

# The Time-Varying Relationship Between Economic Policy Uncertainty and Returns of New Energy Stocks

Jie Peng\*

School of Economics and Management, Nanjing University of Science and Technology, Nanjing, China

\* Corresponding Author Email: pjplum233@163.com

**Abstract.** With the increasing global emphasis on environmental protection, green development has become an important part of high-quality development in various countries and has stirred up enthusiasm for new energy consumption and investment. This paper uses a TVP-VAR model to analyze the dynamic effects between Chinese economic policy uncertainty, international crude oil prices, Guangdong carbon prices, and the CSI New Energy Index from July 2015 to November 2023. It turns out that they are closely linked in the short term, with obvious time-varying features in direction and magnitude. The effects of economic policy uncertainty are more persistent when extreme events occur. Finally, based on the research results, some constructive suggestions are proposed, such as establishing a risk early warning mechanism among them, improving the market system, enhancing regulatory capabilities, and promoting the development of green finance.

**Keywords:** Economic policy uncertainty, International crude oil prices, Carbon prices, New energy stocks, TVP-VAR model.

## 1. Introduction

Since the early 21st century, there have been a number of significant global events that have increased uncertainty. The financial crisis of 2008 resulted in severe economic fluctuations in many economies. To stimulate economic recovery, various countries implemented a series of policies in the economic area and others. According to data on economic policy uncertainty in mainland China compiled by Davis et al. [1], significant fluctuations were observed in the economic policy uncertainty (EPU) index during events such as 2008, 2018 and 2020, which represent the Global Financial Crisis, the US-China Trade War and the COVID-19 pandemic respectively. As the process of globalization and financialization deepens, it is closely linked to all industries and also affects the prices of commodities, stocks, and other assets [2,3,4,5]. The issue of climate change has been gaining increasing attention For the past few years. In 2013, China initiated carbon emission trading pilots in several regions including Hubei, Guangdong, and Shenzhen. In September 2020, China announced the "carbon peaking and carbon neutrality" strategy, aiming to peak carbon emissions before 2030 and achieve carbon neutrality by 2060. Since then, the government has promulgated a series of policies related to this strategy, demonstrating China's commitment to environmental governance. Fossil fuels, represented by crude oil, are one of the major causes of environmental problems and high carbon emissions. To mitigate carbon emissions, China has implemented numerous economic policies to support the new energy industry, driving innovations and development of the industry. The mainstream new energy indices in China currently comprise the CSI New Energy Index, CSI New Energy Automobile Industry Index, and CSI New Energy Automobile Index. These indices cover stocks of listed enterprises involved in renewable energy production and other applications. Fluctuations in economic policy uncertainty will affect crude oil and carbon prices, which in turn influences market demand and costs for new energy enterprises, subsequently reflecting on stock prices[6]. Therefore, there exists a certain linkage among economic policy uncertainty, the new energy market, the crude oil market and the carbon market. However, there is currently limited research that integrates them, especially focusing on the Chinese market. Hence, this paper aims to explore the time-varying relationship between domestic economic policy uncertainty, the new energy stock, the international oil and the carbon market. This paper will contribute to enhancing policy

effectiveness, and financial system stability, and provide insights for investment decisions of market participants.

The literature review constitutes the second part of this paper, which describes the relationship between economic policy uncertainty, the crude oil market, the carbon market and the new energy market as the theoretical basis for the subsequent empirical research. The third and fourth parts introduce the TVP-VAR model and data. The fifth part is empirical analysis, using the TVP-VAR model to study the impact relationships among variables. The final part provides the summary and suggestions.

## 2. Literature Review

Economic policy uncertainty is closely related to the costs, operations, and investments of enterprises. According to real options theory, investment opportunities are considered as resources held by economic agents. Enterprises may alter production and investment to avoid financial costs in times of high economic policy uncertainty, resulting from factors such as low expectations and confidence. Rodrik [7], in his study of the impact of policy uncertainty on private investment in developing countries, found that even small fluctuations in policy uncertainty can have a large effect on investment. Policy uncertainty including fiscal and monetary policies may affect the decision-making activities of enterprises [8].

Therefore, economic policy uncertainty affects the financing costs of enterprises, which in turn reflects on stock prices. Chen et al. [9] found that economic policy uncertainty can increase stock price risk through enterprise discount factors and correlation coefficients, especially when there are significant changes in policy reforms. Moreover, if there is the significant changes in economic policy uncertainty can lead to reduced consumption of current investors, resulting in decreased investment in assets and possibly increasing investor pessimism, leading to stock price declines [10,11]. The authors noted that economic policy uncertainty is negatively correlated with stock returns in the current period, but positively correlated in later periods. In the context of the energy stock market, Ji et al. [12] examined the relationship between economic policy uncertainty and multiple energy markets and found that economic policy uncertainty has a greater impact on the stock prices of renewable energy compared to traditional energy. Zhao [13] found that economic policy uncertainty adversely affects the stock prices of green energy. Liu et al. [14] studied renewable energy stocks in the US and EU and found that economic policy uncertainty often has a high-frequency impact on these stocks. Additionally, stock price volatility also affects policy uncertainty. Antonakakis et al. [15] concluded that the higher the stock price volatility, the higher the economic policy uncertainty will be.

Under the influence of economic policy uncertainty, enterprises' financing costs may face upward pressure. The reduction in energy demand and related energy prices may result from a decrease in investment demands due to changes in their impact on economic growth. Kang and Ratti [16] proposed that the growth in crude oil prices is associated with a significant rise in economic policy uncertainty. Several scholars have investigated the connection between economic policy uncertainty and crude oil price returns through various methods, and their findings show that there is a time-varying relationship between the two. Throughout the entire sample period, a negative relationship was observed [17]. This relationship was considerably strengthened under extreme conditions [18], such as a positive correlation before the break-out of the Financial Crisis [19]. Additionally, the correlation between traditional and new energies is also changing due to the impact of economic policy uncertainty. Firstly, traditional energy and new energy are substitutes for each other. When oil prices rises, the demand for new energy also increases, leading to increased profitability for relevant enterprises and consequently higher stock prices. Wen et al. [20] empirically found asymmetric spillover effects of West Texas Intermediate (WTI) futures price on the Chinese new energy stock market via an asymmetric GARCH model. Ahmad et al. [21] discovered that the volatility of new energy stocks is negatively affected by oil price volatility. This effect is particularly pronounced when

oil prices are low [22]. During the COVID-19 pandemic, the demand for fossil fuels, such as crude oil, has decreased due to obstacles in international transportation and economic shocks. This has had a positive spillover effect on the new energy market [23].

