J Syst Sci Complex (2023) 36: 1169–1188

Economic Policy Uncertainty: Cross-Country Linkages and Spillover Effects on Economic Development in Some Belt and Road Countries*

YUAN Jing · DONG Yajing · ZHAI Weijie · CAI Zongwu

DOI: 10.1007/s11424-023-1060-0
Received: 4 March 2021 / Revised: 4 November 2021
©The Editorial Office of JSSC & Springer-Verlag GmbH Germany 2023

Abstract With the increase of economic environment uncertainty, it is of great importance to study the linkage and spillover effects of economic policy uncertainty among countries. Especially, this article selects eight countries along the Belt and Road as the core countries (China, Korea, Croatia, India, Russia, Greece, Pakistan, and Singapore) and four countries (Germany, France, Japan, and UK) as the peripheral countries, and then copula technique and mixed-frequency global vector autoregressive model are employed to analyze the correlation and the spillover effect of the economic policy uncertainty (EPU) for the twelve selected countries, respectively. The proposed empirical findings show clearly that the EPU correlation among the eight core Belt and Road countries is stronger and the spillover effect of the core countries to the peripheral countries is statistically significant. As a result, for harmonious and win-win development, the Belt and Road countries should pay a close attention to the EPU, because the stability of the EPU promotes greatly the economy development.

Keywords Belt and road initiative, copula functions, economic policy uncertainty, global VAR, spillover effects.

1 Introduction

The Belt and Road (B&R) is short for "The Silk Road Economic Belt" and "The 21st Century Maritime Silk Road", proposed by Chinese President Xi Jinping in September and

YUAN Jing · DONG Yajing
School of Statistics, Shandong Technology and Business University, Yantai 264005*, China.*
Email: xoy1977@126.com; 745240125@qq.com.
ZHAI Weijie
School of Statistics and Data Science, Nankai University, Tianjin 300071*, China.*
Email: 2120200114@mail.nankai.edu.cn.
CAI Zongwu (Corresponding author)
Department of Economics, University of Kansas, Lawrence, KS 66045*, USA.* Email: caiz@ku.edu.
*This research was supported by the National Natural Science Foundation of China under Grant Nos. 71631004, 72033008 and the Humanity and Social Science Foundation of Ministry of Education of China under Grant No. 18YJA790101.
◇ *This paper was recommended for publication by Editor YANG Cuihong.*

October 2013, respectively. Dependent on existing multilateral mechanisms between China and relevant countries concerned, and with the help of the effective platform for the regional cooperation, the Belt and Road Initiative (BRI) aims to actively develop economic partnership with the countries along the B&R. The BRI was originally planned to include 64 countries. At present, the B&R countries involve 71 countries (According to the website at www.yidaiyilu.gov.cn), covering a population of about 4.4 billion and an economic aggregate of about 21 trillion dollars, accounting for 63% and 29% of the world's population and economic aggregate, respectively, see, for example, Aoyama[1], Huang[2], Zhai[3], Du and Zhang[4], Ullah, et al.[5], and Liu, et al.[6].

Under the background of economic globalization and financial market integration, countries are increasingly interdependent in their economies. The degree of economic interdependence and the mutual restriction and influence of economic policies among countries are getting stronger and stronger. Therefore, a research on the spillover effect of policies has been a demanding topic in the field of macro finance in the recent years. With the implementation of the BRI, the economic and trade exchanges between China and the countries along the B&R are getting closer and the degree of economic correlation among them is constantly increasing. The economic development of the countries along the B&R is largely affected by the economic policies in each country. There are many studies in literature on the transmission effect of geopolitical risks in countries along the B&R. The original intention and ultimate goal of the BRI are to promote the long-term economic development of countries along the B&R. The outbreak of the COVID-19 in 2020 has made global economic uncertainty reaching a high point. Therefore, the spillover effects of economic policy uncertainty (EPU) among countries along the B&R deserve more attention and investigation.

Economic policies are the guiding principles and measures formulated by the state or government to solve economic problems in order to achieve the established macroeconomic goals and promote social welfare. Influenced by the characteristics of economic policies themselves and the internal and external environmental factors, economic policies often have varying degrees of uncertainty; that is, all kinds of unpredictable elements contained in future economy-related policy change. Compared with the western developed countries, policy uncertainty is more obvious in developing countries.

It is well known in economic theory literature that EPU has sizable effects on the real economy. Indeed, there are extensive literatures to study the effects of EPU on financial and economic fundamentals, and most of the papers in this field emphasize that EPU is an important influence factor of economic fluctuations. The recent papers show clearly that EPU has a significant negative effect on the macro-economy, including economic growth, employment, household consumption and enterprise investment, and more, see, for example, Bloom[7], Caggiano, et al.[8], and Jurado, et al[9]. Some scholars constructed EPU indicators based on text analysis as in Gentzkow and Shapiro[10], Hoberg and Phillips[11], and Alexopoulos and Cohen[12]. The most representative one is the EPU index constructed by Baker, et al.[13] based on the text analysis of media, newspapers and magazines. According to the media, newspapers and magazines of all countries in the world, Baker, et al.[13] selected the mainstream newspapers of each country to construct the relevant thesaurus, and constructed the EPU index through word frequency statistics, which is widely used in the world. At present, the EPU index has been compiled for 26 countries, including the eight countries such as China, Croatia, Greece, India, Korea, Pakistan, Russia and Singapore, along the B&R.

The existing literatures on the correlation and spillover effects of EPU among countries mainly focus on the developed countries, such as Europe and the United States, and the conclusion is unanimous that there is a strong correlation and spillover effect of EPU among these developed countries. At present, there is no literature that analyzes the correlation and spillover effect of EPU between China and countries along the B&R. To fill this gap, this paper selects eight countries along the B&R as the core countries (China, Korea, Croatia, India, Russia, Greece, Pakistan, and Singapore), and chooses four countries (Germany, France, Japan, and UK) that are close to the countries along the B&R geographically and closely related to their trade and economic policies as the peripheral countries. This paper adopts the copula method to measure the correlation of EPU among the eight B&R countries. Also, we utilize the generalized variance decomposition under mixed-frequency global vector autoregressive (GVAR) model as in Diebold and Yílmaz[14], Cipollini and Mikaliunaite[15] and Greenwood-Nimmo, et al.[16] to measure the spillover effects of EPU among the eight B&R countries and the four peripheral countries. Interestingly, our empirical findings are promising, which show clearly that EPUs among the B&R countries are closely linked, and the EPU from the core countries has a spillover effect on the periphery countries that can not be ignored. The conclusion of this paper verifies the linkage and spillover effects of policy uncertainty risks brought about by the increasingly close trade and economic exchanges among B&R countries, which is consistent with the existing results in literature that there are also strong correlation and spillover effects of EPU risks among the developed countries.

The contributions of this paper include mainly the following aspects. First, to study the correlation and spillover effect of EPU is an attractive topic in the field of macroeconomic research. The existing literatures have carried out relevant studies on the correlation degree and international spillover effect of EPU, and many valuable conclusions have been obtained. However, previous studies mainly focused on the developed countries, such as Europe and the United States. To be the best of our knowledge, this paper is the first attempt to study the correlation degree and spillover effect of EPU in countries along the B&R. Second, different from the existing literature that the classical vector autoregressive (VAR) model is used to analyze the correlation and spillover effect of EPU index, to capture tail risks, this article utilizes copula methods to measure the correlation degree for the country's EPU. Also, because the EPU index is monthly data and the gross domestic product (GDP) data of economic development is quarterly data, this paper employs the mixed-frequency GVAR model to measure the spillover effects of EPU among countries. Finally, our empirical results can be used to predict the spillover effects of individual countries' policies on other countries, and then can promote the country's actual economic cooperation and policy coordination in the future.

