and empirical analysis and discuss how to better achieve the goal of reducing carbon emissions from a macro perspective on the basis of a large number of existing microanalyses.

The main contributions of this paper are as follows. (1) Macropolitical uncertainties, i.e., geopolitical risks and economic policy uncertainties, are included in the same analysis system as carbon emission intensity, which enriches the research on the impact factors of energy savings and emission reduction in China. (2) The linkage between uncertainty risk and carbon emission intensity in China is explored by selecting relevant indicators at both the Chinese and global levels. (3) Empirical analysis is conducted using time-varying parameter stochastic fluctuation vector autoregressive models, especially split-pilot impulse response analysis and same-frequency segmented impulse response analysis, to carefully portray the time-varying effects of uncertainty risk on China's carbon emission intensity at different historical points and over different time spans and to provide relevant empirical support to achieve the dual-carbon target and low-carbon cycle development at present based on the empirical analysis results.

The second part of this paper is a literature review, the third part is data sources and model setting, the fourth part is empirical results and analysis, and the fifth part is research conclusions and insights.

2 Literature Review

According to the Global Risk Report released by the World Economic Forum in recent years, as one of the five major risks affecting the peaceful and stable development of the world, geopolitical risk has become the primary risk affecting global development, and its impact is stronger than that of environmental risk factors. Especially in the past 20 years, with the deep adjustment of the global political and economic landscape, the points of global turbulence and risks have increased significantly, and geopolitical risks and world political uncertainties have continued to deepen. Therefore, scholars at home and abroad have conducted much research on international and regional geopolitical risk dynamics, focusing on the risk-causing factors and impact of geopolitical risk. First, although there is no clear and uniform definition of geopolitical risk, scholars have emphasized the conflict and uncertainty of impact (Caldara et al., 2017.Liu & Zhou,2017). In this paper, we prefer the definition of geopolitical risk by Bohl and others, namely, political risk arising from regional violent conflicts and power struggles, economic risk arising from local and global economic and financial turmoil, natural risk arising from natural disasters, and the possibility of systemic impacts arising from the combined effects of the three risks (Bohl et al., 2017). Second, with regard to the risk-causing factors of geopolitical risks, economic factors, armed conflicts and power struggles become key factors. Regional financial crises, economic sanctions by major powers, and frequent policy adjustments within economies have become economic-type factors that trigger geopolitical risks. For example, economic events such as the U.S. subprime mortgage crisis, the U.S.–China trade friction, and the UK's exit from the European Union have caused global and local geopolitical risks to escalate (Root,1968; Kobrin,1978). Terrorist attacks and local wars have become armed conflict factors that trigger geopolitical risks, such as the recent outbreak of the Russia-Ukraine conflict, which has raised the risk of geopolitics worldwide (Hu et al., 2017; Lu, 2016). In addition, the power struggle between major powers is also a key factor triggering geopolitical risks. With the development of global technology, economy and culture, the traditional world pattern has quietly changed. The hegemonic Western countries, such as the United States and European countries, covet the development paths of other countries and try to hinder the rise of developing countries in many fields; for example, the pursuit of China's development by some developed countries led by the United States and the power struggles in the Middle East and Islamic countries have led to a significant increase in geopolitical risks (Tian, 2018). The impact of geopolitical risk has been studied in the political, economic, and sociocultural fields, and Chinese scholars have mainly studied the impact of geopolitical risk on China's diplomatic relations with neighboring countries, on the construction of "One Belt, One Road", and on overseas investment projects. For example, subtle changes in China's diplomatic relations with neighboring countries were triggered by SAD's entry into Korea, the Diaoyu Islands issue, and the Tibet issue (Fan, 2017; Yang & He, 2020). Meanwhile, scholars have found that geopolitical risks have different degrees of heterogeneous effects on China's energy consumption, stock market volatility, foreign trade, and food security (Yang & Xin,2020; Li et al., 2021). Geopolitical risk plays an important role in macroeconomic development and political stability, and it also has a profound impact on energy consumption, financial markets and personal consumption in the microfield. However, few scholarly studies have addressed the impact of geopolitical risk on carbon emissions in China.

Economic policy uncertainty refers to the uncertainty arising from the inability of economic entities to predict when and how strongly the government will change existing policies, and the risks associated with such uncertainty affect economic and social development in many ways. Since the Chinese economy has entered the new normal phase, especially in the face of the complex domestic and international environment, the Chinese government, as the escort of the market economy, has been implementing regulatory policies in various fields to protect the healthy and stable operation of the economy to ensure that the economy is moving toward a high-quality development model. By observing the frequency of various policies implemented in the past three years, the frequent introduction of regulatory policies has continued to increase economic policy uncertainty. The three main measures of economic policy uncertainty are local elections, official transfer changes, and economic policy uncertainty (EPU) indices based on newspaper information (Hong & Kostovetsky, 2010), among which EPU indices are widely used in current research due to their advantages of continuity, comparability, and comprehensiveness(Geng et al., 2016). Current scholars' research on the impact of economic policy uncertainty focuses on two aspects: first, the impact on the macro level such as economic development, GDP level, exchange rate fluctuation, import and export, social consumption, and financial stability, and the conclusions are mostly negative (Ouyang et al., 2019); and second, the impact on the micro level such as enterprise innovation, investment and financing, and cash holding, except that these conclusions themselves do not form(Zhang et al., 2019). For example, regarding the impact of economic policy uncertainty on corporate innovation, some scholars consider that this uncertainty risk leads to a lack of confidence in future development, which in turn reduces R&D investment and lowers the level of technological innovation （Xue et al., 2022）. In contrast, other scholars found that the fierce market competition brought by high policy uncertainty makes companies increase R&D to survive, develop investment and increase the level of innovation so that they can expand their competitive advantage （Meng & Shi，2017）. Factors such as firms' production, innovation, and investment can affect firms' CO2 emissions to varying degrees, but there is no literature that explores the impact of economic policy uncertainty on carbon emissions.

Geopolitical risks are mainly external uncontrollable risks, and economic policy uncertainty is an internal risk caused by frequent internal policy adjustments, both of which belong to the category of political risks. The world's economic and political situation is complex and changeable, and the relationship between geopolitical risks and economic policy uncertainty is not static. Only by mastering the abrupt structural relationship between them can we better put forward targeted policy suggestions. In the fourth part of the article, the deep relationship between them will be shown in the form of figures and texts.