In recent years, with the deepening global attention to environmental issues, the inception of domestic carbon emissions trading markets has garnered scholarly interest in exploring the nexus between the carbon market and the energy market. Battaller [24], focusing on the European carbon market, found that the energy market influenced carbon prices. Guo et al. [25] empirically demonstrated that carbon stock market has a strong influence on the energy stock market. Furthermore, the country has consistently implemented policies to support the new energy industry and is committed to reducing carbon emissions. Some scholars [26,27] suggest that there may be a correlation between economic policy uncertainty and the carbon market. The carbon market price is related to the cost of enterprises, which is further reflected in stock prices. Dutta et al. [28] through the VAR-GARCH model empirically proved that the price of carbon emissions affects the renewable energy stock index in the EU, and Yılcı et al. [29] showed that the variables of oil prices, carbon prices, and interest rate have an obvious implication on the clean energy index when they measured the relationship between them. Hassan et al. [30], on the other hand, used NASDAQ clean energy stocks for their research and discovered that carbon price has a positive effect on it.

As a result, the focus of most research is on foreign markets, and there is less analysis of domestic energy and related markets, particularly the impact of factors related to domestic new energy stocks. This paper utilises time-varying models to investigate the connections among economic policy uncertainty, the crude oil, the carbon, and the new energy market.

### 3. Methods

Since Sims proposed the Vector Autoregressive (VAR) model in 1980, it has been frequently used in subsequent research. However, the variables in this model are static. But in practice, economic environments, institutions, and other factors often change. Therefore, this model has some shortcomings. Consequently, Primiceri and Nakajima developed the model for time-varying relationships, known as the Time-Varying Parameter Vector Autoregressive (TVP-VAR) model. It is becoming the most widely used model for examining relationships between variables.

TVP-VAR model is derived from the Structural Vector Autoregressive (SVAR) model. The form of an SVAR model is as follows:

$$Ay_t = F_1y_{t-1} + \dots + F_sy_{t-s} + \mu_t, t = s + 1, \dots, n \quad (1)$$

where  $y$  is a  $k \times 1$  dimensional observation vector,  $A$  and  $F$  are  $k \times k$  dimensional coefficient matrices,  $s$  is the lag period,  $\mu_t$  is structural shock, and  $\mu_t \sim N(0, \Sigma)$ . Assuming that  $A$  is a lower triangular matrix multiplied by the same number of  $A^{-1}$  on both sides of (1), then rewrite it as  $y_t = B_1y_{t-1} + \dots + B_sy_{t-s} + A^{-1}\sum \varepsilon_t$ , where  $\varepsilon_t \sim N(0, I_k)$ ,  $B = A^{-1}F$ . Defining  $X_t = I_k \otimes (y_{t-1}, \dots, y_{t-s})$ , with  $\beta$  as a  $k^2_s \times 1$  dimensional vector, the above equation is rewritten as  $y_t = X_t\beta + A^{-1}\sum \varepsilon_t$ . Further adding time-varying features to the equation, it is expanded into a TVP-VAR model as follows:  $y_t = X_t\beta_t + A^{-1}\sum \varepsilon_t$ . Arranging the elements that are not 0 or 1 in  $A_t$  into column vectors, so that it is  $a_t = (a_{21}, a_{31}, \dots, a_{k, k+1})$ ,  $\sigma_t$  is the diagonal element matrix of  $\Sigma_t$ , let  $h_t = (h_{1t}, \dots, h_{kt})$ ,  $h_{it} = \log \sigma_{it}^2$ ,  $i = 1, \dots, k$ ,  $t = s+1, \dots, n$ . Assuming that the parameters in the above equation obey a random wandering process, we have:  $\beta_{t+1} = \beta_t + \mu_{\beta t}$ ,  $a_{t+1} = a_t + \mu_{at}$ ,  $h_{t+1} = h_t + \mu_{ht}$ ,

$$\begin{bmatrix} \varepsilon_t \\ \mu_{\beta t} \\ \mu_{at} \\ \mu_{ht} \end{bmatrix} \sim N \left( 0, \begin{bmatrix} I_k & 0 & 0 & 0 \\ 0 & \Sigma_{\beta} & 0 & 0 \\ 0 & 0 & \Sigma_a & 0 \\ 0 & 0 & 0 & \Sigma_h \end{bmatrix} \right)$$

To avoid measurement errors due to endogeneity problems, following the method proposed by Nakajima [31], this paper employs the Markov Monte Carlo algorithm (MCMC) to estimate time-varying parameters.

## 4. Data

In this paper, four variables are used as the research object, with monthly data selected from July 2015 to November 2023. First, domestic economic policy uncertainty (EPU), which adopts the economic policy uncertainty index constructed by Davis et al.[1] for mainland China. This index comes from two representative newspapers, People's Daily and Guangming Daily. It effectively quantifies domestic economic policy uncertainty by covering policies related to financial, monetary, fiscal, bond and other relevant concepts.

Secondly, the CSI New Energy Index (XNY), which is based on the CSI 300 Index. It selects a sample of the top 80 stocks based on the average total daily market value over the past year, representing companies involved in the production, storage, and application of new energy. It is believed to provide a reasonable measure of the level of new energy stocks in the domestic market. Thirdly, the WTI Crude Oil Futures Price (WTI). Crude oil is a commodity that possesses commodity, political, and financial characteristics, as well as being one of the most important sources of energy. WTI crude oil futures are actively traded and its price serves as an important benchmark for global crude oil prices, making it a good guide to crude oil prices. Fourthly, the Guangdong carbon price (GDEA). In 2011, China launched its carbon emission trading market, with Guangdong being one of the first pilot cities. Since then, Guangdong's carbon market has become increasingly active and innovative and is now the largest carbon market in China. For the purpose of this analysis, we have chosen to use Guangdong's carbon market data due to its completeness and accessibility.

For the initial stationarity of the data, logarithmic transformation is applied. Then the logarithmic returns of the CSI new energy index, WTI crude oil futures price, and Guangdong carbon price are obtained by using the formula  $\ln(p_{t+1}/p_t) \times 100$ . Table 1 presents the descriptive statistics of the data. It is observed that the standard deviations of the CSI new energy index, WTI crude oil futures price, and Guangdong's carbon price are relatively large. The largest of these is the price of crude oil futures, which indicates intense fluctuations. The economic policy uncertainty, CSI new energy index, and crude oil futures price are all left-skewed, while the Guangdong carbon price is right-skewed. In addition, the kurtosis is greater than 3, indicating a leptokurtic distribution, for all variables except the economic policy uncertainty.

To avoid pseudo-regression, stationarity tests are conducted on the data. The results in the table show that four variables are all stationary, with all variables being significant at the 5% level.

