Research on the Time-Frequency Spillover Effect of High-Frequency Stock Price and Economic Policy Uncertainty

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Abstract

Through the construction of wavelet coherence analysis and frequency-domain spillover framework, this paper makes a comparative study of the volatility spillover effects of international economic policy uncertainty (EPU) on China’s Shanghai and Hong Kong stock market from a time-frequency perspective. To fully reflect the international EPU, this paper selects China, the United States, Australia, and the United Kingdom and uses the monthly EPU index of these countries and regions. China chooses China’s EPU index and Hong Kong’s EPU index. At the same time, the 5-minute high-frequency volatility of the Shanghai Composite Index (SSEC) and the Hang Seng Index (HSI) is selected to represent the Shanghai and Hong Kong’s stock market, respectively. It is found that there are obvious differences between the EPU and the dependence of the stock market in time domain and frequency domain, and the lead-lag relationship between them has time-varying characteristics. Static and dynamic spillover effects play a dominant role in the analysis of medium- and long-term spillover effects. In particular, the EPU and the risk spillover of the Hong Kong stock market are stronger than those of the Shanghai stock market, and the dynamic frequency-domain net risk spillover between them has frequency characteristics, and there are two-way and asymmetric risk spillovers. This provides a certain reference for policymakers to improve the safety management of financial markets and for market investors to optimize their portfolios.

1. Introduction

The uncertainty of economic policy shows that the economic subject is affected by the impact of economic events, but the future economic situation cannot be accurately predicted. Under the impact of the epidemic of COVID-19 in 2020, the economic uncertainty index of various countries has increased significantly, which has brought a negative impact on China’s macroeconomy and enterprise investment behavior to a certain extent. Since the outbreak of the international financial crisis in 2008, the economies of all countries have been affected to varying degrees, and the global economy is developing slowly and showing a trend of recession. In order to promote economic recovery, countries have issued a series of economic policies. However, the economic environment and economic structure are difficult to predict and are complex, and it is difficult to respond quickly to the market economic situation only through market self-regulation. Therefore, the state is more inclined to intervene and regulate domestic “too big to fail” financial institutions directly. Under this background, this paper uses wavelet coherence and the BK spillover index model to explore the volatility spillover effects of the stock market in the past 20 years from the perspectives of time domain and frequency domain, so as to provide a scientific and reasonable basis for dealing with the future international policy uncertainty.

The main purpose of this paper: first, to use wavelet coherence to analyze the volatility spillover effects of EPU of various countries on China’s Shanghai and Hong Kong stock market from January 2000 to February 2021 from the perspective of the time domain and frequency domain. This helps market decision makers and market participants to identify the factors that lead to the risk of the stock market. Second, construct a frequency-domain framework to quantitatively analyze the spillover direction and persistence.
of international EPU on the stock market. This is helpful for the financial market to carry out scientific and reasonable risk control.

The possible innovation of this paper lies in three aspects: the selection of research perspective, the selection of research objects, and the method of research model. First is the innovation in the choice of research perspective. This paper divides the same frequency band into short-term, medium-term, and long-term segments to explore the spillover effects between them and further analyzes the spillover effects of EPU on the stock market according to specific national conditions and economic events. Second is the innovation in the selection of research objects. This paper uses the EPU index compiled by Baker to quantify the economic uncertainty index, and the stock market selects the Shanghai Composite Index and Hang Seng Index of five-minute high-frequency data to comprehensively investigate the time-frequency spillover effects of EPU on the stock market. Third is the innovation of research model method. The empirical model chooses the more cutting-edge econometric model as the research method. The model chooses the spillover index model based on the generalized spectrum representation, which is improved by the Diebold and Yilmaz spillover index model based on variance decomposition, and captures the static and dynamic time-varying characteristics of the spillover effects of EPU on the stock market by dividing long term, medium term, and short term.

The main contribution of this paper is to compare and analyze the volatility spillover effects of international EPU on Shanghai and Hong Kong stock market from the perspective of time domain and frequency domain. First, this paper makes a comparative study of the volatility spillover effects of the EPU index of countries and regions on China’s Shanghai and Hong Kong stock market and takes into account the study of international economic policies on China’s stock market. In addition, the domestic stock market is divided into inland stock market and offshore stock market for comparative study, using the 5-minute high-frequency realization volatility of Shanghai Composite Index and Hang Seng Index as the research object. We study and analyze the spillover degree of EPU on the stock market to improve the research and analysis. There is little literature in this area, so this paper expands the relevant literature.

Secondly, by using wavelet coherence analysis, this paper reveals the spillover effects of international EPU on the Chinese stock market from the point of view of time domain and frequency domain and captures the time-varying relationship between EPU and the stock market. Furthermore, the construction of a frequency-domain framework focuses on the analysis of the direction and persistence of frequency-domain spillovers between them and compares and analyzes the spillover degree of EPU on the two stock markets. It provides theoretical significance for how to prevent the mainland stock market and the offshore stock market.

Third, this paper adopts the method of the dynamic and static combination when selecting the model and explores the time-varying spillover effects between EPU and the stock market through a rolling window. It mainly studies the impact of the financial things on the economic uncertainty and analyzes the spillover of the impact on the stock market. This will help relevant policymakers to clarify the spillover persistence of EPU on the stock market, to effectively provide targeted suggestions for the Shanghai and Hong Kong stock market, and to help investors avoid risks reasonably.

The main finding of this paper is that this paper selects the Diebold and Yilmaz spillover index model and Barunik spillover index model to analyze the time-varying characteristics of spillover effects from different perspectives of time domain and frequency domain. It is concluded that there are time-varying characteristics between the uncertainty of different economic policies and the spillover of the stock market, and the medium- and long-term spillover effects between the two are dominant. In addition, the study found that the spillover degree of different economic policy uncertainties on the Shanghai stock market is less than that of the Hong Kong stock market, and the Shanghai stock market occupies a dominant position in the spillover between the two, as the main sender of the spillover effect. Hong Kong stock market spillover is between the two as the main receiver.

Based on the above main conclusions, the policy recommendations of this paper are discussed from the perspective of government regulators and investors, respectively. On the one hand, from the perspective of government regulators, first, regulatory departments should closely monitor the changes and direction of the current international economic situation, continue to improve China’s financial development policy, and maintain the stable and healthy operation of the market. We keep the RMB exchange rate floating at a stable and balanced level, guard against the risk of abnormal fluctuations, and focus on monitoring abnormal cross-border capital flows. Second, to create a regulatory environment matched with the high-level opening of the capital market, we should strengthen the construction of the basic system of the stock market and further form a legalized and mature stock market. Third, we strengthen the supervision of offshore financial markets and promote the two-way and orderly opening of financial markets. On the other hand, from the perspective of investors, investors should reasonably refer to the relevant market indicators, observe the market situation, and make correct investment decisions. Investors should not only pay more attention to the changes of international economic policies, that is, the occurrence and changes of international economic events, but also combine the frequency characteristics of spillover effects between economic policies and stock markets, taking into account the long-term impact of spillover effects. In order to constantly optimize their own investment portfolio, we improve investment strategies.