The rest of the paper is organized as follows. Section 2 reviews the relevant literatures and Section 3 describes the related modeling methodologies. In Section 4, the empirical results are presented in detail for both the cross-country EPU linkages and spillover effects between the EPU and economic development. Finally, Section 5 concludes the paper.

2 Literature Review

2.1 Literature Review on BRI

Huang[2] outlined the key formation of the BRI, which aims to promote trade cooperation, investment, consumption and employment among the countries along the Belt and Road in the context of the current close and diversified economic development. Since launching the BRI, many researchers have conducted extensive research on this initiative with most focuses on energy, sustainable development, and the development of investment and trade in the countries along the routes, especially for China. In particular, Du and Zhang[4] showed that through construction of the BRI, China's foreign direct investment has increased significantly, while Liu, et al.[6] evidenced that financial deepening in countries along the BRI has an important effect on attracting foreign investment. Finally, based on data from 32 countries along the Belt and Road, Gao, et al.[17] concluded that the risk of internal conflict in the host country significantly affects the liquidity risk of banks.

2.2 Literature Review on EPU

Since the financial crisis in 2008, many governments around the world have introduced various policy reforms to cope with the economic downturn. Although policy reforms have played a role in the recovery of global economic, the pace of the recovery has been much slower than expected, and the risk factors which affect the economic development for a long term have not been effectively resolved. Some scholars, represented by Baker, et al.[13], found that the policy uncertainty caused by policy reform increased sharply after the financial crisis, hindering the economic recovery all over the world.

According to the research on economic psychology as addressed in Lemieux and Peterson[18], the typical response of economic subjects is to search for more information when facing uncertainty. Therefore, the magnitude of uncertainty can be reflected by the search volume of relevant keywords in the search engine, or the coverage volume of relevant media. The advantage of using text analysis method to construct uncertainty index is timely and convenient, which can directly use the existing search engine and text database to obtain relevant data. More importantly, the method based on text analysis can extract the comprehensive index of policy uncertainty, and many scholars constructed economic policy uncertainty indicators based on this cognition, see, e.g., Gentzkow and Shapiro[10], Hoberg and Phillips[11], and Alexopoulos and Cohen[12]. The most representative one is the economic policy uncertainty index constructed by Baker, et al.[13] based on the text analysis of media, newspapers and magazines. According to the media, newspapers and magazines of all countries in the world, Baker, et al.[13] selected the mainstream newspapers of each country to construct the relevant thesaurus, and constructed the economic policy uncertainty index through word frequency statistics, which is widely used in the world.

Since the seminal paper by Baker, et al.[13], subsequent papers have been devoted to examining the impact of the EPU index constructed as in Baker, et al.[13] on various economic variables, including but not limited to, the effects of EPU on unemployment, economic development, inflation and output, monetary policy, corporate investment, stock and bond market, stock market volatility and financial conditions; see, for example, to name just a few, Jones and Olson[19], Caggiano, et al.[8], Wang, et al.[20], Zhang, et al.[21], Wang, et al.[22], Li, et al.[23], Liu and Zhang[24], Scheffel[25], Aastveit, et al.[26], Li and Peng[27], Phan, et al.[28], Chiang[29], Balcilar, et al.[30], Tiwari, et al.[31], Chen and Chiang[32], Li and Zhong[33], and Li, et al.[6]. Most of papers in literature conclude that EPU has a negative effect on economic fluctuation, which means that EPU aggravates unemployment and restrains investment and consumption and so on.

To sum up, the existing literatures mainly study the impact effect of EPU for one country, and the correlation and studies on spillover effect of EPU always take the developed countries as research objects. In the context of increasing downward pressure on the world economy, countries along the B&R should further strengthen policy cooperation and jointly resist the negative impact of uncertain risks. It is of more practical significance to study the correlation and spillover effects of EPU in countries along the B&R.

3 Econometric Modeling

3.1 Copula Approaches

Based on Sklar[34], copula is a function to connect the joint distribution function with its respective marginal distributions. If a bivariate distribution $F(x, y)$ has continuous marginal distributions of $F_X(x)$ and $F_Y(y)$, then, based on the copula theory as in Sklar[34], there exists a unique connection function $C(u, v)$ that makes the following formula workable:

$$F(x, y) = C(F_X(x), F_Y(y))), \tag{1}$$

where $C(\cdot, \cdot)$ is a distribution function in $[0, 1] \times [0, 1]$. It is well known that different from the linear correlation coefficient, a copula approach can be used to not only characterize a nonlinear relationship and but also describe the so-called tail dependencies; see, for example, the book by Cherubini, et al.[35] and the paper by Cai and Wang[36] for details on the properties of copula and its applications. Clearly, the fitting of (1) can be divided into two steps. The marginal distribution functions $F_X(x)$ and $F_Y(y)$ are fitted firstly, and then an appropriate copula function is selected for fitting. There are many ways to estimate the marginal distribution functions such as parametric approach.

For a bivariate copula, it has many categories, such as Gaussian-copula, T-copula, Gumbel-copula, Clayton-copula, SJC-copula and so on. Different types of copula functions can describe different dependences. The dependencies of Gaussian-copula and T-copula are symmetric. However, the tail of T-copula is thicker than that of Gaussian-copula. Gumbel-copula only applies to the upper tail dependency and Clayton-copula can depict the lower tail dependency. SJC-copula can describe the asymmetrical upper and lower tail dependency.

In this paper, for simplicity, Normal-copula, Gumbel-copula and SJC-copula are adopted to fit the dependency of the EPU for 10 countries. The distribution function of SJC-copula is defined as follows:

$$C_{\text{SJC}}\left(u_1,u_2;\tau^L,\tau^U\right)=0.5[C_{\text{JC}}\left(u_1,u_2;\tau^L,\tau^U\right)+C_{\text{JC}}\left(1-u_1,1-u_2;\tau^L,\tau^U\right)+u_1+u_2-1],$$

where $C_{\text{JC}}(\cdot)$ represents the Joe-Clayton-copula function with the contingency coefficients of upper and lower tails which are τ^U and τ^L, respectively, and its distribution function is given by

$$C_{\text{JC}}=(u_1,u_2;\tau^L,\tau^U)=1-\left\{1-\frac{1}{\left[\frac{1}{(1-(1-u_1)^{\varpi})^{\lambda}}+\frac{1}{(1-(1-u_2)^{\varpi})^{1/\lambda}}\right]}\right\}^{1/\varpi},$$

where $\lambda=-1/\log_2(2-\tau^L)$, $\varpi=1/\log_2\tau^U$, and the value ranges of τ^U and τ^L are both between 0 and 1. For the detailed definitions of τ^L and τ^U, the reader is referred to Cherubini, et al.[35] or Patton[37] or Cai and Wang[36]. Of course, it is desired to use some advanced technique to select a "best" copula to fit a real problem; see the paper by Cai and Wang[36] for details.