As a major CO2 emitter, China's peak and carbon-neutral targets for 2021 were first included in the government's work report, and then major political conferences gradually established guidelines and ideas for energy conservation and emission reduction. The double-carbon target is not only a major initiative of China as a responsible power for global environmental protection but also a key point in the study of China's CO2 emissions. In many studies on the factors influencing carbon emissions, scholars have decomposed the factors leading to CO2 emissions, mainly at the national, provincial and basin levels, using Kaya's constant equation, STIRPAT and mixed regression models. Overall, factors such as economic growth, per capita income level, urbanization rate, and energy structure have significant effects on carbon emissions, and the conclusions on the direction of influence are generally consistent （Lu W.B et al., 2013）. However, when scholars studied how to reduce carbon emissions, the conclusions on the effects of R&D investment and innovation level on carbon emissions are complex. For example, scholars have analyzed the effect of R&D investment on emission reduction, finding both a positive U-shaped relationship and an inverted U-shaped relationship, while others have concluded that there is no correlation between the two（Deng et al., 2014; Gao & Zhu, 2020）. The effect of increased patenting of representative factors in innovation level on emission reduction is also very different in different regions and years (Mo, 2022).

Carney includes geopolitical risks together with economic and policy uncertainties in the "trinity of uncertainties" that can have significant adverse economic impacts. However, the level of economic development can significantly affect the carbon emissions of a region. Therefore, under the high geopolitical risk and economic policy uncertainty caused by the current complex domestic and international situation, it is of great theoretical and practical significance to study the impact of both on carbon emissions and make policy recommendations based on the research findings.

3 Model setup and data sources

3.1. Model setup

The vector autoregressive (VAR) model effectively remedies the endogeneity and identification problems of variables in the joint cubic system model (SIMS, 1980), which incorporates different variables into the same analytical framework to form a vector of different variables at the same point in time, and by performing autoregressive tests on this vector, the coefficients of the interactions are obtained while controlling for other variables. Moreover, it can visually reflect the degree of interaction between different variables through variance decomposition, so it is widely used in time series data analysis. The structural vector autoregressive model (SVAR) overcomes the shortcomings of the ordinary VAR model that cannot effectively portray the contemporaneous correlation between endogenous variables and is widely used in macroeconomic aspects of research. The basic form of this model is as follows:

$$AY_t = F_1 Y_{t-1} + \cdots + F_s Y_{t-s} + v_t \tag{1}$$

where $t = s+1, \cdots, n$, Y_t are $k*1$ order observation vectors, which in this paper are the three major variables of geopolitical risk, economic policy uncertainty and carbon emission intensity, and in the subsequent extended analysis, the variables add R&D investment and innovation capacity indicators; A , F_1 , …, F_k are $k*k$ order coefficient matrices; v_t is the perturbation term, which is a $k*1$ -order structural shock vector; and v_t ~ N(0, ΣΣ). Σ is expressed in the following form. :

$$\Sigma = \begin{pmatrix} \sigma_1 & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & \sigma_k \end{pmatrix} \tag{2}$$

where $\sigma_i (i = 1, \cdots, k)$ is the standard deviation of the structural shock term v_t .

Assume that the parameter matrix A is a lower triangular matrix with the main diagonal element of 1.

$$A = \begin{pmatrix} 1 & 0 & \cdots & 0 \\ a_{21} & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ a_{k1} & \cdots & a_{k,k-1} & 1 \end{pmatrix} \tag{3}$$

Multiplying both the left and right sides of Eq. (1) by A-1, Eq. (1) can be changed to the following form:

$$Y_t = B_1 Y_{t-1} + B_2 Y_{t-2} + \cdots + B_s Y_{t-s} + A^{-1} \sum \varepsilon_t \tag{4}$$

$B_t = A^{-1} F_i$, $i = 1, \ldots, s$, $i = 1, \ldots, s$, and $\varepsilon_t : (0, I_k)$ stack the row elements in the coefficient matrix B_t to form a $k^2 s*1$ dimensional vector β. Additionally, defining $X_t = I_s \otimes (Y_{t-1}, \cdots . Y_{t-s})$, where ⊗

denotes the Kronecker product, Equation (4) can be simplified to the following equation.

$$Y_t = X_t \beta + A^{-1} \Sigma \varepsilon_t \tag{5}$$

Both the basic VAR model and the evolved SVAR model assume that the estimated coefficients and the disturbance terms, i.e., A, β, and Σ in Equation (5), are kept fixed. Although this setting improves the computational efficiency while responding to the overall interaction, it does not truly respond to the change in the role of variable shocks. Therefore, in this paper, we choose the time-varying parameter vector autoregressive (TVP-VAR) model, which is more relevant to theoretical and realistic situations, in the empirical analysis. can effectively test the endogeneity problem of the model system. Based on the SVAR model, the parameters A, β, and Σ are allowed to change over time, thus transforming Equation (5) into the following TVP-VAR model.

$$Y_t = X_t \beta_t + A_t^{-1} \Sigma \varepsilon_t \tag{6}$$

where $t = s+1, \ldots, n$ assumes that $a_t = (a_{21}, a_{31}, a_{32}, a_{41}, \ldots, a_{a,k-1})'$ is a vector in the matrix A_t that is formed by stacking the lower triangular elements and let $h_t = (h_{1t}, \ldots, h_{kt})'$, $hjt = \log \sigma_{jt}^2$, and $j = 1, \ldots, k$. Additionally, assume that the random wandering process in Equation (6) conforms to the following form:

$$\beta_{t+1} = \beta_t + \mu_{\beta t} \tag{7}$$

$$\alpha_{t+1} = \alpha_t + \mu_{\alpha t} \tag{8}$$

$$h_{t+1} = h_t + \mu_{ht} \tag{9}$$

$$h_{t+1} = h_t + \mu_{ht} \tag{10}$$

$$\begin{pmatrix} \varepsilon_t \\ \mu_{\beta t} \\ \mu_{\alpha t} \\ \mu_{ht} \end{pmatrix} : N\left(0, \begin{pmatrix} I & 0 & 0 & 0 \\ 0 & \Sigma_\beta & 0 & 0 \\ 0 & 0 & \Sigma_\alpha & 0 \\ 0 & 0 & 0 & \Sigma_h \end{pmatrix}\right)$$

$t = s+1, \ldots, n$, $\beta_{t+1} : N(\mu_{\beta_0}, \Sigma_{\beta_0}), \alpha_{t+1} : N(\mu_{\alpha_0}, \Sigma_{\alpha_0})$, $h_{t+1} : N(\mu_{h_0}, \Sigma_{h_0})$。Considering that there is no correlation between the stochastic shocks ε_t、$\mu_{\alpha t}$、$\mu_{\beta t}$ and μ_{ht} of time-varying parameters, it is further assumed that Σ_α、Σ_β、and Σ_h are diagonal matrices.