The rest of this paper is arranged as follows. Section 2 introduces the literature review. Section 3 introduces the model method used. Section 4 introduces the results of empirical analysis. Section 5 introduces the robustness test carried out. Section 6 summarizes the conclusions and puts forward countermeasures and suggestions.
2. Literature Review

Studying the changes of EPU is of great significance for predicting macroeconomic situations or microeconomic behavior. How to quantify EPU indicators has been the focus of many scholars. Baker et al. [1] used text analysis to develop a new EPU index according to the frequency of newspaper reports and constructed the EPU index of 12 countries, including the United States. This paper also uses the national EPU index compiled by Baker to quantify the national EPU (EPU).

With the quantification and wide application of uncertainty index, more and more scholars apply uncertainty to the process of empirical research. By studying the impact of EPU (EPU) on stock market returns, Antonakakis et al. [2] found that there is a linkage relationship between economic policy uncertainty and the stock market. Pastor and Veronesi [3] built a model to provide advice for government decision-making. The analysis results show that EPU (EPU) index will lead to risk premium, and then, corporate financing costs will rise. Li and Yang [4] use China’s EPU index to reveal that the increase in EPU will inhibit corporate investment, and this inhibitory effect is more significant due to the impact of the 2008 financial crisis. Gong et al. [5] use the EPU index constructed by Baker to study the impact of policy uncertainty on the corporate leverage ratio. The results show that the increase of EPU will lead to a significant decrease in corporate leverage ratio, and the negative impact is more significant in short-term debt ratio, private, small-scale, and manufacturing enterprises.

In addition, to depict the correlation between markets, pieces of literature use wavelet coherence analysis to capture the dynamic connection between the two. Percival and Walden [6] introduce the importance and relevance of wavelet analysis and different disciplines. Gençay et al. [7–10] began to pay attention to the role of wavelet analysis in finance. Using the wavelet multiscale method to analyze foreign exchange volatility has different fluctuation rules in different periods, and the correlation between them is more obvious in low frequency. At the same time, a new asset pricing model based on the wavelet multiscale method is proposed, and the results show that the effect is obvious in the medium and long term. Nikkinen et al. [11] also proposed that the expected exchange rate has a different lead-lag relationship in the different frequency domains. Aguir-Conarría et al. [12, 13] used cross-wavelet to study policy and macroeconomy for the first time and pointed out that there are significant differences in macroeconomy at different frequencies. And in the analysis of the linkage relationship between oil and macroeconomy, it is concluded that the causal relationship between the two has time-varying characteristics. Vacha and Barunik [14] revealed the correlation between energy commodity markets in the time domain and frequency domain. Tiwari et al. [15] studied the dynamic relationship between oil prices and Indian currency and concluded that there is a causal relationship between them in the long run. Yang et al. [16, 17] studied the linkage between foreign exchange markets and found that they were significantly linked to each other during the crisis. It is also found that the linkage relationship between oil price and exchange rate market is time-varying. In addition, the application of the wavelet analysis method in stock market research also began to develop. Rua and Nunes [18] used the wavelet method to analyze the linkage relationship between international stock markets from the perspective of time domain and frequency domain. Aloui and Hkiri [19] and Gallegati [20] use wavelet analysis to obtain the spillover effects of crisis events on the stock market. When Gherghina and Simionescu [21] studied the spillover relationship between the stock market and COVID-19, it was found that most stock markets showed the same cycle effect. Asafo-Adjei et al. [22] use wavelet coherence to analyze the dynamic impact of African economic policy uncertainty on eight African countries. The study found that most of the global EPU and African markets move together and concentrate for a long time, but short-term investment in African stocks is not easily affected by global economic policy uncertainty. Using continuous and discrete wavelet tools, Li et al. [23] found that the interaction of US economic policy uncertainty on Chinese and Indian stock markets is not significant in the short term, but gradually significant in the long term.

To further study the spillover effect between them and determine the spillover direction and spillover degree, Diebold and Yilmaz [24, 25] improved the variance decomposition model and redefined the spillover degree between sequences. However, the defect of this model is that it cannot describe the frequency domain characteristics of spillovers. To make it clear whether high-frequency spillover or low-frequency spillover is dominant in spillovers, Chen et al. [26] found that there are differences between short-term spillover and long-term spillover between the stock market and economic policy uncertainty. It can be seen that, with the continuous widening of the research perspective, many scholars study the spillover effect from the perspective of the frequency domain. Barunik et al. [27, 28] based on the DY spillover index [24], defined that the frequency domain is divided into short term, medium term, and long term, and the time-frequency dynamic connectivity between sequences is defined. It is found that the high-frequency spillover effect is significant. Naeem et al. [29] used the above research methods and found that the correlation between the energy market and oil is affected by crisis events, and the correlation is significantly increased, and the short-term effect is more obvious. Liu and Hamori [30] studied the relationship between energy stocks and investor sentiment based on the TVP-VAR method and found that the connectivity between energy stocks and investor sentiment increased during market turmoil. The results show that crude oil plays a leading role in the relationship between the two. Le et al. [31] studied the spillover effects between financial technology, bonds, and cryptocurrencies and found that the short-term volatility is more intense, so the holding risk is greater. Wang et al. [32] found that the linkage relationship between hedging and stock index changes with the timetable, and there is a difference between short-term and long-term hedging effects. Based on the frequency domain spillover, Zhang and Hamori [33] found that return
spillover is mainly short-term dominant, while volatility spillover is mainly long-term dominant, and the impact of COVID-19 on the market is greater than the financial crisis. Zhu et al. [34] found that there are obvious differences between the economic policy uncertainty and the dependence of the stock market in the time domain and frequency domain.

To sum up, few studies at home and abroad focus on analyzing the spillover effects of international EPU on China’s Shanghai and Hong Kong stock market from the perspective of time domain and frequency domain. In this paper, the time-domain and frequency-domain frameworks are constructed by using wavelet coherence analysis and the work of Barunik and Křešlik [27]. The time domain is divided into the low, medium, and high frequencies to capture the spillover effects of international EPU on China’s stock market and to analyze the time-varying spillover differences between the mainland stock market and the offshore stock market.

3. Materials and Methods

In order to achieve the above research purpose, this paper chooses wavelet coherence analysis and time-frequency-domain spillover index model. In this section, the principles and steps of each method are mainly introduced, in which wavelet coherence analysis can better deal with nonstationary time series and analyze the relationship between them in different time ranges, which is more inline with the data requirements of this paper. The lead-lag relationship between different research objects can be determined by using the spectrum diagram of wavelet coherence analysis, which provides the feasibility for the study of spillover index. In addition, the spillover index is further used to determine the coherent structure obtained by wavelet coherence. In the study of dy spillover index, the generalized prediction error variance decomposition matrix is selected instead of choresky variance decomposition, and the $H$-step prediction error variance of fluctuation is divided into the part of the impact of the variable itself and the part of the impact caused by the impact of other variables. At the same time, the frequency-domain spillover index is based on the generalized spectrum to study the lasting effects of spillover effects from low, medium, and high frequency. The above research methods all adopt more rigorous calculation steps.