**Table 1.** Descriptive statistics

| Variables | Mean   | Median  | Std.dev | Max     | Min      | Skewnesss | Kurtosis | ADF        |
|-----------|--------|---------|---------|---------|----------|-----------|----------|------------|
| EPU       | 5.5015 | 5.5303  | 0.4749  | 6.4950  | 4.0978   | -0.5012   | 2.8889   | -3.1327**  |
| XNY       | 0.0602 | -0.3375 | 8.9818  | 22.4158 | -36.2393 | -0.2825   | 4.7482   | -8.6013*** |
| WTI       | 0.4775 | 2.0116  | 13.6799 | 63.3269 | -78.1866 | -1.0266   | 16.2991  | -8.2479*** |
| GDEA      | 1.4577 | 0.2440  | 12.9604 | 61.5747 | -50.9455 | 0.3516    | 9.8228   | -13.418*** |

Note: “\*\*\*”, “\*\*”, “\*” represent 1% , 5%and10% significance respectively.

## 5. Empirical Analysis

### 5.1. Parameter Estimation

To construct models for these four variables, the optimal lag order is selected as 2 based on a comprehensive consideration of AIC, SC, FPE, and HQ criteria.

**Table 2.** Optimal Lag Order Results

| Lag | LogL      | LR       | FRE       | AIC      | SC       | HQ       |
|-----|-----------|----------|-----------|----------|----------|----------|
| 0   | -1100.968 | NA       | 317914.6  | 24.0210  | 24.1307* | 24.0653  |
| 1   | -1068.413 | 61.5704  | 221922.5  | 23.6612  | 24.2094  | 23.8824* |
| 2   | -1051.527 | 30.4695  | 218139.2* | 23.6419* | 24.6287  | 24.0402  |
| 3   | -1038.451 | 22.4561  | 233646.7  | 23.7055  | 25.1308  | 24.2808  |
| 4   | -1029.828 | 14.0588  | 276925.6  | 23.8658  | 25.7298  | 24.6181  |
| 5   | -1008.419 | 33.0449* | 250065.0  | 23.7482  | 26.0507  | 24.6776  |
| 6   | -998.6692 | 14.2008  | 293202.1  | 23.8841  | 26.6252  | 24.9904  |

The Markov Chain Monte Carlo algorithm (MCMC) was used for the simulation sampling with a fixed sampling frequency of 10,000 iterations. The results of estimating the parameters are shown in Table 3. The values of the Geweke test for the parameters are all within the critical value of 1.96 at the 5% level of significance, indicating a convergence of the parameters to the Posterior Distribution. Regarding ineffective factors, all ineffective factors are within 100, with the maximum being 84.09, suggesting that the model can obtain at least 119 (10,000/84.09) uncorrelated samples. Therefore, the model estimation is generally valid.

**Table 3.** Parameter estimation results

| Parameter | Mean   | Stdev  | 95%U   | 95%L   | Geweke | Inef  |
|-----------|--------|--------|--------|--------|--------|-------|
| sb1       | 0.0023 | 0.0003 | 0.0018 | 0.0029 | 0.114  | 4.33  |
| sb2       | 0.0023 | 0.0003 | 0.0018 | 0.0029 | 0.294  | 5.49  |
| sa1       | 0.0057 | 0.0017 | 0.0034 | 0.0102 | 0.635  | 32.17 |
| sa2       | 0.0056 | 0.0016 | 0.0034 | 0.0096 | 0.914  | 31.30 |
| sh1       | 0.0056 | 0.0016 | 0.0034 | 0.0094 | 0.832  | 29.94 |
| sh2       | 0.2513 | 0.0973 | 0.0801 | 0.4751 | 0.431  | 84.09 |

## 5.2. Impulse Response Analysis

In this paper, the short, medium and long term are represented by lags of 1, 3 and 6 months respectively. Different colors and shapes of lines will be used in the graph to represent these periods.

### 5.2.1 Different lag periods

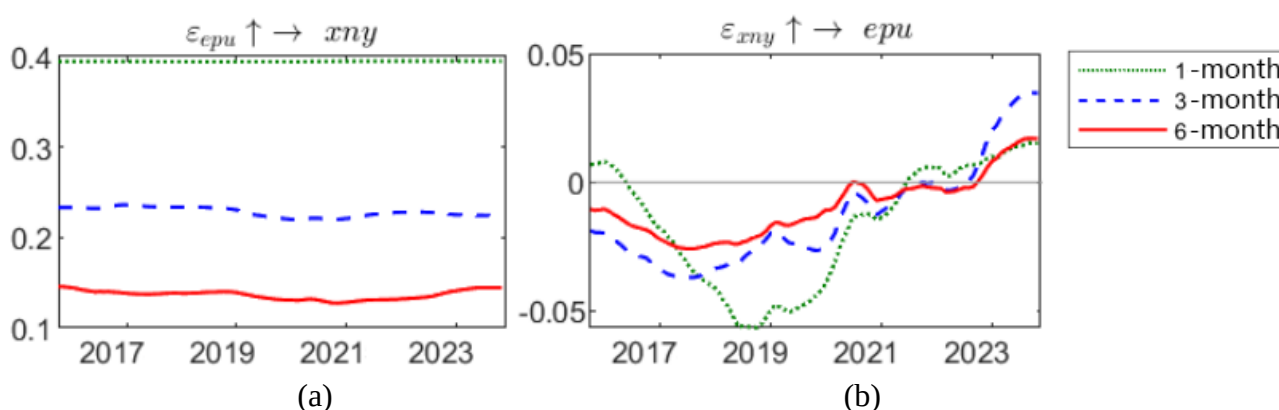
#### (1) Economic policy uncertainty and new energy market

Figure 1(a) shows the graph of the impulse response of a shock of one standard deviation in economic policy uncertainty to the prices of new energy stocks. For lags of 1, 3 and 6, the impulse response function shows positive shocks, and although there are some differences in the magnitude of the shocks, the trend is similar. The intensity of the shocks is highest at lag 1, indicating that changes in economic policy uncertainty may affect new energy stock prices rapidly and substantially in the short run. With increasing lag length, the impact of economic policy uncertainty on new energy stock prices gradually fades in the middle and long term. However, the impact is persistent. From 2015 to 2023, there is a consistent positive effect, which is closely related to the high level of international and domestic attention, as well as the continuous enactment of policies.

The negative impact of the new energy stock price shocks on economic policy uncertainty is depicted in Figure 1.(b). At lag 1, it initially shows the positive shock, but turns into a negative shock after 3 months. The minimum point of the shock was reached around July 2018, which could be related to the tense situation at that time, particularly the US-China trade war. This could be an indication of a significant increase in the correlated impact of the two variables in extreme situations. As time goes by, the negative impact gradually falls and arrives at a value of zero in the middle of 2021, after which the positive shock slowly increases. Compared to the short term, the fluctuation amplitude of the impulse response curves in the medium and long term is not significant, and the trends are generally consistent. Both shocks were initially negative and peaked around the middle of

2017, with the longer-term effects being somewhat less pronounced. By the end of 2019, the medium-term negative shock reached the second low point, coinciding with the initial outbreak of the COVID-19 pandemic. This may indicate a temporary disruption caused by increased uncertainty in the new energy market. However, be benefit from the timely issuance of relevant domestic policies, the negative shock do not last long and gradually turned into the positive shock.