In the VAR model, X and Y can represent each key variable. Because of the relationship between the models studied in this study, each variable can be an explanatory variable or an explained variable. Due to the large number of parameters and the time-varying nature in the TVP-VAR model, the traditional great likelihood estimation is not applicable to the parameter estimation of this model, so the estimation is performed by Markov Monte Carlo in the Bayesian framework, i.e., the MCMC estimation method. The parameter estimation is performed by circular sampling using the Gibbs sampling method based on the posterior distribution in MCMC estimation. In the estimation process, a TVP-VAR model is used to analyze the time-varying relationships among geopolitical risks, economic policy uncertainties, and China's carbon emissions, which can capture the time-varying nonlinear relationships between the variables more flexibly and objectively by fully taking into account the complex and volatile policy situation and environmental dynamics.

3.2. Data Sources

The high uncertainty of geopolitical risk makes its quantitative assessment more difficult, and with the gradual application of geo information technology and statistical tools in this field, the portrayal of geopolitical risk has gradually shifted from qualitative description to quantitative evaluation and visualization. In previous studies, some scholars used the political elections of leaders as a proxy indicator, i.e., election years represent high geopolitical risk, but this approach mainly responds to internal political risk, severing the internal and external links of geopolitical risk. Similarly, some scholars have used social dynamic events to measure risk, and fewer studies have applied this approach due to its endogeneity drawbacks. In this paper, the geopolitical risk index (GPR) constructed by Caldara and Iacoviello using the frequency of relevant words in text-search newspapers is used as an alternative indicator in their study, and this GPR index system involves the major economies and countries in the country, with a large time span, wide coverage, continuity and comparability, and other characteristics, which have been widely used in academia.

Regarding the measurement of economic policy uncertainty, according to previous studies, the earliest use of the turnover of leaders, such as election and change of officials, is a measure of economic policy uncertainty; however, the measurement method is not conducive to cross-sectional and vertical comparison and is weak in continuity. Later, some scholars calculated the economic policy uncertainty index by extracting keyword data from newspapers, and this approach has been widely used with the advantages of comparability, continuity, scientificity, etc. Baker et al. (2012) extracted the economic policy uncertainty index (EPU) based on the frequency of articles related to economic policy changes appearing in the South China Morning Post, an English newspaper in Hong Kong, setting reasonable weights and scientific calculation synthesis. Although the South China Morning Post is the most influential newspaper in Hong Kong, it is different from the actual situation in mainland China in terms of language writing habits and objectivity. Therefore, this paper selects the Chinese EPU index extracted by Steven J. Davis et al. from Guangming Daily and People's Daily using a similar filtering method as the research object.

To protect ecology and control greenhouse gas emissions, the Chinese government has implemented controls from both the total carbon emission and carbon emission perspectives to strictly control carbon emissions throughout the country and in each region. With economic development, carbon dioxide emission intensity shows a decreasing trend under the effect of policy adjustment, macroeconomic regulation and control, technology effects, etc. Local regions show a decoupling state of economic low-carbon development, but the carbon emissions and intensity of most regions are still under great pressure to achieve the goal of carbon neutrality. As the total amount of carbon dioxide emissions increases with the development of the economy, only by studying the influence of external political risks on the intensity of carbon dioxide emissions can we better reflect the in-depth relationship between political risks and environmental damage. This paper takes carbon emission intensity as the research object, which is determined by the ratio of total carbon emissions to GDP, with the original data from the EPS database and China Statistical Yearbook, i.e.$CE=CO2/GDP$.where CE represents carbon emission intensity, CO2 represents total national carbon emissions, and GDP is gross domestic product. Based on data availability and research interval, the data samples in this paper are quarterly data from January 1995 to December 2020, and the data are preprocessed with logarithmic first-order differences according to the requirement of smoothness.

In the following empirical analysis, all variable data that may be used are standardized. Descriptive statistics are shown in Table 1, such as X carbon emission intensity (CE), economic policy uncertainty (EPU), geopolitical risk (GPR), innovation level (R&D), number of patents granted (PT), number of invention patents (INV), and scientific and technological achievements (TAI). The above variable data passed the stationarity test.

Table 1：Descriptive statistics

	N	range	Minimum	maximum	mean	standard deviation	variance	skewness	kurtosis
CE	103	0.1233	-0.0912	0.0322	-0.017914	0.017051	0	-0.769	3.074
EPU	103	2.2389	-1.4203	0.8186	0.012388	0.3183127	0.101	-0.689	3.327
GPR	103	0.804	-0.3679	0.4361	0.004698	0.1574539	0.025	0.135	0.275
R&D	103	0.0899	0.0108	0.1007	0.042017	0.0150222	0	0.401	0.863
PT	103	0.2452	-0.0717	0.1735	0.044136	0.0437473	0.002	0.183	0.865
INV	103	0.2904	-0.0774	0.213	0.048791	0.0529677	0.003	0.36	0.964
TAI	103	0.1592	-0.0805	0.0787	0.00926	0.0207176	0	-0.404	4.856

3.3. Frame Construction

The research framework of this paper is shown in Fig. 1. According to the previous theoretical analysis, the empirical analysis focuses on the time-varying relationship among carbon emission intensity, geopolitical risk and economic policy uncertainty. At the same time, considering the influence path of political risk on carbon emissions, the innovation level and scientific and technological achievements are used as intermediate variables to verify the possibility of the impact.

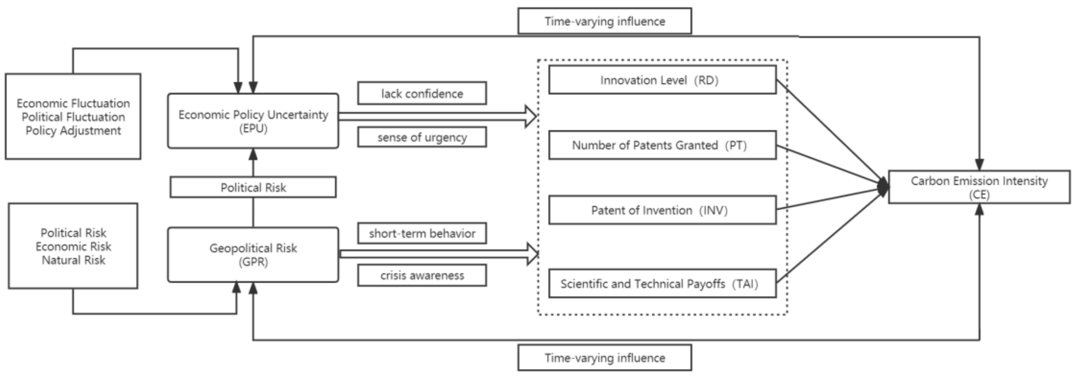


Figure 1: Frame structure diagram

4 Empirical Results

4.1. MCMC algorithm Simulation

MCMC consists of two MCs: the Monte Carlo Simulation (MC) and the Markov Chain (MC). The Monte Carlo simulation is a numerical simulation method that takes probability phenomena as the research object and estimates unknown characteristics by a sampling survey. In the calculation and simulation, by constructing a probability model similar to the system performance and conducting random experiments on digital computers, the random characteristics of the system can be simulated. In principle, the Monte Carlo method can be used to solve any problem with probability explanation.