3.1. Wavelet Coherence Model

3.1.1. Continuous Wavelet Definition. Compared with the traditional Fourier method, the wave coherence analysis can analyze the relevance and guiding status of the research object from the perspectives of time domain and frequency domain. First of all, the continuous wavelet transformation (CWT) transforms a function into a continuous wavelet basis function, which mainly depends on two parameters $s$ and $T$, and then, the function is expanded to obtain the continuous wavelet transformation function:

\[
W_{x,y}(\tau, s) = \langle x(t), \psi^{\ast}_{s,t}(t) \rangle = \int_{-\infty}^{\infty} x(t) \frac{1}{\sqrt{|s|}} \psi^{\ast}(\frac{t-\tau}{s}) \, dt,
\]

where $s$ and $\tau$ represent scale factor and location factor, respectively. $s$ represents the length of the wavelet and $\tau$ represents the central position of the wavelet. $\ast$ denotes complex conjugation. $\psi_{s,t}(t)$ represents the continuous wavelet basis function generated by the wavelet basis function $\psi(t)$ transform, which depends on two parameters.

3.1.2. Cross Wavelet Definition. Wavelet analysis can mainly carry out multidimensional analysis of a single research object, but in order to study the correlation degree of two-time series from the perspective of time domain and frequency domain, it is necessary to use cross-wavelet analysis.

Let the continuous wavelet transformation of two-time series $x = \{x_n\}$ and $y = \{y_n\}$ be $W_x$ and $W_y$, respectively, and the specific expression of the cross-wavelet analysis between them is as follows:

\[
W_{xy}(\tau, s) = W_{x,y}(\tau, s) W_{y,y}(\tau, s),
\]

where $\ast$ denotes complex conjugation.

The specific expression of the cross-wavelet spectrum of the two-time series is as follows:

\[
|W^{xy}| = |W^x W^y|.
\]

Among them, the higher the value of $|W^{xy}|$ indicates that the two-time series have the same high-energy region, indicating that the coherence between the two is greater.

The wavelet correlation of two time series is in the form of the following formula:

\[
R_{xy} = \frac{|S(W_{xy})|^2}{S(|W_{x}|) S(|W_{y}|)}.
\]

where $S$ represents a smooth operator and conforms to $S(W) = S_{scale} (S_{time}(W_n(s)))$.

Among them, $S_{scale}$ and $S_{time}$ are both Morlet wavelet operators, the former represents the scale axis smoothing, and the latter represents the time axis smoothing. The correlation degree of wavelet coherence ranges from 0 to 1, and its value indicates strong or weak correlation.

3.2. Spillover Model. First of all, this paper uses the 5-minute high-frequency closing price to calculate the daily volatility and then calculates the monthly volatility, such as formulae (6) and (7):

\[
r_{j,d} = \ln(p_{d,j}) - \ln(p_{d,j-1}),
\]

\[
RV_m = \frac{1}{mn} \sum_{j=1}^{m} \sum_{i=1}^{n} r_{j,d}^2,
\]

where $r_{j,d}$ is the daily return on day $d$, $p_{d,j}$ is the closing price on day $d$, $ RV_m$ is the monthly volatility, $m$ is the total number of months, and $n$ is the number of days in each month.
where \( m \) is the number of trading days in a month, \( n \) is the measured number of days, \( r_{jd} \) represents the daily rate of return of the stock markets, and \( p_{dt} \) represents the price of a stock index with a trading date of \( d \) and \( a \) trading cycle of \( j \).

Diebold and Yilmaz [25] use the generalized prediction error variance decomposition instead of the traditional variance decomposition to divide the \( H \)-step prediction error variance of volatility into the part of the impact of the variable itself and the impact of other variables, that is, the volatility spillover from the variable \( j \) to the variable \( i \):

\[
\omega_{ij}^H = \sigma_{ijj}^{-1} \sum_{h=0}^{H-1} (e_{ij}^H \sum_{i,j} e_{ij}^H)^2 \sum_{h=0}^{H-1} (e_{ij}^H \sum_{i,j} e_{ij}^H). \tag{8}
\]

Among them, \( i, j = 1, 2, \ldots, N \). \( \Sigma_e \) is the covariance matrix of the error term \( e_i \). \( \sigma_{ijj} \) is the standard deviation of the error term of the \( j \) equation. \( e_i \) and \( e_j \) are selection vectors, where the \( n_i \) and \( j_n \) elements are 1, and the rest are 0.

The overall spillover effect formula is

\[
S^H = 100 \times \sum_{i,j=1}^{N} \omega_{ij}^H \sum_{i,j=1}^{N} \omega_{ij}^H = 100 \times \frac{\sum_{i,j=1}^{N} \omega_{ij}^H}{\sum_{i,j=1}^{N} \omega_{ij}^H}, \tag{9}
\]

Furthermore, Barunik and Křehlík [27] measure connectivity based on the frequency response to shocks to study the lasting effects of spillover effects from low, medium, and high frequencies. The formula is as follows:

\[
\Psi(e^{-iw}) = \sum_{h} e^{-iwh} \Psi_h, \tag{10}
\]

where \( \Psi \) is a \((N \times N)\) matrix of moving average coefficients at lag \( h \) defined above. \( \Psi(e^{-iw}) \) can be obtained as a Fourier transform of the coefficients \( \Psi_h \). Therefore, a generalized causal spectrum in frequency \( w \in (-\pi, \pi) \) is defined as

\[
(f(w))_{j,k} = \frac{\sigma_{kk}^{-1} \left( \Psi(e^{-iw}) \psi_{j,k} \right)}{\Psi(e^{-iw})} \psi_{j,k}(e^{-iw}), \tag{11}
\]

where \( \psi(e^{-iw}) = \sum_i e^{-iwh} \psi_h \) is shock response \( \psi_h \) Fourier transformation and \( (f(w))_{j,k} \) said on the frequency of \( w \), the first \( j \) element for the first \( k \) elements caused by the impact of the ratio of the spectrum. The weighting method is defined as

\[
\Gamma_j(w) = \frac{\psi(e^{-iw}) \psi(e^{+iw})}{(1/2\pi) \int_{-\pi}^{\pi} \psi(e^{-i\lambda}) \psi(e^{+i\lambda}) \psi_{j,k}(e^{-i\lambda}) d\lambda}, \tag{12}
\]

where \( \Gamma_j(w) \) is the power of the \( j \)th element at a given frequency \( w \). The sum of its frequencies is the constant \( 2\pi \), and the spectral expression of the variance decomposition from \( J \) to \( K \) is established (13):

\[
(\theta_{\infty})_{j,k} = \frac{1}{2\pi} \int_{-\pi}^{\pi} \Gamma_j(w) (f(w))_{j,k} dw. \tag{13}
\]

The connectivity measure on the fixed frequency band is as follows:

\[
(\tilde{\theta}_d)_{j,k} = \frac{1}{(\theta_d)_{j,k}} \sum_k (\theta_{\infty})_{j,k} \tag{14}
\]

Among them, \( d \) coincidence formula \( d = (a, b) \): \( a, b \in (-\pi, \pi), a \neq b \).