Upon comparing the impulse response results of various lags and shock objects, it is evident that the overall trends of the effects are similar. Nevertheless, the short-term effects are more prominent. Furthermore, the numerical analysis reveals that the impact of economic policy uncertainty on new energy stock prices is actually stronger than the impact of new energy stock prices on economic policy uncertainty, and this is also more stable and long-lasting. The government's continued provision of subsidies and incentives to promote industry development and innovation is a result of its focus on the new energy sector. For example, in the "13th Five-Year Plan" proposed to accelerate the breakthrough of core technologies in the field of new energy. In 2020, there was increased policy intensity with many fiscal subsidy policies introduced, and investments in new energy projects gradually gained momentum, especially in the new energy vehicle industry. Among the seven major areas, the concept of new energy vehicle charging piles was included. The implementation of policies such as the 'Development Plan for New Energy Vehicle Industry' and the 'Announcement on Continuing the Policy of Exempting New Energy Vehicles from Vehicle Purchase Tax' has influenced the decisions of consumers and investors, leading to a steady rise in related stock prices.



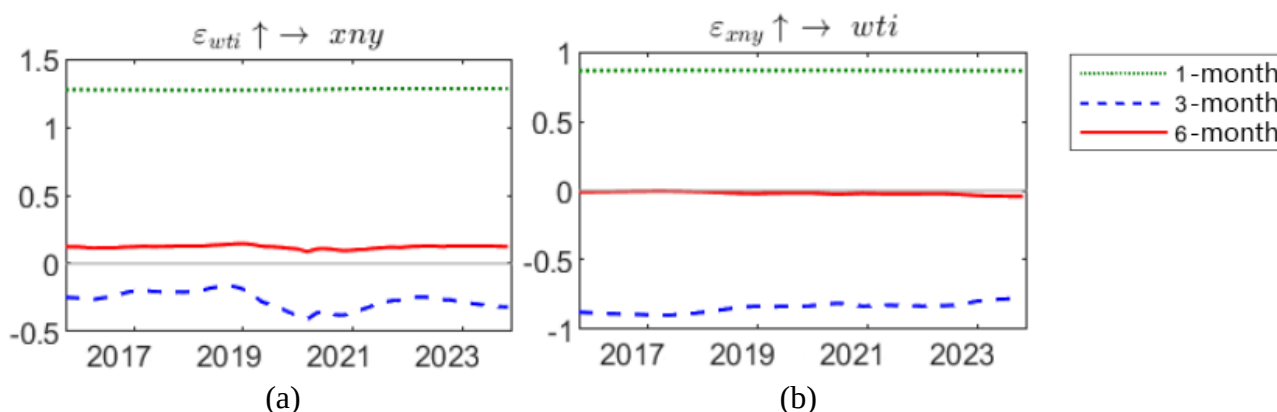
**Fig. 1** Time-varying impulse responses results of EPU and XNY in different lag periods

## (2) Crude oil and new energy markets

Fig.2. shows the impact of a one-unit shock in crude oil prices on new energy stock prices and the impact of a one-unit external shock in new energy stock prices on crude oil prices. Across the three lags, there are large differences in the effects observed. Both shocks have a short-term boost. Crude oil prices have a bigger shock on new energy stock prices, remaining at approximately 1.2. Conversely, in the medium term, the overall effect shifts to negative, with new energy stock prices having a larger impact on crude oil prices. The interaction between the two diminishes significantly in the long term. The impulse response curve for the effect of new energy stock prices is virtually zero, while crude oil prices continue to have a slightly positive effect on new energy stock prices.

In terms of volatility, both trends appear stable, with the effects of both positive and negative shocks being relatively balanced and persistent. In numerical terms, the short-term impact is greater, indicating a close correlation between the crude oil market and the new energy stock market. Crude oil is one of the traditional energy sources, while new energy serves as its substitute. The relationship between them is inherently complex, especially given Chinese large population and significant consumption volume, which inadvertently strengthens their relationship. Both traditional energy and new energy are crucial materials for modern enterprise production, so the fluctuations in their prices directly affect production costs and operating profits for businesses. If crude oil prices rise, businesses may opt for cheaper new energy sources. The sales volume of new energy materials directly impacts the profits of production enterprises, which in turn reflects on stock prices. Coupled with the global

environmental concerns, subsidies for green consumption continue to stack up, and the transmission effect between markets, investors and consumers will be more prone to invest in or consume new energy stocks and products. Thus, an increase in crude oil prices will result in a rise in new energy stock prices, implying a positive correlation between them [32], which is consistent with the short-term impact analysis mentioned above.



**Fig. 2** Time-varying impulse responses results of WTI and XNY in different lag periods

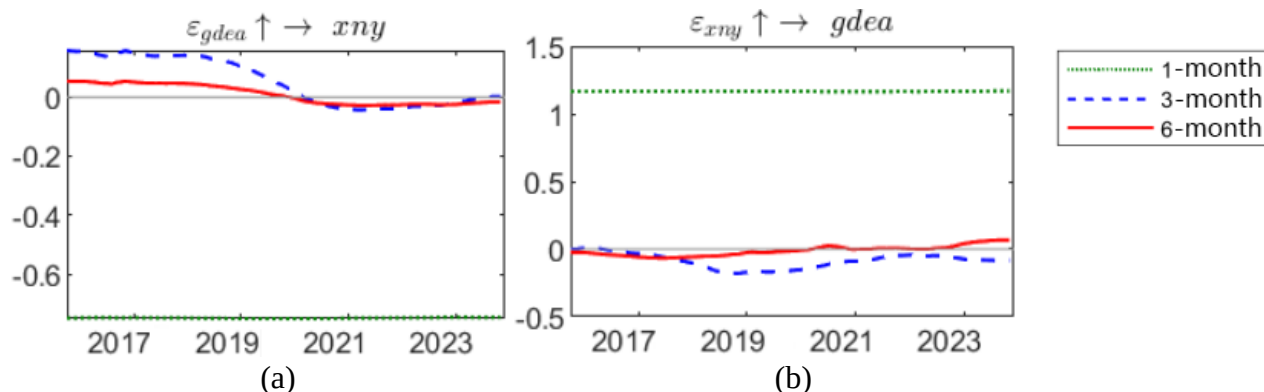
### (3) Carbon and new energy markets

From Fig.3.(a), it can be found that in the short term, a one-standard-deviation shock in carbon prices leads to a rapid negative impact on new energy stock prices, with the value remaining about -0.7. The short-term issue with the positive transmission pathway may be attributed to the inadequate infrastructure for the development of new energy in Chinese enterprises to enable the transformation of the industrial structure in a short period. So if they choosing new energy products to replace traditional energy equipment or products may incur higher costs. Therefore, in the short term, enterprises may still choose to purchase carbon quotas. In the medium and long term, there is a continuous process of switching between positive and negative shocks. Fluctuations are more pronounced in the medium term, with an average of 0.1 value higher than in the long term. The impulse response function exhibits a longitudinal evolutionary process, with diminishing effects over time, returning to zero at the beginning of 2020, but there are also slight fluctuations thereafter. The decrease in investment enthusiasm could be related to the outbreak of the COVID-19 pandemic, which triggered panic in the market. Furthermore, as the Chinese carbon market is relatively new, some transmission mechanisms may not be fully developed.