Because our analysis is targeted at 10 countries, it is necessary to calculate the multivariate copula function. For the easy computation, a multivariate normal copula is implemented and a d-multivariate normal copula function with $d\geq 2$ can be expressed as $C_N(u_1,\cdots,u_n;\rho)=\Phi_\rho\left(\Phi^{-1}(u_1),\cdots,\Phi^{-1}(u_d)\right)$, where ρ is the correlation matrix of k random variables, the symmetric matrix of positive values, $\Phi_\rho(\cdot)$ is the standard multivariate normal distribution with correlation coefficient matrix ρ, and $\Phi^{-1}(\cdot)$ is the inverse of the standard normal distribution function. To capture tail dependences, multivariate copulas can be used, described by a multivariate Archimedean copula as $C(u_1,\cdots,u_k;\theta)=\Phi\{\Phi^{-1}(u_1)+\cdots+\Phi_\theta^{-1}(u_d)\}, u_1,\cdots,u_d\in[0,1]$, and $\Phi_\theta(\cdot)\in\Omega$ is defined as generator element, the usual generators of Archimedes copulas include Gumbel copula, Clayton copula and Frank copula. The density function of Gumbel Copula is asymmetric, its distribution is "J" type, change of the upper tail is very sensitive. Clayton copula density distribution is "L" type, its distribution of the lower tail is very sensitive to change, therefore, it can accurately reflect the degree of tail dependence. Frank Copula function can not only make up the shortcomings of the former two functions, but also can characterize the negative correlation between variables.

A fully nested Archimedes copula model with k variables can be expressed as follows:

$$\begin{aligned}C(u_1,u_2,\cdots,u_k;\theta)&=C_{k-1}\{C_{k-2}(u_1,u_2,\cdots,u_{k-1}),u_k\}\\&=\Phi_{\theta_{k-1}}\{\Phi_{\theta_{k-1}}^{-1}C_{k-2}(u_1,u_2,\cdots,u_{k-1})+\Phi_{\theta_{k-1}}^{-1}(u_k)\},\end{aligned}$$

where $C_j(u_1,u_2,\cdots,u_{j+1})=\Phi_j[\Phi_j^{-1}\{C_{j-1}(u_1,u_2,\cdots,u_j)\}+\Phi_j^{-1}(u_{j+1})]$ for $2\leq j\leq k-1$ and $C_1=\Phi_\theta\{\Phi_\theta^{-1}(u_1)+\cdots+\Phi_\theta^{-1}(u_k)$. The reader is referred to the book by Cherubini, et al.[35] for details on multivariate Archimedes copula. Finally, we would like to note that to avoid a possible misspecification of a chosen copula, one can follow the copula selection approach proposed in Cai and Wang[36]. Also, note that the aforementioned specification can be possibly updated as a dynamic form using the newly proposed techniques as in Yang, et al.[38] and Liu, et al.[39].

3.2 Global VAR Model for Mixed-Frequency Data

A GVAR model is developed on the basis of VAR model and it can be used to study the spillover effect among regions and individuals. For example, Pesaran, et al.[40] used a GVAR model to study the relationship and spillover effects among interest rates, exchange rates, asset prices and output in 26 countries, while Diebold and Yílmaz[14] employed a GVAR model to analyze the spillover effects among the volatility of the U.S. stock, foreign exchange, bond and commodity markets. Furthermore, Greenwood-Nimmo, et al.[16] developed the order-invariant generalized forecast error variance decomposition to evaluate the macroeconomic connectedness for 25 countries, and Cipollini and Mikaliunaite[15] extended the measurement developed by Greenwood-Nimmo, et al.[16] to mixed frequency GVAR and studied the macro-uncertainty and financial distress spillovers within the Eurozone.

By following Diebold and Yílmaz[14], Cipollini and Mikaliunaite[15], and Greenwood-Nimmo, et al.[16], we adopt the mixed frequency GVAR to consider the spillover effects among the EPUs for 10 countries. For this end, we consider the data sets containing a quarterly GDP growth index, denoted by GDPG_i, from World Economic Database, and a monthly indicator, represented by EPU_i, downloaded from the website at `http://www.policyuncertainty.com/index.html`, for $1 \leq i \leq 12$.

At period t, there are three monthly data observations corresponding to one quarterly data observation value. Let $Q_i(t,1)$ be the first monthly data observation. Denote $Q_i(t,2)$ and $Q_i(t,3)$ the second and last monthly data observations, respectively. For each country i, the mixed frequency endogenous vector variable $Y_{i,t}$ is composed of four variables as

$$Y'_{i,t} = (Q_i(t,1)\ Q_i(t,2)\ Q_i(t,3)\ \mathrm{GDPG}_i(t))'.$$

Now, consider each country i respresented by a mixed-frequency vector autoregressive model augmented by a set of foreign variables $Y^*_{i,t}$. Specifically, an MF-VARX(1, 1) model is set up each country i as:

$$Y_{i,t} = \alpha_i + \mathit{\Gamma}_i Y_{i,t-1} + \mathit{\Lambda}_{i0} Y^*_{i,t} + \mathit{\Lambda}_{i1} Y^*_{i,t-1} + \varepsilon_{i,t} \tag{2}$$

for $1 \leq i \leq 12$ and $1 \leq t \leq T$, where $Y_{i,t-1}$ is a $k_i \times 1$ vector of lagged specific country endogenous variables, $Y^*_{i,t}$ is a $k_i \times 1$ vector of country-specific foreign variables, α_i is constant term, $\mathit{\Gamma}_i$ is a $k_i \times k_i$ coefficient matrix associated to lagged endogenous variables, $\mathit{\Lambda}_{i0}$ is the $k_i \times k_i$ coefficient matrices of contemporaneous foreign variables, and $\mathit{\Lambda}_{i1}$ is the coefficient matrices of lagged foreign variables, and $\varepsilon_{i,t}$ is a $k_i \times 1$ vector of serially uncorrelated innovations. The vector of foreign variables in a country-specific MF-VARX is constructed as a weighted average of other countries' variables:

$$Y^*_{i,t} = w_i Y_t, \tag{3}$$

where $Y_t = (Y_{1,t}, \cdots, Y_{12,t})$ and the weight w_i is calculated according to the trade volumes among 12 countries, see Cipollini and Mikaliunaite[15] for details on how to construct w_i.

To apply for the variance decomposition analysis of GVAR, three steps are needed and described as follows. The first step is to adopt OLS according to the same frequency VAR, the second step is to change the same frequency VAR into mixed VAR model, and the last step is to stack VAR of each country together to form the mixed GVAR. For details, the reader is referred to the papers by Diebold and Yílmaz[14], Greenwood-Nimmo, et al.[16], and Cipollini and Mikaliunaite[15]. Finally, by plugging (3) into (2), the MF-GVAR model is constructed by gathering all the specific country models as a global GVAR. Therefore, we have the following country-specific MF-GVAR(1, 1) in terms of $Y_{i,t}$: $Y_{i,t} = \alpha_i + \Gamma_i Y_{i,t-1} + \Lambda_{i0}(w_i Y_{i,t}) + \Lambda_{i1}(w_i Y_{i,t-1}) + \varepsilon_{i,t}$, which, together with a simple algebra, leads to the following $(1 - \Lambda_{i0} w_i) Y_{i,t} = \alpha_i + (\Gamma_i + \Lambda_{i1} w_i) Y_{i,t-1} + \varepsilon_{i,t}$, and $GY_t = \alpha + FY_{t-1} + \varepsilon_t$, where $G = (G_1', \cdots, G_{10}')'$, $F = (F_1', \cdots, F_{10}')'$, $\alpha = (\alpha_1', \cdots, \alpha_{10}')'$, and $u_t = (u_{1,t}', \cdots, u_{10,t}')'$. Here, $G_i = 1 - \Lambda_{i0} w_i$ and $F_i = \Gamma_i + \Lambda_{i1} w_i$.