A Markov chain is a stochastic process in probability theory and mathematical statistics that has Markov properties and exists in a discrete exponential set and state space. The Markov chain can be defined by a transition matrix and transition graph. In addition to the Markov property, the Markov chain may have irreducibility, recurrence, periodicity and ergodicity. The essence of this algorithm is to use randomness to solve deterministic problems. It is mainly used to solve three problems: optimization, numerical integration and sampling from a probability distribution. The Markov chain can be applied to the Monte Carlo method to form the Markov chain Monte Carlo (MCMC). First, the initial assignment of the time-varying parameters is made so that $\mu_{co_{20}} = \mu_{gpr_0} = \mu_{epu_0}$, $\Sigma_{co_{20}} = \Sigma_{gpr_0} = \Sigma_{epu_0} = 10 \times I$, and $\left(\Sigma_{co_2}\right)_i^{-2} : Gamma(20, 0.01)$, $\left(\Sigma_{gpr}\right)_i^{-2} : Gamma(2, 0.01)$, $\left(\Sigma epu\right)_i^{-2} : Gamma(2, 0.01)$ 。

Using the MCMC method to conduct 10,000 sampling iterations, discard the first 1,000 unstable simulation preburning iterations, and only retain the results of the last 9,000 sampling iterations to obtain the mean, standard deviation, 95% confidence interval, CD statistic, and null factor of the posterior distribution of the model parameters. From Table 2, it can be seen that the CD statistics of each parameter do not exceed the critical value of 1.96 at the 5% confidence level, and the original hypothesis that the model parameters converge to the posterior distribution cannot be rejected. Meanwhile, the invalidation factors are low, all less than 120, indicating that the model sampling is valid and the fit is good.

Table 2: Model estimation results

Parameter	Mean	Stdev	95%U	95%L	Geweke	Inef.
sb1	0.0023	0.0003	0.0018	0.0029	0.525	3.76
sb2	0.0022	0.0002	0.0018	0.0028	0.001	6.38
sa1	0.0056	0.0016	0.0034	0.0097	0.897	29.08
sa2	0.0056	0.0016	0.0034	0.0097	0.468	28.14
sh1	0.3981	0.1376	0.1875	0.7236	0.013	82.81
sh2	0.0061	0.0021	0.0035	0.0116	0.501	59.98

The upper, middle and lower parts of Fig. 2 show that the sample correlations of carbon emission intensity, economic policy uncertainty index and geopolitical risk index gradually decrease, the sample simulation paths of the three parameters show significant fluctuating agglomerative characteristics, and the posterior distribution density function of the samples has significant normal distribution characteristics, which shows that the distribution of the parameters can be effectively simulated by MCMC sampling.

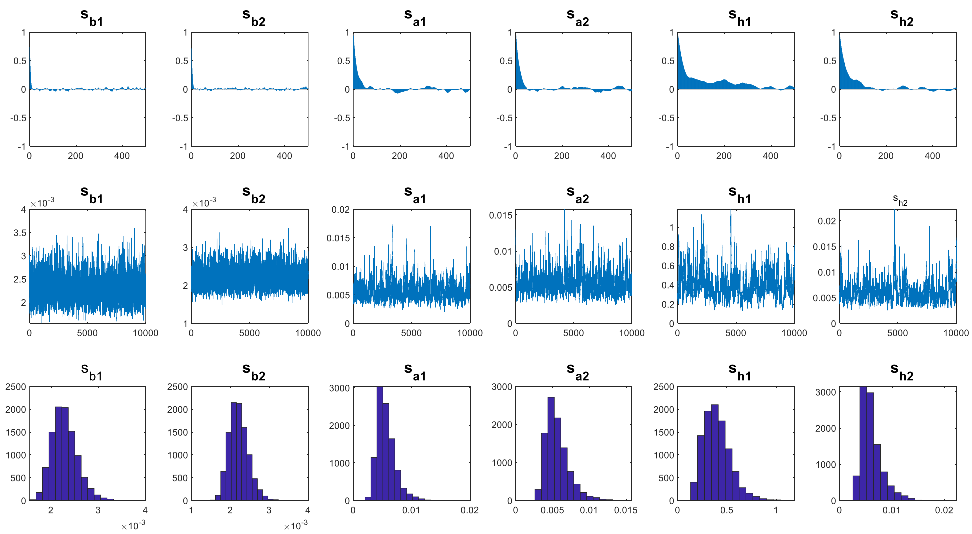


Figure 2: Sample correlation coefficient (top) Sample path (middle) Sample posterior distribution (bottom)

4.2. Equal-interval Impulse Response Analysis

The most important feature of the TVP-VAR model compared with the traditional VAR model is that it allows for the time-variability of the parameters and reflects the dynamic effects of structural shocks between the parameters from multiple perspectives through two time-varying impulse response functions. In this paper, we use equal-interval impulse response plots and time-point impulse response plots to represent the time-varying effects of economic policy uncertainty and geopolitical risk on China's carbon intensity under different states. The top, middle, and bottom parts of Fig. 3 show the equal-interval impulse responses for sample lags 1 (3 months), 2 (6 months), and 4 (12 months), which reflect the different effects of lags in the short, medium, and long term, respectively. Fig. 3 (top) reflects that carbon emission intensity is significantly and positively influenced by its own factors, and the positive response of its own shocks becomes gradually weaker with time and does not present a situation where the impact of shocks becomes consistently larger. The research process of this paper focuses on the middle and bottom parts of Fig. 3, where Fig. 3 (middle) reflects the response of EPU to the equal-interval shock of carbon emission intensity, which basically maintains the positive shock during the period of 1995 Q1–2020 Q4 covered by the sample data, indicating that the increasing uncertainty of economic policies will lead to increasing carbon emission intensity. This indicates that the increase in carbon emission intensity or the adoption of part of the reason for the increase in carbon intensity or the lack of significant reduction by various measures comes from the excessive frequent adjustment of economic policies. Fig. 3 (bottom) shows the equal-interval shock response of GPR to carbon emission intensity, which is positive for approximately two-thirds of the period from 1995 Q1 to 2020 Q4 and negative for only a small part of the middle period, especially after 2013, when the positive response gradually increases.