The definition of internal connectivity of frequency band \( d \) is as follows:

\[
C_{\omega}^d = 100 \left( 1 - \frac{\text{Tr}[\tilde{\theta}_d]}{\sum_{\theta_{\infty}}} \right). \tag{15}
\]

The definition of frequency connectivity of frequency band \( d \) is shown as

\[
C_{\omega}^d = 100 \left( \frac{\sum_{\theta_{\infty}} \text{Tr}[\tilde{\theta}_d]}{(\sum_{\theta_{\infty}} \text{Tr}[\tilde{\theta}_d])} \right) = C_{\omega}^d \frac{\sum_{\theta_{\infty}} \tilde{\theta}_d}{\sum_{\theta_{\infty}}}, \tag{16}
\]

where \( \text{Tr}[\cdot] \) represents the track operators and \( \sum \tilde{\theta}_d \) said all elements \( \theta_d \) of the sum matrix.

4. Results and Discussion

4.1. Data and Descriptive Statistics. This paper studies the time-frequency volatility spillover of international EPU on China’s stock market, in order to reflect the international EPU more comprehensively, select China, the United States, Australia, and the United Kingdom, and use the monthly EPU index of these countries and regions. Among them, China chooses China’s EPU and Hong Kong’s EPU index. At the same time, the 5-minute high-frequency realized volatility of the SSEC and HSI is selected to represent the Shanghai and Hong Kong stock market, respectively. The data sample spans from January 2000 to February 2021, excluding a total of 254 missing values. This paper uses the monthly EPU index compiled by Baker et al. [1], derived from https://www.policyuncertainty.com, and 5-minute high-frequency data are from https://www.realized.Oxford-man.ox.ac.uk/.

For example, Tables 1 and 2 show the descriptive statistical data and unit root test of EPU index and stock index, respectively. The results show that all variables reject the original hypothesis, indicating that each time series is a stationary series.

In terms of average, the average value of the EPU index of the United States is the largest (4.814606), while that of Australia is the lowest (4.51604). From the perspective of standard deviation, the standard deviation of China’s EPU is the largest (0.735862), while that of the United States is the smallest (0.431434), indicating that China’s EPU fluctuates greatly. Similarly, it can be concluded from Table 2 that the volatility of the Shanghai Composite Index is greater than that of the Hang Seng Index. From the ADF test, it can be seen that each time series does not obey the normal distribution, and there is a significant ARCH effect and sequence correlation.

At the same time, from the kurtosis of the EPU index, we can see that the EPU is becoming more and more significant, indicating that it is more and more affected by economic
events. The main reasons are the financial crisis in 2015, the impact of China’s entry into the new economic normal in 2008–2017, Brexit, and the intensification of trade conflicts between China and the United States in 2018.

4.2. Wavelet Coherence Analysis

4.2.1. Continuous Wavelet Analysis. Wavelet coherence analysis is widely used to measure the time-frequency relationship of different financial variables. This paper uses a wavelet to analyze the correlation between EPU and the stock market. In the analysis of time series, in order to obtain smooth and continuous wavelet amplitude, the non-orthogonal wavelet function is more functional, and to analyze the time-frequency spillover effects of different research objects, complex-valued wavelets are selected, while Morlet wavelets are not only non-orthogonal but also exponentially complex-valued wavelets with Gaussian regulation. To analyze the fluctuation law of a single time series, the continuous wavelet transformation of each index is calculated by using Morlet wavelet as the generating function. The results are shown in Figures 1–7. The color on the right side of the picture represents the degree of correlation, from blue to yellow, indicating that the variance of the time series is gradually increasing, which shows that the greater the volatility. The horizontal axis represents time, while the vertical axis represents different frequency periods. The black line is the influence cone curve, for the area far away from the cone curve, because the influence of the boundary effect should be taken into account, so the significance of the analysis reference is small.

| Table 1: Descriptive statistics and unit root test of EPU index of various countries. |
|-----------------|-----------------|-----------------|-----------------|-----------------|
|                | China           | HK              | US              | UK              | Australia       |
| Mean           | 4.570477        | 4.742472        | 4.814606        | 4.707553        | 4.51604         |
| Median         | 4.583349        | 4.776579        | 4.763996        | 4.779984        | 4.505456        |
| Maximum        | 6.495006        | 6.052941        | 6.222504        | 6.32476         | 5.820213        |
| Minimum        | 2.313657        | 3.135981        | 3.801823        | 3.17955         | 3.24501         |
| Std. dev.      | 0.735862        | 0.556914        | 0.431434        | 0.538723        | 0.548169        |
| Skewness       | 0.268719        | −0.271778       | 0.381081        | −0.16292        | 0.023068        |
| Kurtosis       | 2.885763        | 2.750439        | 3.245789        | 2.822462        | 2.570653        |
| Jarque–Bera    | 3.194999        | 3.786023        | 6.787128        | 1.457285        | 1.973446        |
| ADF            | −3.995189**     | −3.995492**     | −3.994744**     | −6.143366***    | −4.937559***    |

Note: ** indicates significance at 5% level and *** indicates significance at 1% level.

| Table 2: Descriptive statistics and unit root test of SSEC and HSI. |
|----------------|----------------|---------------|
|                | SSEC           | HSI           |
| Mean           | −9.191876      | −6.556836     |
| Median         | −9.281615      | −6.687046     |
| Maximum        | −6.657218      | −3.615086     |
| Minimum        | −10.97081      | −7.724878     |
| Std. dev.      | 0.913208       | 0.72501       |
| Skewness       | −0.433321      | −0.941521     |
| Kurtosis       | 2.629457       | 3.868389      |
| Jarque–Bera    | 4.901923       | 45.50775      |
| ADF            | −5.547368***   | −4.352010***  |

Note: ** indicates significance at 5% level and *** indicates significance at 1% level.
From Figures 1 to 5, we can see that the continuous wavelet analysis spectrum of EPU in various countries shows that China’s EPU index is a low-energy region represented by blue, indicating that its fluctuation is weak. On the contrary, there are two obvious yellow high-energy regions in Hong Kong’s EPU index, indicating that the time series of this index fluctuates strongly. Among them, the first region is from 2000 to 2003 and the second region is from 2008 to 2020, which is mainly affected by the return of Hong Kong in 1997 and the financial crisis in 2008. In addition, there are also some high-energy regions in the United States and the United Kingdom, in which the economic policy of the United States fluctuated greatly from 2007 to 2011 due to the subprime mortgage crisis in the United States, while the United Kingdom was affected by Brexit and fluctuated sharply from 2012 to 2019.

From Figures 6 and 7, we can see, from the continuous wavelet analysis spectrum of EPU of various countries, that it was influenced by the macroeconomic policy of the central bank raising the benchmark deposit interest rate six times in 2007. The rise and fall of the SSEC have an obvious fluctuation impact. At the same time, due to the impact of the subprime mortgage crisis, China’s stock market fell sharply and fluctuated violently. In particular, the rise of Hong Kong’s Hang Seng index was mainly due to the return of Hong Kong in 1997 and the global Internet revolution in 2000. Second, after 2008, the global economy gradually recovered, the stock market showed a technical rebound, the HSI was in an upward state, and the overall fluctuation range was obvious.