To derive the directional connectedness measures for spillovers, by following Diebold and Yílmaz[14] for the order-invariant generalized forecast error variance decomposition and its extension to GVAR by Greenwood-Nimmo, et al.[16] and Cipollini and Mikaliunaite[15], the following resulting matrix for the MF-GVAR model is given by a general form as with $K = 48$:

$$\Theta(S) = \begin{pmatrix} \theta_{1\leftarrow 1}(S) & \theta_{1\leftarrow 2}(S) & \theta_{1\leftarrow 3}(S) & \theta_{1\leftarrow 4}(S) & \cdots & \theta_{1\leftarrow K}(S) \\ \theta_{2\leftarrow 1}(S) & \theta_{2\leftarrow 2}(S) & \theta_{2\leftarrow 3}(S) & \theta_{2\leftarrow 4}(S) & \cdots & \theta_{2\leftarrow K}(S) \\ \theta_{3\leftarrow 1}(S) & \theta_{3\leftarrow 2}(S) & \theta_{3\leftarrow 3}(S) & \theta_{3\leftarrow 4}(S) & \cdots & \theta_{3\leftarrow K}(S) \\ \theta_{4\leftarrow 1}(S) & \theta_{4\leftarrow 2}(S) & \theta_{4\leftarrow 3}(S) & \theta_{4\leftarrow 4}(S) & \cdots & \theta_{4\leftarrow K}(S) \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ \theta_{K\leftarrow 1}(S) & \theta_{K\leftarrow 2}(S) & \theta_{K\leftarrow 3}(S) & \theta_{K\leftarrow 4}(S) & \cdots & \theta_{K\leftarrow K}(S) \end{pmatrix},$$

where $\theta_{i\leftarrow j}(S)$ denotes the impact of the four variables (the first, second and last monthly data observation of EPU and GDPG) of all 12 countries on these four variables of each country, and S denotes the forecast horizon, which is specified as $S = 4$ (one year) and $S = 8$ (two years) in our empirical study. To interpret the meaning of each element in $\Theta(S)$ for 12 countries, it is not difficult to see that the first country is China, so that the first row of the matrix is China's EPU quarterly data corresponding to the first month of the forecast variance decomposition from shocks: 1) its own impact ($\theta_{1\leftarrow 1}(S)$); 2) China's EPU quarterly the corresponding second month of its impact ($\theta_{1\leftarrow 2}(S)$); 3) China's EPU quarterly the corresponding third month of its impact ($\theta_{1\leftarrow 3}(S)$); 4) China's quarterly GDP impact ($\theta_{1\leftarrow 4}(S)$); and so on are the response to the impact of the next eleven countries' quarterly EPU of the first month, the second month, the third month and the quarterly GDP growth in the 12th country (UK). Finally, the group connectedness matrix is given by

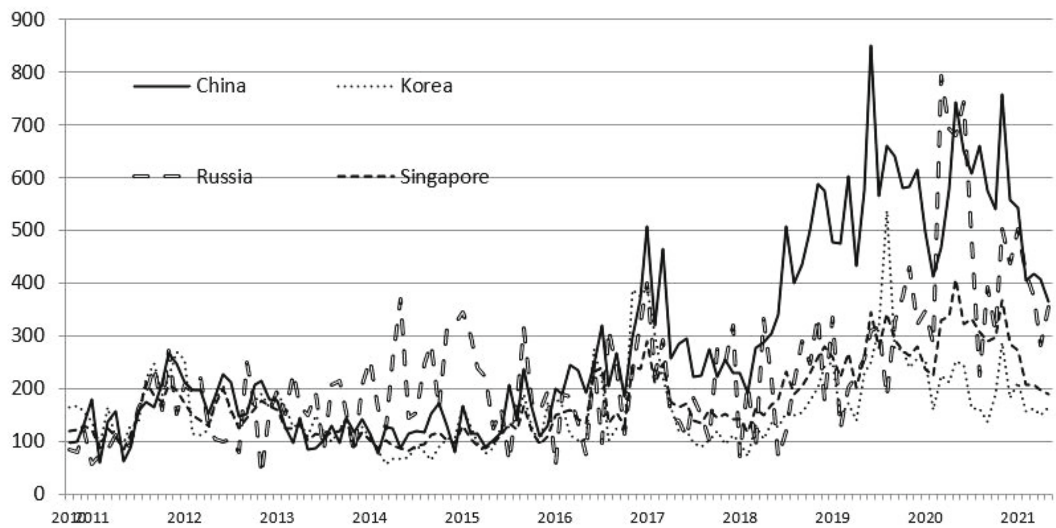
$$\begin{pmatrix} V_{1\leftarrow 1}(S) & U_{1\leftarrow 2}(S) & \cdots & U_{1\leftarrow b}(S) \\ U_{1\leftarrow 2}(S) & V_{2\leftarrow 2}(S) & \cdots & U_{2\leftarrow b}(S) \\ \vdots & \vdots & \ddots & \vdots \\ U_{b\leftarrow 2}(S) & U_{b\leftarrow 2}(S) & \cdots & V_{b\leftarrow b}(S) \end{pmatrix}$$

with $b = 2$, where $V_{i \leftarrow j}(S)$ denotes the impact among groups (for example, in our empirical study, there are two groups, including the eight B&R countries and the four peripheral countries) and $U_{i \leftarrow j}(S)$ stands for the impact from one group to another group. Again, S denotes the forecast horizon, as $S = 4$ (one year) and $S = 8$ (two years) in our empirical study.

4 Empirical Results

4.1 Data

For EPU index, it is computed based on the monthly data from October 2010 to March 2021 for the selected 12 countries which can be downloaded from the website at `http://www.policyun certainty.com/index.html`, as in Baker, et al.[13]. For the GDP growth rate of the selected 12 countries (quarterly data: from the third quarter of 2010 to the first quarter of 2021), we use the data provided by the World Economic Outlook Database. The EPU indices of the eight B&R countries are plotted in Figure 1, which shows clearly that the trend of EPU for the eight countries in recent years is basically the same, and the key nodes of peak and trough also have a basic consistent trend. The EPUs are at a high point at three time points: Financial crisis, the trade war between China and the U.S. beginning in 2018, and the COVID-19 outbreak in 2020. It is evident to observe from Figure 1 that the EPUs for the eight B&R countries reach a high in September 2013, March 2015, and one month after May 2017. These three time points are the BRI put forward by China, "the Vision and Actions for Jointly Building silk Road Economic Belt and 21st Century Maritime Silk Road" issued by China, and "the Joint Construction of the Belt and Road: Concepts, Practices and China's Contribution" announced by the Office of China's Leading Group. This indicates that the proposal and promotion of the B&R policy has a certain impact on the EPUs of the eight B&R countries.



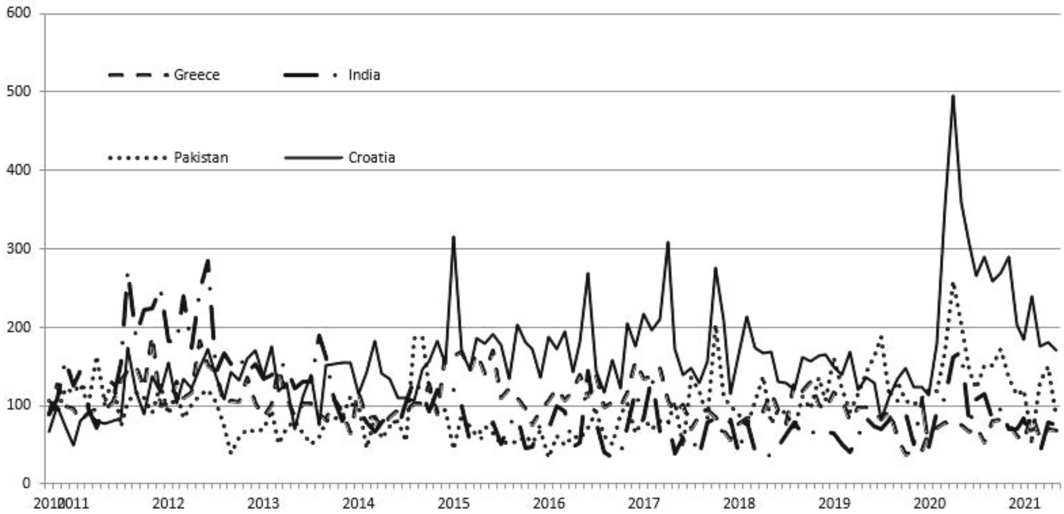


Figure 1 Time series plots for the EPU for the eight B&R countries: The top panel for China, Korea, Russia and Singapore and the bottom one for Greece, India, Pakistan and Croatia, respectively

4.2 Cross-Country Linkages of EPU

4.2.1 Results Based on Bivariate Copula

First, we use the bivariate copula functions to explore cross-country linkages of EPU among the eight core B&R countries and the results are shown in Table 1[†].