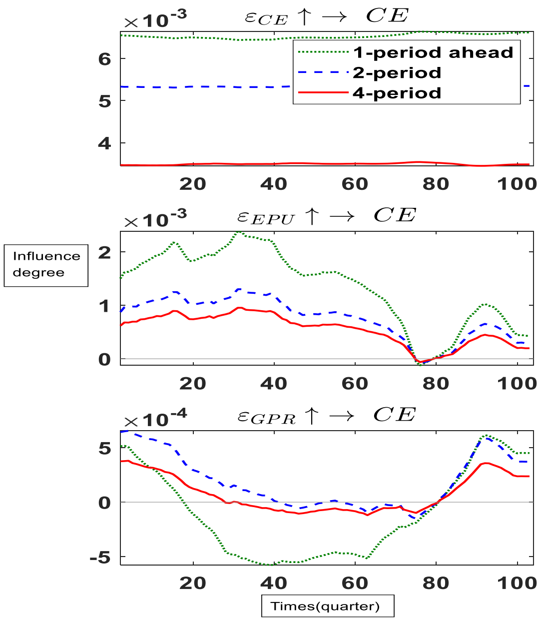


Figure 3: Equal interval impulse response

4.3. Impulse response analysis at time points

The point-in-time impulse response function reflects the change characteristics of economic policy uncertainty and geopolitical risk on carbon emission intensity at different time points, and the three time points selected in this paper are 2003 (Iraq war, SARS), 2008 (global financial crisis), and 2018 (U.S.–China trade war), which correspond to three special periods of highly complex and unstable situations in

China and abroad and represent the sample time period before, during and after the time period, which is highly representative. The following conclusions can be drawn from Fig. 4. First, during the full sample period, frequent adjustments of economic policies all raise the carbon emission intensity level to different degrees, but with the national emphasis on ecological protection and energy conservation and emission reduction, the negative effect of policy fluctuations on reducing carbon emissions continues to diminish. Second, the impact of rising geopolitical risks on carbon emissions shows very different effects in different periods. At two points in time, 2003 and 2008, high geopolitical risks did not have a helper effect on the increase of carbon emissions intensity, but 2018 produced a significant positive effect. The trade war between China and the United States kicked off in approximately 2018, meaning that in terms of China's carbon emissions intensity, it is important to be vigilant to prevent the risk of external risks hindering the domestic double-carbon target.

Fig. 4 shows the impact of carbon dioxide emission intensity on economic policy uncertainty and geopolitical risks. First, from the middle part of Fig. 4, it can be seen that when the carbon emission intensity increases, the uncertainty of economic policies will be reduced in a short time, indicating that the deterioration of the environment has prompted the government to stop from the angle of frequent regulation and control and to think about what policies will not accidentally lead to an increase in carbon emissions. The government's reflection is conducive to reducing the possibility of implementing various policies. Second, from the right part of Fig. 4, it can be seen that the increase in carbon emissions leads to higher geopolitical risks for China to a certain extent. This is because all countries in the world have realized the importance of reducing carbon emissions. As the country with the largest carbon dioxide emissions, China must have made insufficient efforts in environmental protection, which will immediately cause doubts and condemnation from other countries, thus increasing the urgency of the Chinese government for environmental protection. In the three time periods, this effect is consistent.

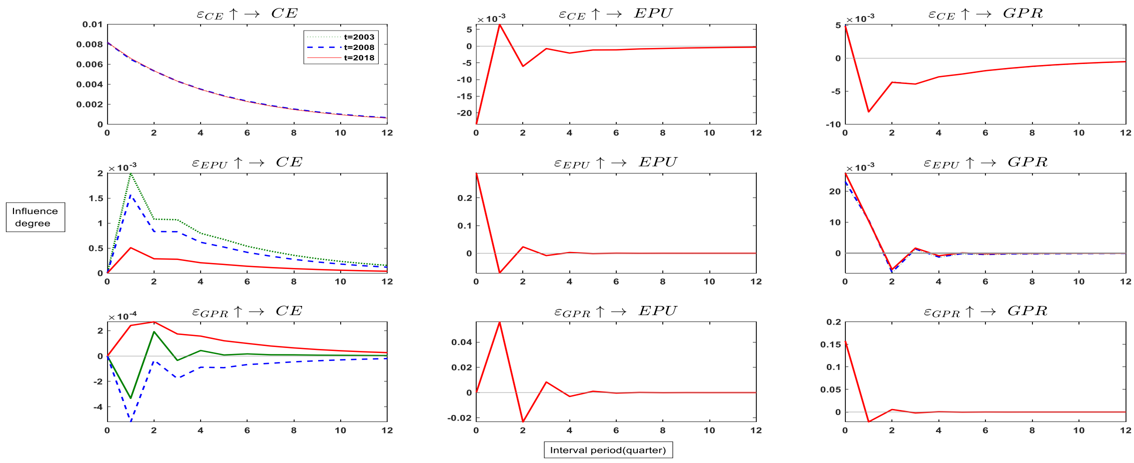
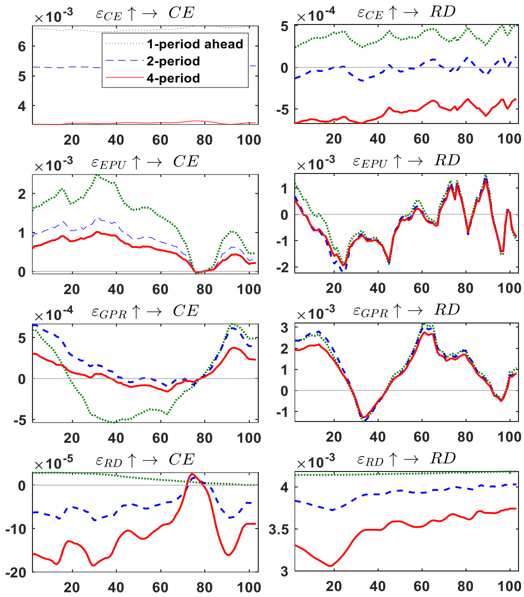


Figure 4: Time-point impulse response

4.4. Transmission path analysis

In terms of possible transmission mechanisms, geopolitical risks and economic policy uncertainties are political risks, and the uncertainties brought by the risks will affect the choices of the government and enterprises. The government may reduce R&D investment, leading to a decrease in technological innovation capacity to maintain economic stability and for enterprises to maintain profitability. Especially since the Sino-U.S. trade war, the external blockade of China in science and technology will also affect the progress of China's science and technology development. In previous studies, scholars have focused on the positive role of innovation level and technological development in reducing carbon emission intensity. Therefore, this paper attempts to explore in an empirical analysis whether geopolitical risks and economic policy uncertainties affect China's R&D investment and innovation level, which, in turn, affect the reduction of carbon emission intensity.