Subsequently, (b) illustrates the alterations in carbon prices resulting from shocks to new energy stock prices, which exhibit an opposite trend to the left graph. Nevertheless, the short-term response remains rapid. In the equally spaced impulse response plots, a positive shock of greater intensity is generated at a lag of 1 period. It has a greater impact on new energy share prices compared to carbon prices, and the impact is long-lasting. In the third lag period, the overall impact is relatively mild, demonstrating a negative relationship, which remained at its lowest point from 2018 to 2019, gradually decreasing thereafter. The impulse response curve for the sixth lag period rises from negative to positive, but roughly hovers around zero.

Overall, the interaction between carbon prices and new energy stock prices plays a significant role in the short term, with diminishing effects in the medium to long term. It is related to the development of the Chinese carbon market. China launched its first set of carbon markets in 2013, followed by two additional carbon markets in 2014 and 2016, and established a national carbon market in 2021. Therefore, Chinese carbon market has undergone more than a decade of development, forming a unique development pattern. From the proposal in 2018 to innovate and improve the pricing mechanism to promote green development to the "carbon peaking and carbon neutrality" strategy proposed at the 75th session of the United Nations General Assembly in 2020, which sent a strong signal for new energy construction and led to a soaring trend in the new energy concept stock prices. In the use of traditional energy sources, enterprises inevitably generate a large amount of carbon

dioxide emissions during the production process, leading to high pollution. As a consequence, the government has announced a carbon market policy that will be reflected in the carbon price. Carbon prices require enterprises to purchase and sell carbon quotas, imposing cost constraints on enterprises and promoting them to undertake industrial transformation and upgrades. Enterprises then shift their focus to more low-carbon new energy products, driving fluctuations in new energy stock prices.



**Fig. 3** Time-varying impulse responses results of GDEA and XNY in different lag periods

### 5.2.2 Different time points

To further explore the relationships between variables, taking into account international and domestic contexts, we will analyze them from different time points. We select three significant time points: July 2018, January 2020, and October 2021.

The first time point coincides with the US-China trade war, where the US announced tariffs on numerous Chinese products, leading to significant impacts on both economic markets. The second time point corresponds to the outbreak of the COVID-19 pandemic. The rampant virus caused disruptions in transportation, stagnation of production, suffer of investor confidence, and resulted in adverse effects on the global economy, leading to a recession. The third time point involves the introduction of crucial documents supporting carbon neutrality initiatives in China. The issuance of documents such as "Opinions on Thoroughly Implementing the New Development Concept and Doing a Good Job in Carbon Peaking and Carbon Neutrality" and "Action Plan for Carbon Peaking by 2030" laid out the top-level design for the "carbon peaking and carbon neutrality" strategy, providing a foundation for subsequent policy implementations.

#### (1) Economic policy uncertainty and the new energy market

It can be noticed that the curves follow a similar trend across the three time points in Figure 4.(a), which shows the impact of economic policy uncertainty on new energy stock prices at different points in time. They exhibit a pattern of initial increase followed by a decrease. The curves rapidly rise within the first period, reaching a peak in the second period. Subsequently, they sharply decline to around 0.13 within the next 3 to 4 periods, maintaining relative stability over the following two periods. The impact gradually diminishes after the 12th period but remains positive until that point. Therefore, it seems that economic policy uncertainty has a relatively persistent effect on the stock prices of new energy.

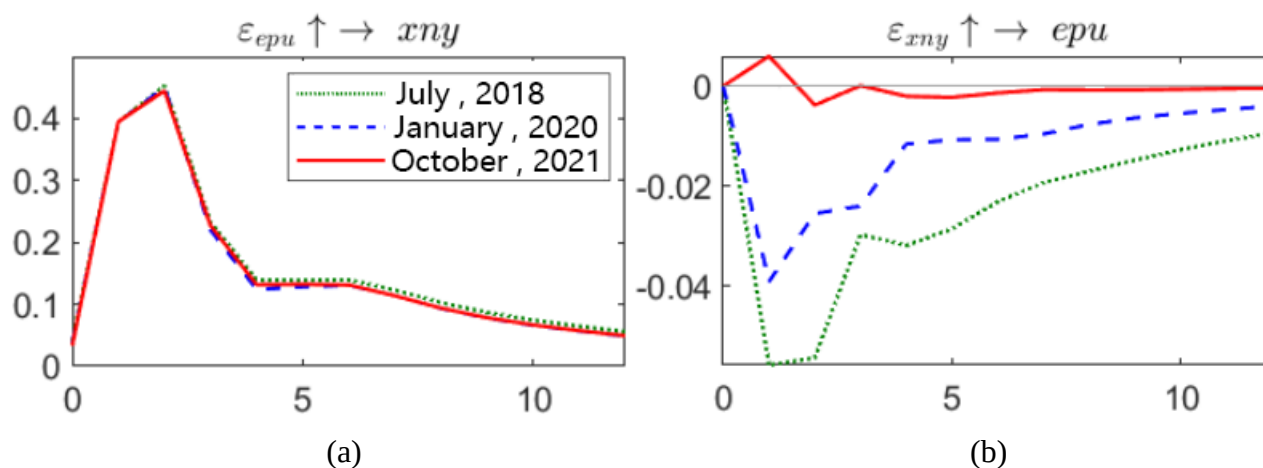
Second, (b) represents the effect of the new energy stock price shock on economic policy uncertainty that differs across the three periods. During the 2018 US-China trade war, new energy stock prices experienced a negative impact, rapidly declining to their lowest point in the first period. The negative impact weakens in later periods, with the effect in the 12th period already below 0.01. The tendency during the COVID-19 pandemic in 2020 was generally essentially the same as in 2018, but with a smaller negative impact. It is possible that in the development of the economy, the Chinese macromarkets and micromarkets have gradually matured, and that economic policies have been formulated with more comprehensive and flexible thinking. They can be applied to a wide range of situations, including major events, and are not easily influenced by the stock market. However, the influence in 2021 differed from the previous two periods. Initially, new energy stock prices has a positive impact on economic policy uncertainty, which then weakens until it turned into be negative.