Table 1 shows that normal copula and Gumbel-copula coefficients of EPU in the eight B&R countries all pass the significance test. The SJC-copula coefficient fails the significance test among individual countries (two-tailed coefficient between Russia and India, two-tailed coefficient between India and Pakistan, two-tailed coefficient between Greece and Croatia, lower-tailed coefficient between India and Singapore, lower-tailed coefficient between Singapore and Greece). The significant lower-tail correlation coefficient and the insignificant upper-tail correlation coefficient indicate that the decline of one country's EPU has a certain pulling effect on the decline of another country's EPU, but the rise of one country's EPU has no obvious pulling effect on the rise of another country's EPU. This shows that the weakening of EPU between countries should have a greater stabilizing effect on the overall economic environment.

[†]Indeed, we also study cross-country linkages of EPU among all 12 selected countries. Because the results are similar, to save space, the results for the four peripheral countries are not presented here, available upon request.

Table 1 Results for bivariate copula functions

China-Russia			Russia-India		
normal copula	0.62**		normal copula	0.12**	
Gumbel-copula	1.65***		Gumbel-copula	1.1**	
SJC-copula	$\tau^L = 0.26^{**}$	$\tau^U = 0.52^{***}$	SJC-copula	$\tau^L = \mathbf{0.05}$	$\tau^U = \mathbf{0.01}$
China-Singapore			Russia-Pakistan		
normal copula	0.805***		normal copula	0.51**	
Gumbel-copula	2.35***		Gumbel-copula	1.3**	
SJC-copula	$\tau^L = 0.55^{**}$	$\tau^U = 0.63^{**}$	SJC-copula	$\tau^L = 0.42^{***}$	$\tau^U = 0.45^{***}$
China-Pakistan			Russia-Singapore		
normal copula	0.66***		normal copula	0.59**	
Gumbel-copula	1.62**		Gumbel-copula	1.61***	
SJC-copula	$\tau^L = 0.5^{**}$	$\tau^U = 0.55^{**}$	SJC-copula	$\tau^L = 0.3^{**}$	$\tau^U = 0.42^{**}$
China-Korea			Russia-Korea		
normal copula	0.68**		normal copula	0.5*	
Gumbel-copula	1.72**		Gumbel-copula	1.42**	
SJC-copula	$\tau^L = 0.41^{**}$	$\tau^U = 0.55^{*}$	SJC-copula	$\tau^L = 0.22^{**}$	$\tau^U = 0.35^{*}$
China-India			Russia-Greece		
normal copula	0.42***		normal copula	0.16**	
Gumbel-copula	1.33**		Gumbel-copula	1.17*	
SJC-copula	$\tau^L = 0.32^{**}$	$\tau^L = 0.31^{**}$	SJC-copula	$\tau^L = 0.05^{**}$	$\tau^U = 0.08**$
China-Croatia			Russia-Croatia		
normal copula	0.57***		normal copula	0.69***	
Gumbel-copula	1.31*		Gumbel-copula	1.71**	
SJC-copula	$\tau^L = 0.31^{*}$	$\tau^U = 0.35^{*}$	SJC-copula	$\tau^L = 0.56^{**}$	$\tau^U = 0.62^{**}$
China-Greece			India-Singapore		
normal copula	0.23**		normal copula	0.2**	
Gumbel-copula	1.25**		Gumbel-copula	1.15**	
SJC-copula	$\tau^L = 0.3^{*}$	$\tau^U = 0.31^{*}$	SJC-copula	$\tau^L = 0.19^{*}$	$\tau^U = 0.02$

Table 1 (continued) Results for bivariate copula functions

India-Pakistan			India-Korea		
normal copula	0.33*		normal copula	0.31*	
Gumbel-copula	1.02*		Gumbel-copula	1.2*	
SJC-copula	$\tau^L = 0.2$	$\tau^U = 0.22$	SJC-copula	$\tau^L = 0.09^{**}$	$\tau^U = 0.13^{**}$
India-Greece			Singapore-Korea		
normal copula	0.34**		normal copula	0.66**	
Gumbel-copula	1.21**		Gumbel-copula	1.95**	
SJC-copula	$\tau^L = 0.07^{**}$	$\tau^U = 0.21^{**}$	SJC-copula	$\tau^L = 0.52^{**}$	$\tau^U = 0.55^{**}$
India-Croatia			Singapore-Greece		
normal copula	0.29*		normal copula	0.33**	
Gumbel-copula	1.04*		Gumbel-copula	1.34**	
SJC-copula	$\tau^L = 0.11$	$\tau^U = \mathbf{0.02}$	SJC-copula	$\tau^L = 0.34^{**}$	$\tau^U = \mathbf{0.006}$
Korea-Greece			Singapore-Pakistan		
normal copula	0.35***		normal copula	0.54***	
Gumbel-copula	1.3**		Gumbel-copula	1.66**	
SJC-copula	$\tau^L = 0.18^{*}$	$\tau^U = 0.26$	SJC-copula	$\tau^L = 0.44^{**}$	$\tau^U = 0.49^{**}$
Korea-Pakistan			Singapore-Croatia		
normal copula	0.45**		normal copula	0.58***	
Gumbel-copula	1.4**		Gumbel-copula	1.69***	
SJC-copula	$\tau^L = 0.36^{*}*$	$\tau^U = 0.42^{*}*$	SJC-copula	$\tau^L = 0.47^{**}$	$\tau^U = 0.59^{**}$
Korea-Croatia			Greece-Pakistan		
normal copula	0.42***		normal copula	0.38***	
Gumbel-copula	1.37**		Gumbel-copula	1.31**	
SJC-copula	$\tau^L = 0.35^{**}$	$\tau^U = 0.41^{**}$	SJC-copula	$\tau^L = 0.22^{*}$	$\tau^U = 0.31^{*}$
Greece-Croatia			Pakistan-Korea		
normal copula	0.28*		normal copula	0.51***	
Gumbel-copula	1.1*		Gumbel-copula	1.35**	
SJC-copula	$\tau^L = \mathbf{0.08}$	$\tau^U = \mathbf{0.15}$	SJC-copula	$\tau^L = 0.33^{**}$	$\tau^U = 0.42^{**}$

Note: The digits in parentheses represent the standard deviations. *, **, and *** indicate the significance at the p-value of 10%, 5%, and 1%, respectively. Meanwhile, the parameters that do not pass the significance test are also marked.