First, the indicators of R&D investment take the overall R&D investment level as the data source, and the data preprocessing is consistent with the indicators covered in the previous paper. The results of data analysis are shown in Fig. 5 and Fig. 6. In Fig. 5, R&D input is included in the analysis framework as a transmission mechanism, and as R&D input increases, it has a significant negative impact on carbon emission intensity, indicating that increasing R&D input can effectively reduce carbon emission intensity, which is more conducive to achieving the goal of energy saving and emission reduction. However, economic policy uncertainty and geopolitical risks have negative impacts on R&D inputs to different degrees, especially after 2018. With the increase in economic policy uncertainty and geopolitical risks, the negative impact on R&D inputs is significant, among which the negative effect from internal policy



instability is greater.

Figure 5: CE EPU GPR R&D Equal interval impulse response

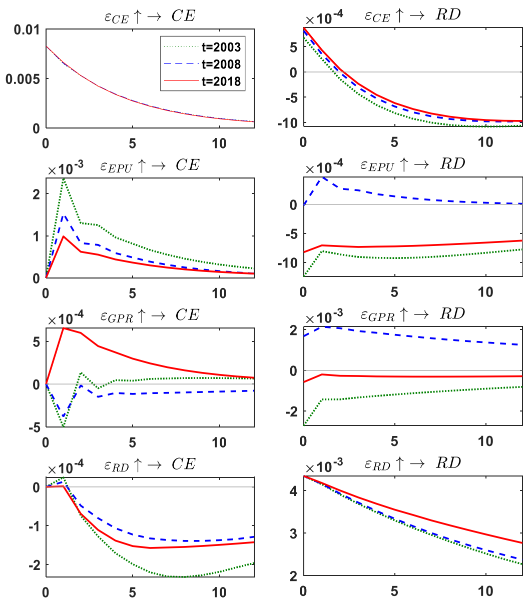


Figure 6: CE EPU GPR R&D Time-point impulse response

Second, in the empirical analysis of the innovation level in different time periods, the number of patents granted (pt) is chosen as a proxy index, and the results of the analysis are shown in Fig. 7 and Fig. 8. However, from the time-point and equal-interval impulse response plots, it is not found that the innovation index represented by the number of patents granted strongly reduces carbon emission intensity or has a positive effect on the reduction of carbon emission intensity with the increase of the number of patent grants before 2008. After 2008, this positive effect became negative, when economic policy uncertainty further increased carbon intensity by positively influencing the number of patents granted, while geopolitical risk had a significant negative impact on the number of patents granted. Considering that the number of patents granted includes invention patents, design patents and utility model patents, among which invention patents are closely related to actual industrial technology innovation and have a more direct effect on energy saving and emission reduction, this paper selects invention patents for the number of patents granted as a new innovation index for in-depth research. The alternative index and the empirical results are shown in Fig. 9 and Fig. 10. According to the equal-interval impulse responses and split-time impulse responses of the four variables, the reselection of invention patents as an alternative indicator of innovation is similar to the empirical results with the number of patents granted as an alternative indicator, i.e., the positive effect of invention patents on the reduction of carbon emission intensity is not found, but the positive stimulation of carbon emission intensity itself.