4.2.2. Cross Wavelet Analysis. Based on the above research, this paper analyzes the correlation degree and lead-lag relationship between them through the wavelet coherent cross-spectrum analysis of different time series. The results are shown in Figures 8–17. Figures 8–12 shows the cross-wavelet cross-spectral analysis of national EPU and SSEC, and Figures 13–17 shows the cross-wavelet cross-spectral analysis of national EPU and HSI. The color on the right side of the picture represents the degree of correlation between the two, ranging from blue to yellow, indicating that the degree of coherence is gradually increasing. In this paper, 0–3 months are defined as short term (high frequency), 4–12 months are defined as medium term (intermediate frequency), and more than 12 months are defined as long term (low frequency). The arrow from left to right indicates that there is a positive correlation between the EPU index and the change of stock index and a negative correlation between them from left to right. The arrow pointing to the upper left or lower right indicates that the EPU is ahead of the stock market, while the arrow direction of the lower left or upper right indicates that the stock market is ahead of the EPU. In addition, the arrow direction is right, and maintaining the horizontal direction indicates that there is a two-way guiding relationship between EPU and the stock market.

As can be seen from the chart, there are obvious differences between the EPU and the dependence of the stock market in time domain and frequency domain, and the dependence between them mainly occupies a medium-and long-term dominant position in the frequency domain. For the Shanghai stock market, the EPU of Hong Kong is the strongest, followed by the EPU of the United States and Australia. However, the overall EPU of China and the United Kingdom have relatively low dependence on the Shanghai Composite Index. This is mainly due to the fact that the mainland stock market has a relatively rich investment portfolio and a relatively large proportion of foreign investment. As an important offshore financial market in China, the fluctuations of its economic policies will have a greater impact on the mainland stock market. The two maintain a relatively high degree of consistency. As the most developed country in the world as well as China’s trade exporter and importer, the implementation of its economic policy will have a certain impact on the global economy. At the same time, for the Hong Kong stock market, the EPU of Hong Kong and the United Kingdom has the strongest dependence on the Hang Seng Index, while the dependence on the EPU of China, the United States, and Australia is relatively weak. This is because the Hong Kong stock market, as a diversified financial market, has a relatively large number of overseas investors and is vulnerable to changes in the policies of overseas countries.
In addition, from the perspective of time domain, due to the influence of the 2008 financial crisis, the dependence of US EPU on the Shanghai stock market and Shenzhen stock market increased significantly after the financial crisis. Especially, in the important areas of its impact on the Hang Seng Index, there are more phase arrows pointing to the upper right and lower left, indicating that the uncertainty of economic policy is ahead of the Hang Seng Index. On the
contrary, the EPU of Hong Kong and the arrows of the Shanghai Composite Index and Hang Seng Index point to the right and horizontal, indicating that the EPU and the Shanghai and Hong Kong stock markets are in a mutually guiding relationship during the financial crisis. As a result of the Sino-US trade war in 2018, the Shanghai Composite Index and the EPU of China, the United States, the United Kingdom, and Hong Kong are the upper right-hand corner, indicating that EPU is ahead of the stock market. However, after 2018, the phase arrow between the Hang Seng Index and EPU in China, the UK, and Hong Kong points to the upper left corner, indicating that the stock market is leading EPU. Therefore, based on the results of wavelet coherence analysis, it can be concluded that Shanghai and Shenzhen stock markets are highly dependent on the EPU of Hong Kong and the United Kingdom. And the dependence between the two has obvious time-varying characteristics and medium-and long-term dominant frequency-domain characteristics.

4.3. Analysis of Spillover Effect in Time Domain and Frequency Domain

4.3.1. Static Spillover Effect in Time Domain and Frequency Domain. In order to further measure the spillover direction and degree of EPU of each country or region on the Shanghai and Hong Kong stock market, the first step is to use the Diebold–Yilmaz method to calculate the time-domain spillover index of five countries and regions for SSE and HSI, respectively. The results are shown in Tables 3 and 4. It can be concluded that, first of all, the overall spillover effect of the EPU of the five countries on the Shanghai Composite Index is as high as 35.57%, but it is still less than its overall spillover effect on the Hang Seng Index, indicating that there is a strong correlation between the economic uncertainty of these countries and regions, that is, the degree of economic risk contagion between countries may be greater. Among them, the correlation with the Hong Kong stock market is greater than that with the Shanghai stock market mainly due to the fact that Hong Kong’s offshore market is vulnerable to foreign investment. Second, for the Shanghai stock market, China’s EPU has the greatest impact on its spillover degree (1.79%), followed by US EPU (1.35%), and UK EPU (1.34%) has the least impact on it. As for the
Hong Kong stock market, the degree of spillover caused by EPU in the United States (5.73%), Australia (4.76%), and the United Kingdom (3.72%) is far greater than that in Hong Kong and China; the main reason is that domestic consumption is relatively stable, while the United States is China’s main trading partner and has a large demand for imports of Chinese products. In recent years, under the influence of Sino-US trade disputes, the greater uncertainty of US economic policy has posed a great challenge to China’s import and export trade, resulting in a relatively large spillover relationship between US economic policy and China’s consumer industry. Finally, in the spillover relationship between the two, for the Shanghai stock market, different economic policy uncertainties dominated the spillover of the SSEC, with a FROM of 0.9% greater than TO (4.11%), while for the Hong Kong stock market, the HSI dominated the spillover of different economic policy uncertainties, with a FROM of 2.74% less than TO (4.11%).

Because the EPU and the time-domain spillover analysis of the stock market cannot capture the spillover effects of EPU in different frequencies, but for policymakers and market participants, the persistence and contagion of systemic risk are very important. Therefore, the second step of this paper uses Baruink–Krehlik’s method to construct a frequency-domain framework to explore EPU and frequency-domain spillover effects of the stock market in short term (0–3 months), medium term (4–12 months), and long term (more than 12 months). The results are shown in Tables 5–10.

On the one hand, the EPU of different countries and regions dominates the long-term (low frequency) spillover effects of Shanghai and Hong Kong stock markets, that is, the degree of spillover between them increases with time. This result is consistent with the findings of Baruink, which found that low frequency plays a dominant role in estimating the connectivity of short-term, medium-term, and long-term financial cycles. Among them, the total spillover rate of short-term (0–3 months) EPU to Shanghai stock market is 0.12%, medium term (4–12 months) is 0.1%, long term (more than 12 months) is 0.67%, and the total spillover rate of short-term (0–3 months) EPU to Hong Kong stock market is 0.58%. The medium term (4–12 months) and long term (more than 12 months) are 0.35% and 1.81%, respectively. It can be seen that the spillover of EPU on the Shanghai stock market is less than that on the Hong Kong stock market at different frequencies. It shows that different economic policy uncertainties are more related to the Hong Kong stock market, which is consistent with the analysis of time-domain results.