Since the BRI was put forward, among B&R countries, trade, import, export, and bilateral investment have all shown an increasing trend year by year. As China is the initiator, there is a strong correlation between China and the other seven core countries. Moreover, for China, in terms of total volume, the trade volume of countries along the B&R shows the same trend of wavelike, and the proportion of trade volume of countries along the B&R in China's trade volume increased from 24.49% in 2004 to 33.21% in 2018. China's imports from countries along the B&R are mainly from East Asia. In 2017, Korea, Singapore, and Russia accounted for 26%, 8% and 7% of China's imports from countries along the B&R, respectively. Copula coefficient calculated by our empirical study also shows that China has the strongest copula correlation with Korea, Singapore, and Russia. Among the eight core countries, India has the weakest economic links with other countries, so that the copula correlation coefficients between India and several other countries are also low. The copula correlation coefficients calculated in this paper are consistent with the strength of economic ties among the eight core countries.

4.2.2 Results Based on Multivariate Copula

Now, we use the multivariate normal copula functions to consider the correlation among the 8 countries and the estimation results are given in Table 2, which implies that the estimation results are consistent with bivariate copula function estimation results in Table 1. Also, as seen from Table 2, the copula functions estimation results between China and other seven countries (Russia, Singapore, India, Korea, Greece, Pakistan, and Croatia) are 0.6, 0.85, 0.0.33, 0.68, 0.21, 0.61, and 0.52, respectively, which demonstrate that China has strong connections with seven other countries for EPU. With the promotion of the BRI and the increase of bilateral trade between the two countries, the coordination between China and Singapore, Korea, and Russia in economic policy making is getting stronger and stronger, so that the correlation coefficient of EPU is also the strongest. According to the bilateral trade data of the eight countries, India's trade volume with the other seven countries is the lowest, so that the copula correlation coefficients between India and the other seven countries are the weakest among the eight B&R countries. The analysis results are consistent with the economic cooperation among countries.

Table 2 Estimation results based on multivariate normal copula functions for the eight B&R countries

	China	Russia	Singapore	Pakistan	Croatia	India	Korea	Greece
China	1	0.6	0.85	0.55	0.52	0.33	0.68	0.21
Russia	0.6	1	0.62	0.47	0.45	0.08	0.44	0.19
Singapore	0.85	0.62	1	0.41	0.39	0.20	0.67	0.22
Pakistan	0.55	0.47	0.41	1	0.63	0.19	0.41	0.28
Croatia	0.52	0.45	0.39	0.63	1	0.19	0.15	0.13
India	0.33	0.08	0.20	0.19	0.19	1	0.30	0.32
Korea	0.68	0.44	0.67	0.41	0.15	0.30	1	0.36
Greece	0.21	0.19	0.22	0.28	0.13	0.32	0.36	1

In conclusion, according to the estimation results of copula coefficients between two countries, the copula coefficients of the eight core countries are correlated, especially between China and the other seven countries. In the future, countries should stick to the BRI and pursue win-win cooperation. To strengthen cooperation among countries along the B&R, enhance trade and investment connectivity, and also boost trade and financial links. China needs to exert the "locomotive effect", especially in the face of the global economic recession, and jointly reduce the negative impact of uncertain shocks.

In order to select the marginal distribution models of the sample sequences with better fitting degree, GARCH family models are used to describe the marginal distribution of each sequence. As a result, based on the Akaike information criterion (AIC), the conditional variance is modeled by the EGARCH$(1,1)$ model and the mean value equation is the ARMA$(1,1)$ model with the student t-distribution as the error term. Therefore, the model can be expressed as follows:

$$r_t = \mu + \phi\, r_{t-1} + \lambda\, e_{t-1} + e_t \tag{4}$$

with $e_t = \sigma_t z_t$ and

$$\ln \sigma_t^2 = \omega + \alpha[|e_{t-1}| + \gamma\, e_{t-1}]/\sigma_{t-1} + \beta\, \ln \sigma_{t-1}^2,$$

where μ, ϕ, and λ are the parameters for ARMA model, and ω, α, and β are the parameters for EGARCH model. Then, the estimation results are shown in Table 3.

Table 3 Estimation results for EGARCH model parameters

	China	Russia	Singapore	Pakistan	India	Croatia	Korea	Greece
μ	−0.0001	−0.0008	0.0001	−0.0002	−0.0001	−0.0005	0.0003	−0.0003
	(0.0002)	(0.0002)	(0.0001)	(0.0004)	(0.0001)	(0.0002)	(0.0003)	(0.0004)
ϕ	0.123**	−0.217***	0.71**	0.15**	−0.233**	−0.221***	0.67**	0.15**
	(0.056)	(0.013)	(0.013)	(0.017)	(0.005)	(0.011)	(0.014)	(0.012)
λ	−0.17***	0.16***	−0.74***	−0.19***	0.12***	0.23***	−0.64***	−0.15***
	(0.054)	(0.009)	(0.012)	(0.017)	(0.045)	(0.006)	(0.011)	(0.013)
ω	−0.09***	−0.03***	−0.05***	−0.04***	−0.07***	−0.06***	−0.08***	−0.09***
	(0.0077)	(0.0046)	(0.0058)	(0.0031)	(0.0071)	(0.0025)	(0.0055)	(0.0031)
α	0.0136	−0.009	0.02	−0.02	0.007	−0.012	0.05	−0.03
	(0.0181)	(0.0176)	(0.014)	(0.02)	(0.012)	(0.017)	(0.015)	(0.021)
β	0.989***	0.996***	0.994***	0.991***	0.967***	0.995***	0.997***	0.988***
	(0.0008)	(0.0005)	(0.0007)	(0.0001)	(0.0005)	(0.0003)	(0.0007)	(0.0001)
γ	0.159***	0.131***	0.132***	0.196***	0.1113	0.161	0.153	0.115
	(0.0061)	(0.005)	(0.007)	(0.004)	(0.0021)	(0.005)	(0.006)	(0.004)
AIC	12.59	12.64	12.93	12.77	11.96	12.33	12.56	12.06
Log likelihood	1772.37	1779.27	1821.28	1809.16	1683.10	1724.56	1767.67	1696.50
ARCH test	0.87	0.82	0.81	0.88	0.88	0.84	0.82	0.82

Note: The numbers in parentheses are standard error, ARCH test is p-value of 5-phase heteroscedasticity test with residual sequence lag; *, **, and *** indicate the significance at the p value of 10%, 5%, and 1%, respectively.

From Table 3, it is clear to see that all αs are statistically insignificant, suggesting that their residuals may have no effect on volatility. All βs are significant at the 1% level, which implies that the last period of volatility on the current volatility impact is very large. Also, all γs are greater than zero and statistically significant at 1%, indicating that the volatility is highly leveraged, but the volatility in positive policies is higher than that in negative policies.

Finally, we extract residuals and conditional variances of the EGARCH model, and the residuals are standardized to obtain new sequences. According to the model in (4), the new time series is analyzed by Gumbel, Clayton and Frank copulas to fit the tail risk-dependent structure and level of EPU for the eight B&R countries. The risk dependence coefficients are shown in Table 4 and the hierarchical structure is shown in Figure 2. From Table 4 and Figure 2, one can observe evidently that the risk dependence structure of EPU for the eight B&R countries is almost same, in which China and Singapore belong to the first tier, and up goes Korea, Russia, Pakistan, Croatia, Greece, and India. From this, one can conclude that China is in the core position in the eight B&R countries, and its EPU has close relations with other countries, and its fluctuation deeply influences the fluctuation of other countries' EPU.