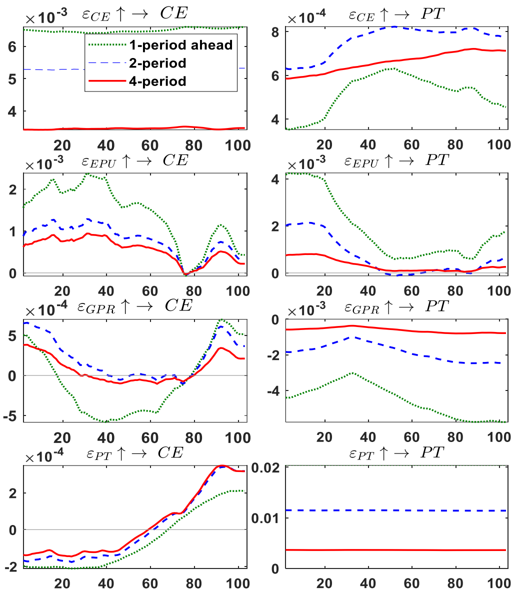


Figure 7: CE EPU GPR PT Equal interval impulse response

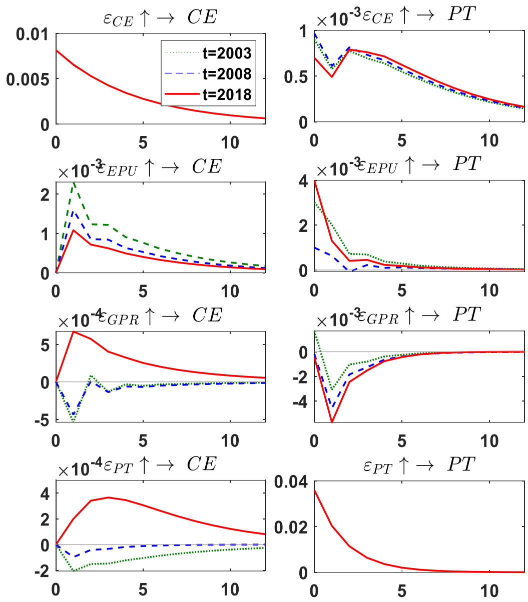


Figure 8: CE EPU GPR PT Time-point impulse response

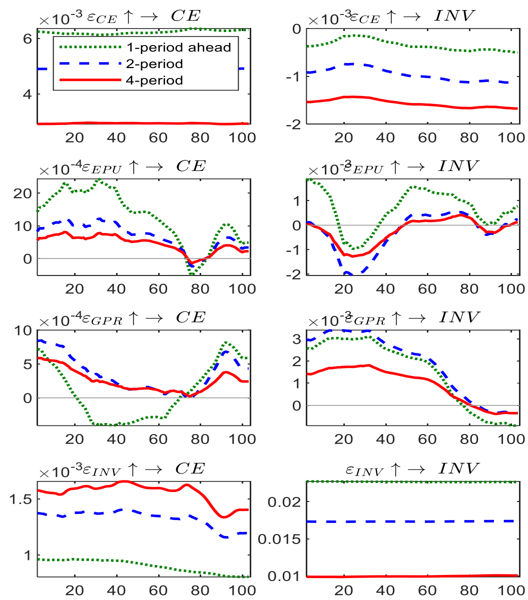


Figure 9: CE EPU GPR INV Equal interval impulse response

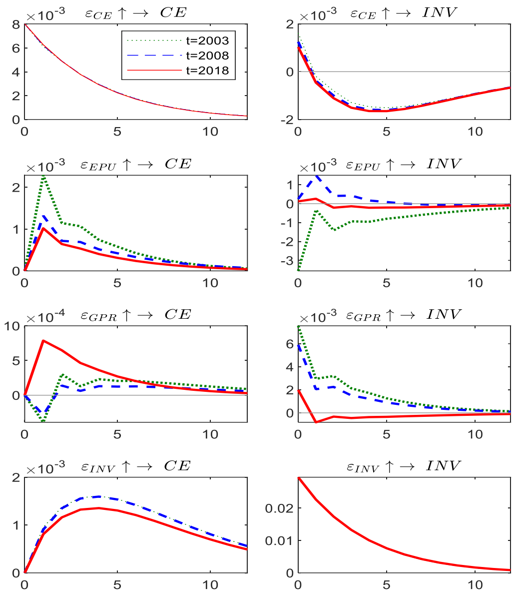


Figure 10: CE EPU GPR INV Time-point impulse response

Finally, this paper selects the number of scientific and technological achievements (TAI), which is more directly related to science and technology in invention patents, as an innovation alternative indicator, and the results of the empirical analysis are shown in Fig. 11 and Fig. 12. In the full sample period, the increase in the number of scientific and technological achievements has a significant negative impact on carbon emission intensity, and the progress in scientific and technological achievements has a significant positive effect on the reduction of carbon emission intensity as time advances. This indicates that the efforts through scientific and technological research and development have a very important impact on achieving the goal of energy saving and emission reduction. Economic policy uncertainty had a negative impact on the increase in S&T outcomes for most of the 1995–2020 period, but frequent policy adjustments after 2018 have somewhat contributed to the increase in S&T outcomes, suggesting that the Chinese government's S&T strengthening strategy has played a key role in recent years. However, geopolitical risks have had a significant negative impact on the increase in Chinese S&T achievements, especially since the Sino-U.S. trade war in 2018. This negative impact has tended to increase as external political risks have been raised in vain, suggesting that the technology blockade brought about by the trade war has indeed had a negative impact on Chinese S&T achievements.

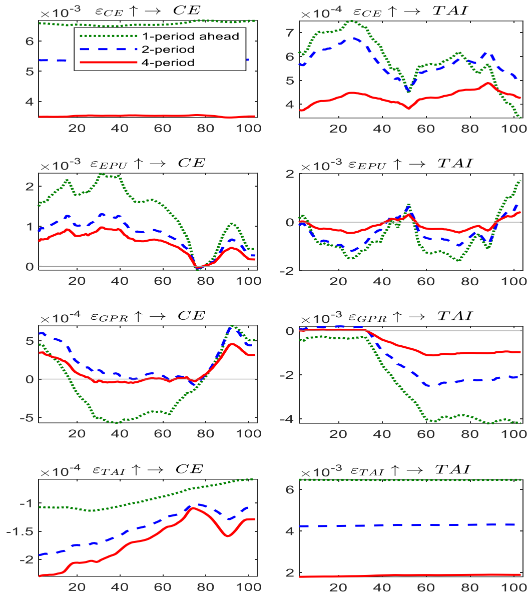


Figure 11: CE EPU GPR TAI Equal interval impulse response

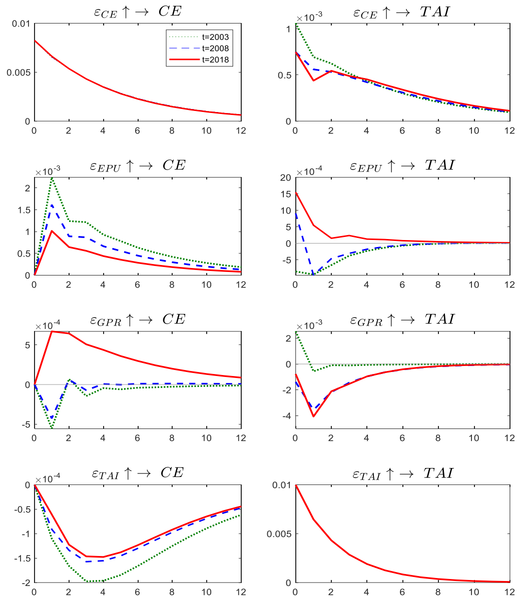


Figure 12: CE EPU GPR TAI Time-point impulse response

In searching for the path of the influence of political risks on carbon emission intensity, this paper takes innovation ability as the breakthrough point, gradually refines the research scope and narrows the variable range from R&D investment to the number of patents granted, and then refines the number of patents granted to invention patents, and finally to scientific and technological achievements. Through the above analysis, it is found that innovation capabilities are not the only influence path; the core scientific and technological strength is the relationship that affects the carbon emission intensity, which also shows that rejuvenating the country through science and education is an important strategy.

4.5. Robustness test

To verify the negative effects of geopolitical risk and economic policy uncertainty on the reduction of China's carbon emission intensity, this paper selects global geopolitical risk and the global economic policy uncertainty index as alternative indicators for robustness testing. As shown in Fig. 13, the effects of global economic policy uncertainty and global geopolitical risk on China's carbon emission intensity are similar to the findings of the previous study. Both the equal-interval impulse response and the time-point impulse response generate positive shocks, which indicates that the results of the previous empirical analysis are robust. Among them, global geopolitical risk has a positive effect in the full sample cycle, with a weaker impact than domestic geopolitical risk in terms of strength. The impact of global economic policy uncertainty also shows a certain phase, but at this stage, it significantly stimulates carbon emission intensity, but the effect is weaker than the impact of domestic economic policy uncertainty.