On the other hand, the spillover relationship between EPU and the stock market has time-varying characteristics. For the Shanghai stock market, the degree of spillover of EPU is larger in the United States (0.21%, 0.22%) and Australia (0.29%, 0.22%) in the short- and medium-term frequency, while in the long-term frequency. China’s EPU spillover to it is 1.52%. For the Hong Kong stock market, the EPU dominates the spillover of the Hang Seng Index in the short-term frequency, that is, the HSI is the main recipient, while with the increase of the time span, in the medium and long term, the spillover of the HSI to the EPU is dominant, that is, the HSI is the main sender.

### Table 3: Uncertainty of international economic policy and static time-domain spillover index of Shanghai composite index.

| SSEC | China | HK | US | UK | Australia | FROM |
|------|-------|----|----|----|-----------|------|
| 94.62 | 1.79 | 0.5 | 1.35 | 0.39 | 1.34 | 0.9 |
| 0.45 | 61.93 | 6.03 | 9.9 | 12.57 | 9.12 | 6.35 |
| 1.71 | 10.96 | 70.15 | 4.53 | 4.24 | 8.41 | 4.97 |
| 0.45 | 8.52 | 3.54 | 47.43 | 15.51 | 24.54 | 8.76 |
| 0.2 | 11.07 | 4.25 | 12.89 | 53.94 | 17.65 | 7.68 |
| 0.86 | 2.87 | 4.25 | 16.26 | 17.24 | 58.52 | 6.91 |
| 0.61 | 5.87 | 3.09 | 7.49 | 8.33 | 10.18 | 35.57 |

### Table 4: International EPU and static time-domain spillover index of HSI.

| HSI | China | HK | US | UK | Australia | FROM |
|-----|-------|----|----|----|-----------|------|
| 83.55 | 0.72 | 1.52 | 5.73 | 3.72 | 4.76 | 2.74 |
| 1.91 | 59.52 | 6.06 | 9.67 | 13.15 | 9.69 | 6.75 |
| 2.34 | 10.96 | 69.01 | 4.02 | 4.27 | 9.39 | 5.16 |
| 7.11 | 8.82 | 3.24 | 43.83 | 15.2 | 21.79 | 9.36 |
| 4.36 | 11.22 | 4.28 | 11.87 | 51.12 | 17.15 | 8.15 |
| 8.93 | 3.49 | 4.19 | 14.92 | 16.75 | 51.72 | 8.05 |
| 4.11 | 5.87 | 3.22 | 7.7 | 8.85 | 10.46 | 40.21 |

#### 4.3.2. Dynamic Frequency-Domain Spillover Effect.

As the frequency reflected by static spillover effects is fixed, it is impossible to analyze the impact of economic events at different time points on EPU and stock market spillover effects from a dynamic perspective. These crisis events have a certain impact on the direction and degree of spillover between the two. Therefore, in order to further analyze the risk spillover combined with economic events, this paper carries on the dynamic frequency-domain spillover analysis by setting the rolling window to 24 and the prediction range to 10 in advance. The result is shown in Figures 18–25. Among them, Figures 18 and 19 show the dynamic frequency-domain spillover of the SSEC, HSI, and EPU, which shows that there are obvious time-varying characteristics in the dynamic correlation between the two. The impact of the global financial crisis from 2008 to 2010 continues to ferment, and the scope extends from the United States to China and other countries and from the fictitious economy to the real economy, which leads to consumer market panic, which makes the spillover of the EPU shock to the stock market risk even greater. The debt crisis of 2010–2012 and Brexit in 2016 brought all kinds of uncertainty, the EPU of various countries was affected to a certain extent, and the degree of spillover has also greatly increased. The trade war between China and the United States in 2018, the Brexit incident in 2019, and the riots in Hong Kong, as well as the COVID-19 epidemic in 2020 and the correlation between EPU and the stock market, increased significantly; especially during the financial crisis, the total dynamic frequency-domain spillover between the two increased sharply mainly due to the continuous expansion and deepening of the global spread of...
the financial crisis. Reduced portfolio returns. In addition, China’s economy has entered a new normal; as a result, EPU has a greater impact on the stock market risk. Secondly, it can be concluded that the dynamic frequency-domain spillover between EPU and the stock market is mainly dominated by long-term frequency, which is consistent with the results of the static spillover analysis above. Finally, comparing the Shanghai and the Hong Kong stock market, we can find that the spillover of EPU on the Hong Kong stock market is larger than that of the Shanghai stock market, which is also consistent with the results of static time-domain spillover analysis.

To reflect the EPU and the dynamic risk spillover direction of the stock market more directly, this paper reveals

| Table 5: Uncertainty of international economic policy and static short-term (0–3 months) spillover index of Shanghai composite index. |
|---------------------------------------------------------------|
| **SSEC** | **China** | **HK** | **US** | **UK** | **Australia** | **FROM ABS** | **FROM WTH** |
|---|---|---|---|---|---|---|---|
| SSEC | 14.47 | 0.15 | 0.03 | 0.21 | 0.06 | 0.29 | 0.12 | 0.75 |
| China | 0.13 | 9.2 | 0.09 | 0.09 | 0.03 | 0.15 | 0.08 | 0.5 |
| HK | 0.14 | 0.42 | 25.04 | 0.89 | 0.22 | 1.32 | 0.5 | 3.06 |
| US | 0.17 | 0.25 | 0.35 | 11.89 | 1.34 | 1.91 | 0.67 | 4.12 |
| UK | 0.01 | 0.1 | 0.07 | 1.12 | 9 | 1.22 | 0.42 | 2.59 |
| Australia | 0.18 | 0.05 | 0.68 | 2.19 | 1.67 | 12.34 | 0.8 | 4.9 |
| TO ABS | 0.1 | 0.16 | 0.2 | 0.75 | 0.55 | 0.82 | 2.59 |
| TO WTH | 0.64 | 1 | 1.25 | 4.62 | 3.41 | 5.02 | 15.94 |

| Table 6: International EPU and static medium-term (4–12 months) spillover index of Shanghai composite index. |
|---------------------------------------------------------------|
| **SSEC** | **China** | **HK** | **US** | **UK** | **Australia** | **FROM ABS** | **FROM WTH** |
|---|---|---|---|---|---|---|---|
| SSEC | 12.54 | 0.13 | 0.03 | 0.22 | 0.01 | 0.22 | 0.1 | 0.93 |
| China | 0.06 | 3.61 | 0.13 | 0.16 | 0.11 | 0.13 | 0.1 | 0.9 |
| HK | 0.14 | 0.37 | 14.14 | 0.56 | 0.13 | 1.21 | 0.4 | 3.67 |
| US | 0.11 | 0.08 | 0.26 | 7.62 | 1.15 | 2.51 | 0.68 | 6.24 |
| UK | 0.01 | 0.05 | 0.14 | 0.84 | 6.11 | 1.15 | 0.36 | 3.32 |
| Australia | 0.17 | 0.06 | 0.42 | 1.76 | 1.47 | 7.97 | 0.65 | 5.9 |
| TO ABS | 0.08 | 0.12 | 0.16 | 0.59 | 0.48 | 0.87 | 2.3 |
| TO WTH | 0.75 | 1.05 | 1.48 | 5.38 | 4.36 | 7.95 | 20.97 |