Table 4 Risk dependence coefficients based on stratified Archimedean copula model

	θ_1	θ_2	θ_3	θ_4	θ_5	θ_6	θ_7	Log likelihood
Gumbel	2.23	2.01	1.96	1.75	1.63	1.12	1.08	1517.28
Clayton	1.72	1.64	1.52	1.46	1.33	1.19	1.06	1533.46
Frank	6.628	6.132	5.901	5.528	4.997	4.755	4.281	1547.09

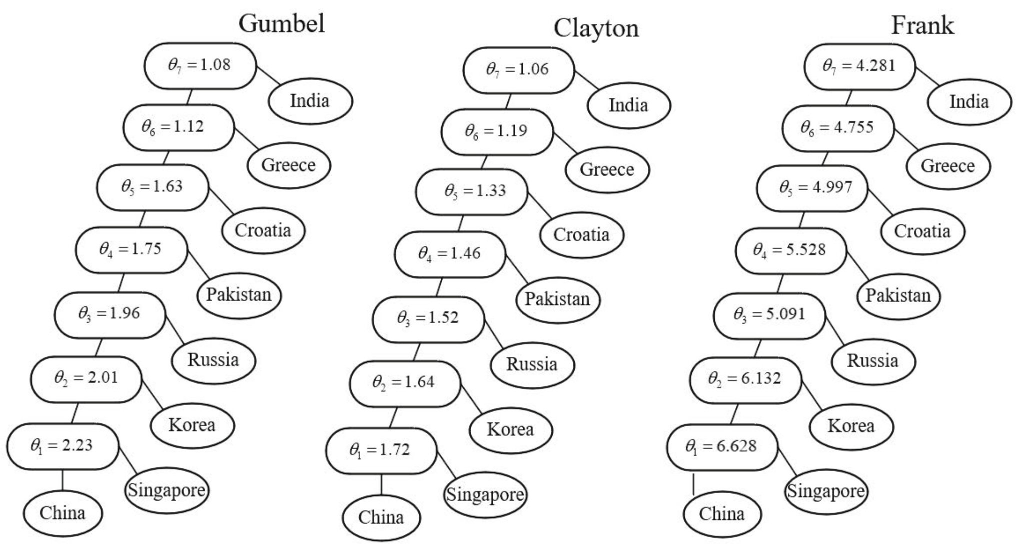


Figure 2 Risk dependent structure based on stratified Archimedean copula model for the eight B&R countries

4.3 Regional Spillovers Between Economic Development and EPU

4.3.1 EPU-Economic Development Connectedness

Next, we take a look at the spillover effects of EPU and economic growth in the eight B&R core countries and the four peripheral countries. First, we examine the spillover effects of the EPU and economic growth for the eight B&R countries. To this end, we analyze the correlation between EPU and economic growth and focus on the contribution of EPU to economic growth and the vise visa. The connectedness measures are presented in Table 5.

Table 5 Regional spillovers between EPU and economic development

Forecast horizon	$S = 4$ (one year)		$S = 8$ (two years)	
	EPU	GDPG	EPU	GDPG
EPU	8.92	13.64	10.11	21.07
GDPG	17.33	6.78	35.29	31.24

Note: Within-group connectedness indices are on the main diagonal, and the off-diagonal elements show the to/from contributions.

The estimation results in Table 5 show that, for forecast horizon of one year ($S = 4$), the internal spillover effect of EPU in the eight B&R countries reaches 8.92%, and the internal spillover effect of GDP is up to 6.78%, while the spillover effect of EPU on GDP achieves 17.33%, and the spillover effect of GDP on EPU arrives at 13.64%. For the variance decomposition with forecast horizon of two years ($S = 8$), the internal spillover effects of EPU and GDP of the eight B&R countries are 10.11% and 31.24%, respectively. The spillover effect of EPU on GDP is 35.29% and GDP on EPU extends to 21.07%. It can be concluded that, first of all, the internal spillover effects of EPU and GDP in the long run are significantly higher than those in the short run. The results show that the spillover effect of EPU on GDP increases from 17.33% to 35.29% from short run to long run, and the effects in the long run is almost double of the effect in the short run. Second, the spillover effect of EPU on GDP is significantly higher than that of GDP on EPU. This conclusion shows that as the spillover effect of EPU is significant, B&R countries should strengthen policy coordination to reduce the negative effects of uncertain shocks.

4.3.2 Core-Periphery Spillovers

Finally, we investigate the net effect of EPU and economic growth spillovers between the eight B&R countries and the four peripheral countries. The results are displayed in Table 6.

We still decompose the variance of GVAR model under forecast horizon of one year ($S = 4$) and two years ($S = 8$), and obtain the connectedness matrix within and among groups of B&R countries and the four peripheral countries. The estimation results in Table 6 show that, under forecast horizon of one year ($S = 4$), the EPU spillover effect of the eight B&R countries on the EPUs of the four peripheral countries reaches 38.82%, and the GDP spillover effect of the EPU of the eight B&R countries on the GDP of the four peripheral countries arrives at 26.55%. On the contrary, the EPU spillover effect of the four peripheral countries on the eight B&R countries achieves 29.07%, and the GDP spillover effect on the eight B&R countries extends to 25.34%. Under forecast horizon of two years ($S = 8$), the EPU spillover effect of the eight B&R countries on the four peripheral countries is higher than the estimated result for one year, reaching 41.62%. The GDP spillover effect of the EPU of the eight B&R countries on the four peripheral countries reaches 28.51. On the contrary, The EPU spillover effect of the four peripheral countries on the eight B&R countries is 30.07%, and the GDP spillover effect on the eight B&R countries is around 26.32%.

Table 6 Regional spillovers

Forecast horizon:	$S = 4$ (one year)			
	Core (EPU)	Core (GPDG)	Periphery (EPU)	Periphery (GDPG)
Core (EPU)	8.92	13.64	29.07	16.68
Core (GPDG)	17.33	6.78	25.34	39.88
Periphery (EPU)	38.82	17.22	20.72	24.62
Periphery (GDPG)	26.55	46.18	26.21	28.91
	$S = 8$ (two years)			
	Core (EPU)	Core (GPDG)	Periphery (EPU)	Periphery (GDPG)
Core (EPU)	10.11	21.07	30.07	21.34
Core (GPDG)	35.29	31.24	26.32	40.03
Periphery (EPU)	41.62	23.23	33.78	29.66
Periphery (GDPG)	28.51	48.11	36.11	29.95
	$S = 4$ (one year)			
	From others	To others	Net	
Core (EPU)	22.17	35.28	13.11	
Core (GPDG)	16.87	21.55	4.68	
Periphery (EPU)	22.11	19.12	−2.99	
Periphery (GDPG)	29.35	18.71	−10.64	
	$S = 8$ (two years)			
	From others	To others	Net	
Core (EPU)	28.38	35.29	6.91	
Core (GPDG)	20.07	27.88	7.81	
Periphery (EPU)	35.16	22.77	−12.39	
Periphery (GDPG)	28.23	21.71	−6.52	

We estimate the net spillover effect of EPU and GDP of the eight B&R countries and the four peripheral countries. The results show that under forecast horizon of one year ($S = 4$), the net spillover effect of EPU of the eight B&R countries is about 13.11%, and remains stable at 6.91% under forecast horizon of two years ($S = 8$). The net spillover effect of GDP of the eight B&R countries is up to 4.68%, and it is stable at 7.81% under forecast horizon of two years ($S = 8$). The net EPU spillover effect of the peripheral countries arrives at −2.99% under forecast horizon of one year ($S = 4$), and stabilized at −12.39% under forecast horizon of two years ($S = 8$). The net GDP spillover effect of the peripheral countries reaches −10.64% under forecast horizon of one year ($S = 4$), and stabilized at -6.52% under forecast horizon of two years ($S = 8$).

According to the estimation results in Table 6, it can be concluded that the spillover effects of EPU (GDP) of the eight B&R countries on EPU (GDP) of the four peripheral countries are greater than vise visa. The eight B&R countries are geographically close to the four peripheral countries and their bilateral trade is also close, so the spillover effects among them can not be ignored.