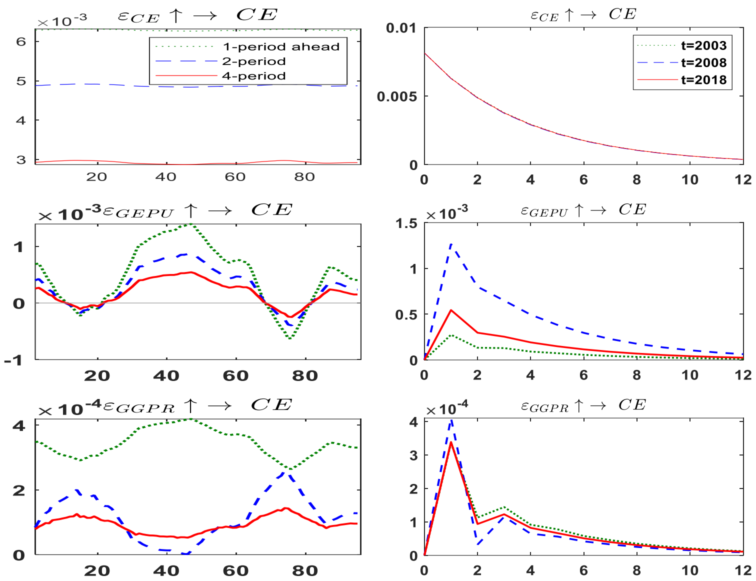


Figure 13: Global data equal interval and point-in-time impulse response

5 Conclusion

Based on quarterly data on China's economic policy uncertainty, geopolitical risk and carbon emission intensity from January 1995 to December 2020, this paper quantitatively examines the impact of two political uncertainties and risks on China's carbon emissions. It constructs a time-varying parametric vector autoregressive model with stochastic fluctuations (TVP-VAR) to analyze whether the two factors will hinder carbon emissions. The main findings are as follows.

(1) Economic policy uncertainty shocks have a significant positive impact on carbon intensity over the entire sample period, and this impact decreases slowly with the lag period, as seen in the equal interval sample shock analysis. After dividing the sample into early, middle, and late periods, we select the representative years of 2003, 2008, and 2018 for the time-point shock experiments and find that the effect of economic policy uncertainty shocks on carbon emission intensity decreases over. The effect of 2018 is significantly smaller than that of the previous years, which indicates the current strengthening of environmental protection concepts and the change in attitude in China. While continuously adjusting policies to cope with the complex and volatile economic situation, China is paying increasing attention to the protection of the environment and controlling carbon emission intensity through various efforts.

(2) The iso-interval shock response of geopolitical risk on carbon emission intensity shows that during the period of 1995Q1–2020Q4, approximately two-thirds of the time is a positive shock, and only the middle small period is a negative shock, especially after 2013. The positive shock gradually increases, and numerically, the positive impact of geopolitical risk on carbon emission shock exceeds the impact of economic policy uncertainty. In the time-point shock analysis, it is found that the positive impact of geopolitical risk on carbon emission intensity is significant especially after 2018, indicating that on the way to achieve the double-carbon target, the obstructive effect of geopolitical risk has been significantly greater than the impact of domestic economic policy uncertainty.

(3) R&D investment has a significant negative impact on carbon emission intensity, indicating that increasing R&D investment can effectively reduce carbon emission intensity, which is more conducive to achieving the goal of saving energy and reducing emissions. However, economic policy uncertainty and geopolitical risks affect the increase in R&D investment to different degrees, especially after 2018. The degree of hindrance of R&D investment is significant, among which the negative effect of internal policy instability is greater.

(4) The innovative proxies selected are the number of patents granted, the number of invention patents granted, and the number of scientific and technological achievements. The rise in the number of scientific and technological achievements, which are directly related to the level of scientific and technological innovation, effectively reduces carbon emission intensity during the full sample period, which indicates that efforts through scientific and technological R&D have a significant impact on achieving the goal of energy saving and emission reduction. Economic policy uncertainty has been detrimental to the increase in S&T outcomes most of the time, but the frequent policy adjustments after 2018 have somewhat contributed to the increase in S&T outcomes, suggesting that the Chinese government's focus on the S&T strengthening strategy has played a key role in recent years. The increase in geopolitical risk has always significantly hindered the increase in China's S&T outcomes, especially since the Sino-U.S. trade war in 2018. This negative impact has tended to increase as external political risk has been raised in vain, indicating that the technology blockade by the trade war has a greater negative effect on China's S&T outcomes.

(5) In the robustness test, the effects of global economic policy uncertainty and global geopolitical risks on domestic carbon emission intensity are similar to the findings of the previous study, with slightly weaker effects, indicating that the results of the previous empirical analysis are reliable.

In view of the findings of the empirical analysis, the following suggestions are made to reduce the obstacles on the road to energy saving and emission reduction and to effectively achieve the carbon peaking and carbon neutrality goals.

(1) Humans and nature exist in a symbiotic relationship. Reducing carbon dioxide emissions and economic development can be achieved at the same time. China needs to adhere to ecological priorities and green development, take the synergistic effect of reducing pollution and carbon as the general starting point, and promote "reducing pollution, reducing carbon and strengthening ecology" as a whole. Through the restriction of ecological environmental protection, the economic structure and industrial structure are forced to accelerate transformation and upgrading, thus boosting the comprehensive green transformation of economic and social development and promoting high-quality economic development.

(2) Through the empirical analysis of this paper, we found that the more frequently the government implements policies to regulate economic fluctuations, the more likely it is to lead to more negative consequences and short-term behaviors that harm the sustainable development of society. While frequently adjusting domestic economic policies to adapt to complex situations, we should always adhere to the implementation and stability of energy conservation and emission reduction policies. Especially in the next few decades, saving energy and reducing carbon dioxide emissions will be the focus of China's social development, and we are committed to reducing the negative effects of various policies on the environment.

(3) We should be more vigilant of external political risks, especially the current white-hot local military conflicts and the continuous unwarranted accusations of Western powers against China's problems, which will continue to increase geopolitical risks and affect the reduction of domestic carbon emission intensity. It is necessary to maintain a high degree of alertness to external risks and adjust foreign policy appropriately to protect the smooth implementation of energy conservation and emission reduction policies. However, it is not necessary to regard geopolitical risks and the reduction of carbon emissions as

opposing factors. To safeguard China's commitment to environmental protection and avoid the responsibility of the international community for its environmental situation, the government has greater motivation to reduce carbon emissions to achieve the double-carbon goal at an early date.

(4) It is necessary to pay attention to the promotion and protection of scientific and technological achievements, especially the key technologies related to the lifeblood of national science and technology. Under the reality of external technology blockade, increase investment and support for scientific and technological research, always maintain the strategy of strengthening the country with science and technology, and promote the transformation of scientific research achievements to effectively reduce the carbon emission intensity, thus helping to achieve the double-carbon goal.

China's double-carbon strategy advocates a green, environmentally friendly and low-carbon lifestyle. Accelerating the pace of carbon emissions is conducive to guiding green technology innovation and improving the global competitiveness of industry and the economy. However, there are many difficulties on the road to reducing carbon emissions. All sectors of society must realize the importance of environmental protection, speed up the pace of innovation and work together to reduce carbon dioxide emissions.

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