After the second period, the impact is almost zero and its duration is very short. On the whole, the impact is relatively small. Considering that 2021 is mainly associated with the implementation of policies aimed at guiding investment and consumption, which further affect stock prices, the impact of new energy stock prices on economic policy uncertainty is both smaller and more transitory.

Combining the analysis from both graphs, it is evident that the impacts generated by the two shocks are distinctly differentiated. The influence of economic policy uncertainty on new energy stock prices is both strong and persistent at the three key points in time. As import and export tariffs have risen amid a trade war between the US and China, trade policy uncertainty has risen as well, impacting numerous commodities, including energy products. This uncertainty would transmit domestically, affecting energy-related stock prices. The rise in crude oil prices would raise demand for new energy products, thereby boosting new energy stock prices. During the pandemic period, disruptions in the transportation of commodities, coupled with various other issues, led to production stagnation. To expand consumption of new energy vehicles, the government implemented many policies to save the market.

For example, in the State Council executive meeting proposed to the year-end expiration of the new energy vehicle purchase subsidy policy extended for two years and financial awards in substitution for subsidies to support key areas to phase out the National III and the following emission standards for diesel trucks. This undoubtedly injected vitality into enterprises related to new energy. In the post-pandemic era, all economies are engaged in an economic recovery programme that includes support for renewable energy. Major documents released in 2020 highlight the necessity to improve current economic policies and increase support for green and low-carbon industries. With policy support, the access threshold for enterprises decreased, costs reduced, and the enthusiasm for consumption and investment increased. New energy stock prices have undergone a new development and this development plan is designed for the long term. Economic policy will continue to play a major role in determining how new energy is priced.



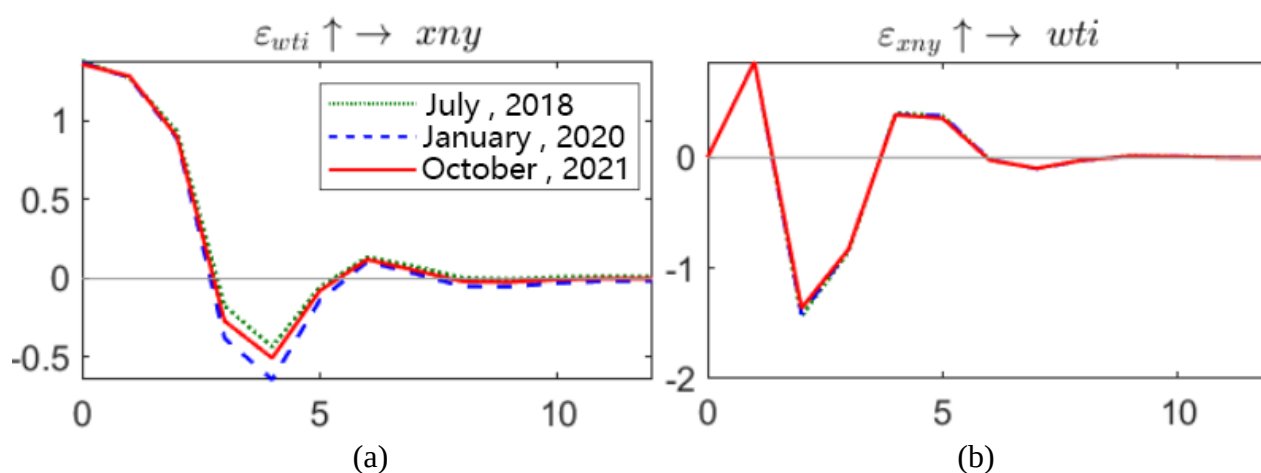
**Fig. 4** Time-varying impulse responses results of EPU and XNY in different time points

## (2) Crude oil and new energy markets

The interaction between international crude oil price shocks and new energy stock price shocks is shown in Figure 5. The trend of crude oil price shocks on new energy stock prices is roughly similar at three important time points, as seen in (a). They cause significant positive shocks in the first two periods, but the intensity gradually decreases, shifting from positive to negative until reaching the peak impact in the fourth period. At this time, during the COVID-19 pandemic, the impact of crude oil price shocks is the strongest, while the impact is slightly weaker during the US-China trade war. Subsequently, the negative effects gradually diminish and turn into a weak positive effect, which disappears by the 12th period. This alternating development pattern is also related to the international situation. In the first phase, the rise in crude oil prices leads to an increase in the value of new energy stocks. This may be due to the fact that, during the US-China trade war, tariffs were continuously raised, forcing domestic enterprises to purchase oil at higher prices and thereby incurring higher costs.

To improve their position, these enterprises need to produce themselves or choose other sources, and new energy becomes an option. And the demand for crude oil could not be satisfied in time during the COVID-19 pandemic due to the stagnation of cross-border transportation. So enterprises are also turning their attention to new energy sources. The third time point coincides with the context of energy conservation and emission reduction. With the rise in international crude oil prices, domestic enterprises using crude oil as raw materials face increased costs. At this time, policy guidance makes new energy more price competitive, leading to a huge increase in demand for new energy products. New energy-related enterprises expand their production scale, further gaining operating profits, while the favor of consumers and investors also boosts the related stock prices. In the second phase, the positive effects turn negative, possibly due to the fact that the rise in stock prices motivates new energy enterprises to continuously expand their scale and innovate in research and development. The value added to new energy products leads to price increases, and the high demand for new energy products leads to supply shortages, further driving up prices. There may be a reduction in consumption and investment in related sectors as many enterprises switch to alternative products. In the third phase, the impact gradually degrades and disappears, and enterprises reach a stable and optimal balance in their energy use decisions.

On the other hand, the impulse response curve of new energy stock prices to crude oil prices shows consistent trajectories at the three time points, experiencing significant fluctuations. Initially, there is a brief rise in crude oil prices, lasting only one period, before turning into a negative impact. The negative effect reaches a peak of about -1.4 in the second period and then gradually diminishes. By the fourth period, it transitions from negative to positive, causing two periods of positive impact before stabilizing, and eventually, the impact fades away. The reason for this repetition of changes may be that the market reaction was not immediate in the beginning. At that time, demand for crude oil continued because the new energy companies had not yet started large-scale production. Nevertheless, in subsequent periods, such as the US-China trade war, the COVID-19 pandemic, and the introduction of the "carbon peaking and carbon neutrality" strategy, enterprises were urged to substitute crude oil with new energy products. As a result, the demand for crude oil will shift to have a negative impact on it.