5 Conclusions

In this paper, we adopt copula techniques to analyze the correlation between the EPU of the eight B&R countries, and then use an MF-GVAR model to investigate the spillover effects between the EPUs of the eight B&R countries and four Periphery countries. The results in this paper show that the EPU correlation among the eight B&R countries is strong, and the EPU spillover effect of the eight B&R countries to the four peripheral countries is also significant. With the construction of the BRI, more countries have joined this cooperation platform, so that the spillover effects should be stronger. Countries should keep moderate and neutral expectations when formulating and implementing economic policies in the future all over the world.

References

[1] Aoyama R, One Belt, One Road: China's new global strategy, *Journal of Contemporary East Asia Studies*, 2016, **5**(2): 3–22.

[2] Huang Y P, Understanding China's Belt & Road initiative: Motivation, framework and assessment, *China Economic Review*, 2016, **40**(1): 314–321.

[3] Zhai F, China's belt and road initiative: A preliminary quantitative assessment, *Journal of Asian Economics*, 2018, **55**(1): 84–92.

[4] Du J L and Zhang Y F, Does One Belt One Road initiative promote Chinese overseas direct investment, *China Economic Review*, 2018, **47**(1): 189–205.

[5] Ullah S, Wang Z, Stokes P, et al., Risk perceptions and risk management approaches of Chinese overseas investors: An empirical investigation, *Research in International Business and Finance*, 2019, **47**(1): 470–486.

[6] Liu H Y, Islam M A, Khan M A, et al., Does financial deepening attract foreign direct investment? Fresh evidence from panel threshold analysis, *Research in International Business and Finance*, 2020, **53**: 101198.

[7] Bloom N, The impact of uncertainty shocks, *Econometrica*, 2009, **77**(3): 623–685.

[8] Caggiano G, Castelnuovo E, and Groshenny N, Uncertainty shocks and unemployment dynamics in US recessions, *Journal of Monetary Economics*, 2014, **67**(1): 78–92.

[9] Jurado K, Ludvigson S C, and Ng S, Measuring uncertainty, *American Economic Review*, 2015, **105**(3): 1177–1216.

[10] Gentzkow M and Shapiro J M, What drives media slant? Evidence from US daily newspapers, *Econometrica*, 2010, **78**(1): 35–71.

[11] Hoberg G and Phillips G, Product market synergies and competition in mergers and acquisitions: A text-based analysis, *Review of Financial Studies*, 2010, **23**(10): 3773–3811.

[12] Alexopoulos M and Cohen J, The power of print: Uncertainty shocks, markets, and the economy, *International Review of Economics & Finance*, 2015, **40**(1): 8–28.

[13] Baker S R, Bloom N, and Davis S J, Measuring economic policy uncertainty, *Quarterly Journal of Economics*, 2016, **131**(4): 1593–1636.

[14] Diebold F X and Yílmaz K, Better to give than to receive: Predictive directional measurement of volatility spillovers (with discussion), *International Journal of Forecasting*, 2012, **28**(1): 57–66.

[15] Cipollini A and Mikaliunaite I, Macro-uncertainty and financial stress spillovers in the Eurozone, *Economic Modeling*, 2020, **89**(1): 546–558.

[16] Greenwood-Nimmo M, Nguyen V H, and Shin Y, Measuring the connectedness of the global economy, *International Journal of Forecasting*, 2021, **37**(2): 899–919.

[17] Gao B, Li J J, Shi B Y, et al., Internal conflict and Bank liquidity creation: Evidence from the belt and Road initiative, *Research in International Business and Finance*, 2020, **53**: 101–227.

[18] Lemieux J and Peterson R A, Purchase deadline as a moderator of the effects of price uncertainty on search duration, *Journal of Economic Psychology*, 2011, **32**(1): 33–44.

[19] Jones P M and Olson E, The time-varying correlation between uncertainty, output, and inflation: Evidence from a DCC-GARCH model, *Economics Letters*, 2013, **118**(1): 33–37.

[20] Wang Y Z, Chen C R, and Huang Y S, Economic policy uncertainty and corporate investment: Evidence from China, *Pacific-Basin Finance Journal*, 2014, **26**(1): 227–243.

[21] Zhang G L, Han J L, Pan Z Y, et al., Economic policy uncertainty and capital structure choice: Evidence from China, *Economic Systems*, 2015, **39**(3): 439–457.

[22] Wang Y D, Zhang B, Diao X D, et al., Commodity price changes and the predictability of economic policy uncertainty, *Economics Letters*, 2015, **127**(1): 39–42.

[23] Li X M, Zhang B, and Gao R Z, Economic policy uncertainty shocks and stock–bond correlations: Evidence from the US market, *Economics Letters*, 2015, **132**(1): 91–96.

[24] Liu L and Zhang T, Economic policy uncertainty and stock market volatility, *Finance Research Letters*, 2015, **15**(1): 99–105.

[25] Scheffel E M, Accounting for the political uncertainty factor, *Journal of Applied Econometrics*, 2016, **31**(6): 1048–1064.

[26] Aastveit K, Natvik G J J, and Sola S, Economic uncertainty and the effectiveness of monetary policy, *Journal of International Money and Finance*, 2017, **76**(1): 50–67.

[27] Li X M and Peng L, US economic policy uncertainty and co-movements between Chinese and US stock markets, *Economic Modelling*, 2017, **61**(1): 27–39.

[28] Phan D H B, Sharma S S, and Tran V T, Can economic policy uncertainty predict stock returns? Global evidence, *Journal of International Financial Markets, Institutions and Money*, 2018, **55**(1): 134–150.

[29] Chiang T C, Economic policy uncertainty, risk and stock returns: Evidence from G7 stock markets, *Finance Research Letters*, 2019, **29**: 41–49.

[30] Balcilar M, Gupta R, Kim W J, et al., The role of economic policy uncertainties in predicting stock returns and their volatility for Hong Kong, Malaysia and South Korea, *International Review of Economics & Finance*, 2019, **59**(1): 150–163.

[31] Tiwari A K, Jana R K, and Roubaud D, The policy uncertainty and market volatility puzzle: Evidence from wavelet analysis, *Finance Research Letters*, 2019, **31**(1): 278–284.

[32] Chen X Y and Chiang T C, Empirical investigation of changes in policy uncertainty on stock returns — Evidence from China's market, *Research in International Business and Finance*, 2020, **53**: 101183.

[33] Li Z H and Zhong J H, Impact of economic policy uncertainty shocks on China's financial conditions, *Finance Research Letters*, 2020, **35**: 101303.

[34] Sklar A, Fonctions de repartition à n dimensions et leures marges, *Publications de L'Institut de Statistique de L'Université de Paris*, 1959, **8**(1): 229–231.

[35] Cherubini U, Luciano E, and Vechiato W, *Copula Methods in Finance*, John Wiley & Sons, New York, 2004.

[36] Cai Z W and Wang X, Selection of mixed copula model via penalized likelihood, *Journal of the American Statistical Association*, 2014, **109**(506): 788–801.

[37] Patton A J, Modeling asymmetric exchange rate dependence, *International Economic Review*, 2006, **47**(2): 527–556

[38] Yang B D, Cai Z W, Hafner C M, et al., Time-varying mixture copula models with copula selection, *Statistica Sinica*, 2022, **32**(4): 1049–1077.

[39] Liu G N, Long W, Yang B D, et al., Semiparametric estimation and model selection for conditional mixture copula models, *Scandinavia Journal of Statistics*, 2022, **49**(1): 287–330.

[40] Pesaran H, Schuermann T, and Weiner S M, Modeling regional interdependencies using A global error-correcting macroeconometric model, *Journal of Business and Economic Statistics*, 2004, **22**(2): 129–162.