| Table 7: Uncertainty of international economic policy and static long-term (more than 12 months) spillover index of Shanghai composite index. |
|---------------------------------------------------------------|
| **SSEC** | **China** | **HK** | **US** | **UK** | **Australia** | **FROM ABS** | **FROM WTH** |
|---|---|---|---|---|---|---|---|
| SSEC | 67.62 | 1.52 | 0.44 | 0.93 | 0.32 | 0.83 | 0.67 | 0.92 |
| China | 0.26 | 49.11 | 5.81 | 9.65 | 12.43 | 8.83 | 6.16 | 8.47 |
| HK | 1.43 | 10.16 | 30.98 | 3.08 | 3.89 | 5.88 | 4.07 | 5.6 |
| US | 0.17 | 8.2 | 2.93 | 27.92 | 13.02 | 20.13 | 7.41 | 10.18 |
| UK | 0.18 | 10.92 | 4.05 | 10.93 | 38.83 | 15.27 | 6.89 | 9.47 |
| Australia | 0.51 | 2.75 | 3.15 | 12.31 | 14.1 | 38.21 | 5.47 | 7.51 |
| TO ABS | 0.43 | 5.59 | 2.73 | 6.15 | 7.29 | 8.49 | 30.68 |
| TO WTH | 0.58 | 7.68 | 3.75 | 8.45 | 10.02 | 11.66 | 42.15 |

| Table 8: Uncertainty of international economic policy and static short-term (0–3 months) spillover index of HSI. |
|---------------------------------------------------------------|
| **HSI** | **China** | **HK** | **US** | **UK** | **Australia** | **FROM ABS** | **FROM WTH** |
|---|---|---|---|---|---|---|---|
| HSI | 13 | 0.08 | 0.56 | 1.09 | 0.7 | 1.03 | 0.58 | 3.64 |
| China | 0.04 | 8.67 | 0.09 | 0.09 | 0.03 | 0.15 | 0.07 | 0.41 |
| HK | 0.85 | 0.36 | 24.61 | 0.95 | 0.22 | 1.45 | 0.64 | 4.03 |
| US | 0.71 | 0.23 | 0.3 | 10.33 | 1.16 | 1.61 | 0.67 | 4.23 |
| UK | 0.39 | 0.09 | 0.06 | 1.04 | 8.24 | 1.12 | 0.45 | 2.85 |
| Australia | 0.67 | 0.06 | 0.65 | 1.83 | 1.47 | 10.98 | 0.78 | 4.93 |
| TO ABS | 0.44 | 0.14 | 0.28 | 0.83 | 0.6 | 0.89 | 3.18 |
| TO WTH | 2.8 | 0.86 | 1.76 | 5.25 | 3.78 | 5.65 | 20.1 |
the role of the market in the risk spillover by calculating the dynamic risk spillover, which the "TO_ABS" spillover value minus the "FROM_ABS" spillover value is used to represent the net risk spillover, the positive value represents the market as the risk sender, and the negative value represents the market as the risk receiver. The result is shown in Figures 20–25. On the one hand, for the Shanghai stock market, the net spillover value of China’s overall EPU is negative in the short-term and positive in the medium and long term, indicating that China’s EPU is the receiver of risk spillover in the short term and the sender of risk spillover in the medium and long term. This is mainly due to the impact of the promotion of the internationalization of RMB in 2009 and the successful implementation of the G20 summit to promote a new international financial order. The international economic situation is showing a trend for the better. In addition, China’s economy entered a new normal in 2014 and the development of the "Belt and Road Initiative" further deepened China’s opening up to the outside world. Even under the influence of the COVID-19 epidemic in 2020, the net spillover effect is still positive, which indicates that China’s economic policy plays a key guiding role in stabilizing the national economy and investor sentiment in the long-term development process. Hong Kong, the United States, the United Kingdom, and Australia are mainly recipients. For the Hong Kong stock market, the HSI as the main sender shows that the HSI dominates the spillover of EPU, which is consistent with the results of static analysis. On the contrary, under the influence of economic events such as the financial crisis, the Sino-US trade war, and Brexit, there are positive and reverse oscillations in the dynamic risk spillover. This shows that there is a two-way and asymmetric risk spillover between EPU and the stock market.
5. Robustness Test

5.1. Robustness Test Based on Window Value. In order to judge whether the empirical conclusions obtained under the selected model parameters are robust, this section selects different window periods to test the robustness. Because the data used in this paper are monthly data, the length of time series has some limitations, so this section selects the window period of 24 months and 36 months, respectively, for test and analysis. The overall spillover chart of the Hang Seng Index in the frequency domain is shown in Figures 26 and 27. By comparison, it can be concluded that when the window period becomes larger, the change range of the dynamic spillover index becomes smaller and the whole is smoother, but the specific upward and downward trends are similar.

First of all, the overall spillover fluctuation of the Hang Seng Index in the frequency domain is obvious during the period from 2007 to 2010, indicating that the spillover effect between the two increases and occupies a dominant position for a long time due to the influence of domestic and foreign economic events. Secondly, under the condition that the window period is 30, the short-term and medium-term spillover effect is relatively smooth, and compared with the window period of 24 months, the change range is smaller, but the fluctuation trend tends to be consistent, and the two
are similar in time. Generally speaking, although there are some deviations in the specific numerical calculation of the dynamic spillover index in different window periods, the conclusions are basically the same. Therefore, it can be considered that the empirical conclusion obtained under the condition of the model parameters of the selected 24-month window period is robust.

5.2. Robustness Test Based on the Lag-Order Value. In order to judge whether the lag order in the model has an impact on the empirical analysis results, this section selects the lag order to test the robustness of the frequency-domain spillover model. Because there are some limitations in the length of time series in this paper, this section chooses lag order 3 and lag order 2, respectively, for test and analysis. The international EPU with lag order 3 and the static frequency-domain spillover index of Shanghai Composite Index are shown in Tables 11–13.

Compared with the results of Tables 5–7, it can be concluded that although there are differences between the international economic and political uncertainty and the static spillover index of the SSEC, the overall conclusion remains the same. On the one hand, from Tables 11 to 13, it can be seen that the long-term (low frequency) spillover effects of EPU in different countries/regions are dominant from short-, medium-, and long-term static spillover tables. Among them, the total spillover rate of EPU for the Shanghai
Figure 24: Medium-term dynamic net spillover of HSI and EPU.

Figure 25: Long-term dynamic net spillover of Shanghai composite index and EPU.