**Fig. 5** Time-varying impulse responses results of WTI and XNY in different time points

### (3) Carbon and new energy markets

Figure 6 provides the impulse response results for carbon prices and new energy stock prices at different time points. The impulse response curve in 2018 is distinguished from the following two-time points. During the US-China trade war, carbon prices initially created a downward impact on new energy stock prices, and the intensity gradually increased, reaching its peak in the first period. Afterward, the impact becomes positive in the following period and peaks again in the third period. Then the effect begins to be weak, gradually leveling off. However, the negative impact predominates totally. The impulse response curves during the COVID-19 pandemic and the period

when the important documents about carbon peaking and carbon neutrality were issued were generally similar. Carbon prices leads negative impact to new energy stock prices during these periods, lasting only three periods before trending towards zero, indicating a relatively temporary effect.

The right graph depicts the response of carbon prices to the impact of new energy stock prices, which is in stark contrast to the left graph. Overall, the effects under the three time points are positively dominant and the intensity of the positive shocks is stronger, differing only in the intensity of the negative effects. Specifically, during the US-China trade war in 2018, the negative impact in periods 3 to 4 is more pronounced, with the influence virtually disappearing by period 5, although the lagged effect of the impact is not persistent.

However, it seems to be certain transmission barriers to the impact of both sides. Policy guidance becomes an important tool in the global context of carbon reduction. When policies that encourage the development of new energy, such as subsidies, are implemented, they are intended to induce enterprises to reduce the use of high-carbon products, thereby lowering the price of carbon emission rights. However, a reverse problem in the feedback mechanism can be detected from the impulse response results in the figure. Several reasons may account for this phenomenon. Firstly, Chinese carbon market started relatively later, and the development mechanism are not comprehensive enough, with inadequate supervision, causing a significant amount of speculation disrupting normal transmission effects. Secondly, It is challenging for China's energy consumption structure to shift from high-carbon to low-carbon products in the short term. It takes time for factories to update equipment and adjust production, so significant positive impacts in the short term may not be achieved and sustained over the long term.

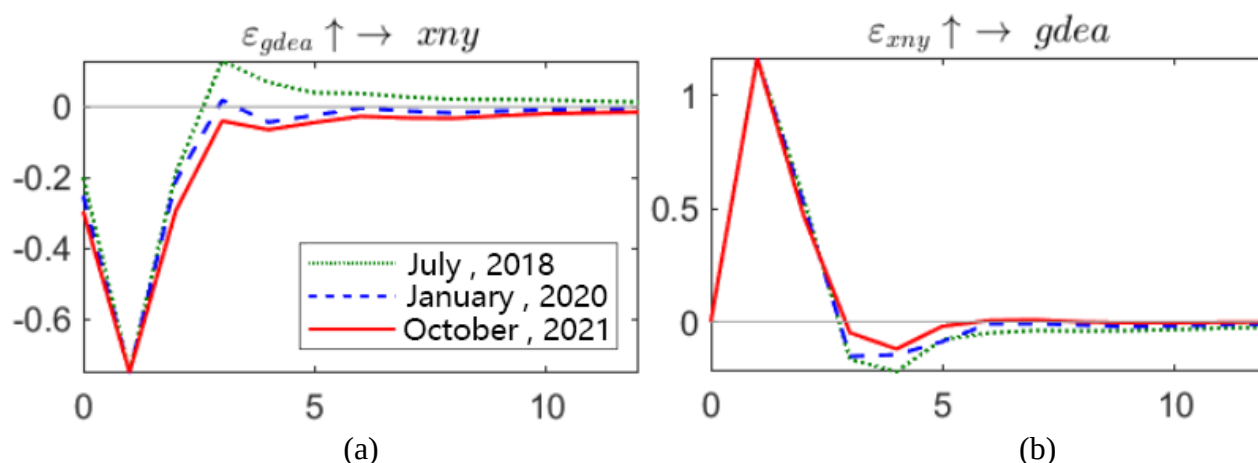


Fig. 6 Time-varying impulse responses results of GDEA and XNY in different time points

## 6. Conclusion

Analyzing the impulse response results from different lag periods and time points, the following conclusions can be drawn:

Firstly, In the short term, there is a close relationship between economic policy uncertainty, international crude oil prices, Guangdong carbon prices, and the CSI New Energy Index. Economic policy uncertainty and international crude oil prices positively impact the CSI New Energy Index, while Guangdong carbon prices have a negative impact. However, in the medium term, the CSI New Energy Index tends to be affected by these factors to a lesser extent. In the shorter run, international crude oil prices and Chinese carbon prices have opposing effects, while in the longer run the effects are close to zero. Additionally, economic policy uncertainty has a more persistent positive effect on the CSI New Energy Index during important time periods. International crude oil price has an alternating positive and negative effect, while Guangdong carbon prices have the negative effect, but the effects of the latter two are relatively temporary. Thirdly, in terms of numerical values, the relationship between international crude oil and the CSI New Energy Index is closer. It indicates that

traditional energy is still an indispensable raw material for contemporary business production and its price fluctuations are more easily transmitted to other energy or stock markets. Fourthly, there are obstacles in the transmission mechanism between carbon price and the CSI New Energy Index, and it cannot effectively conduct positive transmission. This is related to the lack of perfection and maturity of Chinese market and the difficulty of rapid transformation of enterprises.

Therefore, we based on the findings of the above study, the following recommendations are suggested:

Firstly, government departments should formulate or adjust economic policies based on the current status and needs of industries and enterprises, taking into account both overall considerations and sustainability. Given that enterprises in the new energy sector are particularly vulnerable to economic policy uncertainties, especially experiencing huge impacts on their stock prices in the short term. To promote the transformation of traditional energy enterprises into efficient and clean energy enterprises, the government should enhance the effectiveness of economic policies, continuously adjust and strengthen subsidies, preferential policies and other relevant mechanisms, and realise the optimisation and upgrading of the energy structure. Additionally, during major events or extreme risks, considering the long-term and lagging effects of economic policy uncertainties, precise timing and implementation of economic policies are crucial for addressing key issues accurately.

Secondly, new energy-listed enterprises have to take international crude oil prices into account when formulating future development plans. Traditional energy is still a crucial raw material for modern development, and its price fluctuations can significantly impact production costs for enterprises. Therefore, it is essential for these enterprises to incorporate the dynamics of international crude oil prices into their strategic considerations. When necessary, adjustments to existing strategies should be made to maximize profits.

Thirdly, it is crucial to enhance the market mechanisms of the carbon market, improve the liquidity and transparency, and learn from the experiences of mature carbon markets worldwide. Introducing risk management tools and attracting domestic and foreign investors are essential steps. There is also a requirement to further improve the regulatory regime for the carbon market. Be alert to abnormal financial flows and international financial risk inputs to reduce the risk of impacts under extreme events.