Figure 26: Dynamic total frequency connection between Shanghai composite index and EPU index.
Figure 27: Dynamic total frequency connection between HSI and EPU index.

| Table 11: Uncertainty of international economic policy and static short-term (0–3 months) spillover index of Shanghai composite index. |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
|                | SSEC           | China          | HK             | US             | UK             | Australia      | FROM_ABS       | FROM_WTH       |
| SSEC           | 15.01          | 0.09           | 0.03           | 0.16           | 0.08           | 0.25           | 0.1            | 0.6            |
| China          | 0.1            | 9.62           | 0.06           | 0.09           | 0.02           | 0.16           | 0.07           | 0.44           |
| HK             | 0.12           | 0.35           | 25.45          | 1.09           | 0.25           | 1.27           | 0.51           | 3.09           |
| US             | 0.15           | 0.26           | 0.48           | 11.82          | 1.36           | 1.95           | 0.7            | 4.2            |
| UK             | 0.02           | 0.06           | 0.09           | 1.19           | 9.58           | 1.32           | 0.45           | 2.67           |
| Australia      | 0.17           | 0.02           | 0.72           | 2.29           | 1.75           | 12.52          | 0.82           | 4.95           |
| TO_ABS         | 0.09           | 0.13           | 0.23           | 0.8            | 0.58           | 0.82           | 2.66           |                |
| TO_WTH         | 0.57           | 0.77           | 1.39           | 4.82           | 3.45           | 4.95           |                | 15.95          |

| Table 12: Uncertainty of international economic policy and static medium-term (4–12 months) spillover index of Shanghai composite index. |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
|                | SSEC           | China          | HK             | US             | UK             | Australia      | FROM_ABS       | FROM_WTH       |
| SSEC           | 24.22          | 0.12           | 0.07           | 0.42           | 0.08           | 0.47           | 0.19           | 0.95           |
| China          | 0.04           | 4.82           | 0.15           | 0.32           | 0.19           | 0.2            | 0.15           | 0.74           |
| HK             | 0.28           | 0.38           | 20.65          | 1.3            | 0.34           | 2.27           | 0.76           | 3.76           |
| US             | 0.14           | 0.32           | 0.8            | 14.27          | 2.68           | 6.05           | 1.67           | 8.21           |
| UK             | 0.03           | 0.12           | 0.41           | 1.79           | 11.27          | 2.62           | 0.83           | 4.09           |
| Australia      | 0.3            | 0.06           | 0.95           | 3.97           | 3.46           | 16.18          | 1.46           | 7.18           |
| TO_ABS         | 0.13           | 0.17           | 0.4            | 1.3            | 1.13           | 1.94           | 5.06           |                |
| TO_WTH         | 0.66           | 0.82           | 1.95           | 6.41           | 5.55           | 9.54           |                | 24.92          |

| Table 13: Uncertainty of international economic policy and static long-term (more than 12 months) spillover index of Shanghai composite index. |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
|                | SSEC           | China          | HK             | US             | UK             | Australia      | FROM_ABS       | FROM_WTH       |
| SSEC           | 54.81          | 1.34           | 0.3            | 1.02           | 0.62           | 0.91           | 0.7            | 1.11           |
| China          | 0.43           | 48.39          | 5.63           | 9.75           | 11.42          | 8.61           | 5.97           | 9.47           |
| HK             | 1.15           | 9.66           | 25.11          | 2.47           | 2.99           | 4.85           | 3.52           | 5.58           |
| US             | 0.08           | 8.38           | 2.43           | 20.9           | 11.05          | 16.89          | 6.47           | 10.26          |
| UK             | 0.71           | 10.33          | 4.36           | 9.86           | 31.81          | 14.42          | 6.62           | 10.49          |
| Australia      | 0.52           | 2.6            | 2.79           | 10.11          | 11.77          | 29.81          | 4.63           | 7.35           |
| TO_ABS         | 0.48           | 5.38           | 2.59           | 5.54           | 6.31           | 7.61           | 27.91          |                |
| TO_WTH         | 0.77           | 8.54           | 4.1            | 8.78           | 10.01          | 12.07          |                | 44.27          |
stock market is 0.1% in the short term (0–3 months), 0.19% in the medium term (4–12 months), and 0.7% in the long term (more than 12 months). On the other hand, the spillover relationship between EPU and stock market has time-varying characteristics. For the Shanghai stock market, the degree of spillover of EPU is larger in the United States (0.16% and 0.42%) and Australia (0.25% and 0.47%) in the short- and medium-term frequency. In the long-term frequency, China’s EPU spillover to it is 1.34%. This is consistent with the result of static spillover in frequency domain with lag order 2, so it can be considered that the empirical conclusion is robust under the condition of model parameters with lag order 2.

6. Conclusions

In the era of rapid development of information technology, the research on the relationship between EPU and the stock market and risk spillover effect plays an important role in the improvement of financial risk management and portfolio optimization. However, the existing research focuses on the market risk from the time-domain framework, ignoring the frequency characteristics of market risk contagion. The main purpose is to study the direction and degree of risk spillover of international EPU on the stock market by using wavelet coherence and frequency-domain framework, respectively, taking Shanghai and Hong Kong stock market as research objects, to reveal the risk factors of Chinese stock market and put forward reasonable and effective control suggestions for different stock markets.

This paper selects China, the United States, Australia, and the United Kingdom and uses the monthly EPU index of these countries or regions. The 5-minute high-frequency realized volatility of the SSEC and HSI is used to analyze the dynamic spillover effects of international EPU on the stock market. The main conclusions of this paper are as follows.

First, the EPU and the dependence of the stock market are obviously different in the time domain and frequency domain, and the phase arrow is constantly changing, indicating that the lead-lag relationship between them has time-varying characteristics. Among them, the EPU of the Shanghai and Hong Kong is the strongest, followed by the EPU of US and Australia. On the other hand, the Hong Kong stock market and the United Kingdom have the strongest dependence on the HSI. Therefore, policymakers and portfolio managers should pay attention to the policy fluctuations of China’s offshore financial markets and overseas countries and improve the risk link information sharing and supervision mechanism.

Second, the long-term effects of EPU and stock market risk spillover are dominant, and the EPU and risk spillover in the Hong Kong stock market is stronger than those in the Shanghai stock market. For the Shanghai stock market, the EPU of the US, Britain, Hong Kong, and Australia is mainly the sender of risk spillover, while the EPU of China is mainly the receiver. In the Hong Kong stock market, the HSI is mainly the sender of risk spillover. Therefore, market investors are required to constantly optimize investment strategies for different stock markets, consider the persistence of risk spillover, and better guard against financial risks.

Third, the EPU and the frequency-domain risk net spillover of the stock market have frequency characteristics, while the positive and negative alternation of the net risk spillover indicates that there is a two-way and asymmetric risk spillover between them. Similarly, net risk spillover has long been dominant. The outbreak of the crisis has increased the risk of spillover between the two. Therefore, the country should strengthen the emergency mechanism to deal with the crisis so that the market investors can better deal with the crisis.

This paper hopes to improve the management strategies for different stock markets as much as possible by comparing and analyzing the time-frequency risk spillover effects of EPU on the Shanghai and Hong Kong stock market, so as to provide higher risk management measures for the stock market and provide scientific and reasonable reference and support for investors of different investment portfolios. Based on the above research, this paper still has some shortcomings and fails to explore the main factors leading to the difference between the Hong Kong and the Shanghai stock market, which will become the main content of the next step of this paper.

Section 6 clearly explains the main findings and implications of the work, highlighting its importance and relevance.

Data Availability

The data sample spans from January 2000 to February 2021, excluding a total of 254 missing values. This paper uses the monthly economic policy uncertainty index compiled by Baker et al. [1], derived from https://www.policyuncertainty.com, and 5-minute high-frequency data from https://www.realized.Oxford-man.ox.ac.uk/.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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