Fourthly, The establishment of a risk warning mechanism between economic policy uncertainty, international oil prices, the Chinese carbon market and the new energy stock market is essential. This mechanism should detect adjustments in both domestic and international macro and micro-environments. Utilizing scientifically effective methods to establish a risk identification system can enhance the ability to recognize risk changes. To maintain the stability and development of the domestic financial market, it is crucial to prevent market contagion and linkage risks during extreme events.

## References

- [1] Davis S J, Liu D, Sheng S X. Economic policy uncertainty and trade policy uncertainty for China[J]. Working Paper. University of Chicago Booth School of Business, 2019.
- [2] Yu J, Shi X, Guo D, et al. Economic policy uncertainty (EPU) and firm carbon emissions: evidence using a China provincial EPU index[J]. *Energy Economics*, 2021, 94: 105071.
- [3] Jiang Y, He L, Meng J, et al. Nonlinear impact of economic policy uncertainty shocks on credit scale: Evidence from China[J]. *Physica A: Statistical Mechanics and its Applications*, 2019, 521: 626-634.
- [4] Chevallier J. A model of carbon price interactions with macroeconomic and energy dynamics[J]. *Energy Economics*, 2011, 33(6): 1295-1312.
- [5] Adedoyin F F, Zakari A. Energy consumption, economic expansion, and CO2 emission in the UK: the role of economic policy uncertainty[J]. *Science of the Total Environment*, 2020, 738: 140014.
- [6] Gong X, Ji Q, Lin B. Review of energy finance research and exploration of frontier directions[J]. *Systems Engineering Theory and Practice*, 2021, 41(12): 3349-3365.

- [7] Rodrik D. Policy uncertainty and private investment in developing countries[J]. *Journal of Development Economics*, 1991, 36(2): 229-242.
- [8] Baker S R, Bloom N, Davis S J. Measuring economic policy uncertainty[J]. *The quarterly journal of economics*, 2016, 131(4): 1593-1636.
- [9] Chen G,Zhang R,Zhao X.Economic policy uncertainty and equity risk characteristics[J].*Journal of Management Science*,2018,21(04):1-27.
- [10] Dong Z,Cai Y,Li L.Analysis of the mechanism of consumption and stock price[J].*Quantitative and Technical Economic Research*, 2003.(1):61-67.
- [11] Brogaard J, Detzel A. The asset-pricing implications of government economic policy uncertainty[J]. *Management science*, 2015, 61(1): 3-18.
- [12] Ji Q, Liu B Y, Nehler H, et al. Uncertainties and extreme risk spillover in the energy markets: A time-varying copula-based CoVaR approach[J]. *Energy Economics*, 2018, 76: 115-126.
- [13] Zhao X. Do the stock returns of clean energy corporations respond to oil price shocks and policy uncertainty?[J]. *Journal of Economic Structures*, 2020, 9: 1-16.
- [14] Liu T, Nakajima T, Hamori S. The impact of economic uncertainty caused by COVID-19 on renewable energy stocks[J]. *Empirical Economics*, 2021: 1-21.
- [15] Antonakakis N,Chatziantoniou I,Filis G.Dynamic co-movements of stock market returns,implied volatility and policy uncertainty[J].*Economics Letters* 2013 120(1):87-92.
- [16] Kang W, Ratti R A. Structural oil price shocks and policy uncertainty[J]. *Economic Modelling*, 2013, 35: 314-319.
- [17] Joëts M, Mignon V, Razafindrabe T. Does the volatility of commodity prices reflect macroeconomic uncertainty?[J]. *Energy Economics*, 2017, 68: 313-326.
- [18] Lyu Y, Tuo S, Wei Y, et al. Time-varying effects of global economic policy uncertainty shocks on crude oil price volatility: New evidence[J]. *Resources Policy*, 2021, 70: 101943.
- [19] Aloui R, Gupta R, Miller S M. Uncertainty and crude oil returns[J]. *Energy Economics*, 2016, 55: 92-100.
- [20] Wen X,Wei Y,Huang D.Volatility spillover and correlation between stock price and crude oil price of new energy companies in China[J].*Management Review*,2012,24(12):20-30.
- [21] Ahmad W, Sadorsky P, Sharma A. Optimal hedge ratios for clean energy equities[J]. *Economic Modelling*, 2018, 72: 278-295.
- [22] Tan X, Geng Y, Vivian A, et al. Measuring risk spillovers between oil and clean energy stocks: Evidence from a systematic framework[J]. *Resources Policy*, 2021, 74: 102406.
- [23] Corbet S, Goodell J W, Günay S. Co-movements and spillovers of oil and renewable firms under extreme conditions: New evidence from negative WTI prices during COVID-19[J]. *Energy economics*, 2020, 92: 104978.
- [24] Keppler J H, Mansanet-Bataller M. Causalities between CO<sub>2</sub>, electricity, and other energy variables during phase I and phase II of the EU ETS[J]. *Energy policy*, 2010, 38(7): 3329-3341.
- [25] Guo X, Wang Y, Hao Y, et al. Spillover effect among carbon bond market, carbon stock market and energy stock market: Evidence from China[J]. *Finance Research Letters*, 2023, 58: 104521.
- [26] Ye S, Dai P F, Nguyen H T, et al. Is the cross-correlation of EU carbon market price with policy uncertainty really being? A multiscale multifractal perspective[J]. *Journal of environmental management*, 2021, 298: 113490.
- [27] Liu, Tao, et al. Impact of economic policy uncertainty on the volatility of China's emission trading scheme pilots[J].*Energy Economics*,2023,121: 106626.
- [28] Dutta, Anupam, Elie Bouri, Md Hasib Noor. Return and volatility linkages between CO<sub>2</sub> emission and clean energy stock prices[J].*Energy*,2018,164 : 803-810.
- [29] Yıılancı, Veli, Ö. N. D. E. R. Özgür, Abdulkadir Altınsoy. The dependence of clean energy stock prices on the oil and carbon prices: A nonlinear perspective[J]. *Economic Computation and Economic Cybernetics Studies and Research*,2022,56.2.
- [30] Hassan, Aminu. Does clean energy financial market reflect carbon transition risks? Evidence from the NASDAQ clean energy stock volatility[J]. *Journal of Sustainable Finance & Investment*,2022, 1-19.

- [31] Nakajima J. Time-varying parameter VAR model with stochastic volatility: An overview of methodology and empirical applications[J]. 2011.
- [32] Kumar, S., Managi, S., Matsuda. A Stock prices of clean energy firms, oil and carbon markets: A vector autoregressive analysis [J]. Energy Economics,2012, 34(1):215-226.