Dynamic connectedness between stock markets in the presence of COVID-19 pandemic: Does economic policy uncertainty matter?

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Abstract

In this paper, we investigate the dynamic connectedness between the stock indices in the eight most endemic countries by the COVID-19 (China, Italy, France, Germany, Spain, Russia, U.S., and the U.K) as well as the effect of the economic policy uncertainty (EPU) by implementing the TVP-VAR model for daily data over the period spanning from 01/01/2015 to 05/18/2020. Results show that stock markets are highly connected during the entire period, while the dynamic spillovers reached unprecedented heights during the COVID-19 pandemic in the first quarter of the year 2020. Moreover, we find that the European stock markets transmit more spillovers to all other stock markets more than they receive (except for Italy), mainly during the outbreak of the COVID-19 pandemic. Also, findings show that the sign of the effect of the EPU on the net connectedness changes during the onset of the pandemic, showing that information spillovers from a given market may be seen as good or bad news for other markets, given the economic situation prevailing. From the results of this study, important implications can be provided for individual investors, portfolio managers, policymakers, investment banks, and central banks.

Keywords: Stock markets; Dynamic connectedness; COVID-19 pandemic; Economic Policy Uncertainty; TVP-VAR model.

JEL codes:

1. Introduction

Analyzing connectedness between financial markets is a heated discussion among academics, policymakers, and investors. Recently, such an analysis was reinforced by the development of mathematical and econometrical tools and became more crucial by providing a comprehensive picture in market risk and credit risk as well as the macroeconomic and system risk evaluation (Gong et al., 2019). Furthermore, the connectedness analysis between stock markets is also essential for investors to make suitable decisions and to assess the diversification opportunities in international portfolios. However, the degree of spillover effects among international stock markets is subject to several factors that can influence its dynamics and even change its direction.

In this context, the economic policy uncertainty (EPU) is the most important measure of uncertainty that can be an influential factor affecting the stock market linkages. Also, several studies investigating the relationship between financial markets, report that the degree of connectedness between these markets is subject to financial stress and crisis periods (Jondeau and Rockinger, 2006; Mokni and Mansouri, 2017). Therefore, crises play a crucial role in influencing the connectedness between international stock markets.

During the last few months, the world has suffered a severe crisis due to the so-called “Coronavirus” (COVID-19). This rapidly expanding pandemic has enormous negative impacts on financial markets all over the world. It has created an unprecedented level of risk, causing investors to suffer significant losses in a very short period (Zhang et al., 2020). In fact, this crisis results in a depreciation of the stock indices, especially in the most infected countries. Moreover, the degree of uncertainty increased remarkably, especially after the official declaration of the World Health Organization (WHO) on 11 March 2020 that the Coronavirus outbreak becomes a global pandemic.

At this point, given that the stock markets in all the world are linked directly or undirectedly to the economic systems and the strong financial integration, they will suffer enormous losses due to precautionary measures proceed by the majority of countries in the world. Therefore, the implication of this outbreak on the stock markets, let asking serious questions about its dynamics and the connectedness between them.

Azimli (2020) reports that COVID-19 pandemic can impact the stock market through two channels. First, the high uncertain economic policy, given spreading patterns and the unknown future situation of the COVID-19, the cash flows are very lowly expected, leading to the stock market depreciation. Second, the disfunction of the industrial, tourism, aviation sectors, among others, can affect the stock index directly by the depreciation of the related stocks. Therefore, this degradation could negatively impact some macroeconomics, such as investment and consumption patterns (Azimli, 2020).

Other than crisis and stress conditions, it is documented in the literature that the economic policy uncertainty, measured by Baker et al. (2016), can influence the stock markets returns (Antonakakis et al. 2013; Arouri et al. 2016; Christou et al. .2017; Guo et al. 2018; Hu et al. 2018; Phan et al. 2018; Xiong et al. 2018; Wang et al., 2020; He et al., 2020) and volatility (Yu et al. 2018; Yu and Song 2018; Mei et al. 2018; Balcilar et al. 2019). In this context, a recent strand of literature interests to the effect of EPU on the relationship between financial assets including these between stock markets (Li and Peng, 2017), bonds and stocks (Fang et al., 2017; Li et al., 2015), commodity and stock markets (Fang et al., 2018; Badshah et al., 2019), and Bitcoin and conventional assets (Matkovskyy et al., 2020). Almost all these studies report the evidence of a negative impact of EPU on the co-movements between these variables and highlight, in some cases, a significant portfolio implication of EPU (Badshah et al., 2019).

In this study, we investigate the dynamic connectedness between the stock indices in the most pandemic countries by the coronavirus and examine the effect of EPU on this connectedness before and during the COVID-19 pandemic crisis. The dynamic connectedness is measured following the approach of Antonakakis and Gabauer (2017), which combines the time-varying VAR model with the popular model of Diebold and Yelmaz (2014). We choose the TVP-VAR approach to overcome the burden of the often arbitrarily chosen rolling-window-size which could lead to very erratic or flattened parameters as well as a loss of valuable observations (Antonakakis and Gabauer, 2017; Antonakakis et al., 2018; Gabauer and Gupta, 2018; Korobilis and Yilmaz, 2018).

This study contributes to the existing literature in three ways. First, it fills the gap in the literature by investigating the dynamic connectedness between a large number of international stock markets in most affected countries by COVID-19. Second, we use a sophisticated framework such as the time-varying parameter vector autoregressive (TVP-VAR) methodology of Antonakakis and Gabauer (2017) to investigate the connectedness between stock indices. This methodology improves the one provided by Diebold and Yılmaz (2012, 2014) because it allows for a measure of connectedness that adjusts immediately to events. Finally, a further study dealing with the effect of EPU on the dynamic connectedness is also provided to control for a possible change in this effect during this COVID-19 period compared to the pre-outbreak period.

The remainder of this paper is organized as follows. The second section is reserved to the literature review. The third section presents the data and the employed methodology. Section 4 provides the results and discussion. Finally, section 5 concludes the paper.

2. Literature review

During the last two decades, financial crises were behind renewing interest in examining connectedness, contagion, and the correlation between stock markets using different econometric techniques. Overall, financial crises increased market connectedness among stock markets. For example, Madaleno and Pinho (2012) explored stock market contagion using a continuous-time wavelet method (Coherence Morlet Wavelet) considering financial crisis episodes. They showed a significant time evolution, especially due to the financial crisis that occurred at different periods. Kim et al. (2015) used multivariate GARCH models to investigate the impact of the U.S. financial crisis on spillover effects between five emerging Asian countries and the U.S. stock markets. They showed clear evidence of financial contagion around the collapse of Lehman Brothers in September 2008. Li and Giles (2015) investigated both shock and volatility spillovers in the long-run and the short-run periods among the U.S. and Japan and six emerging stock markets (China, India, Indonesia, Malaysia, the Philippines, and Thailand) using the asymmetric BEEK-MGARCH model. They report the intensification of the integration between developed and emerging stock markets during financial crises.

Also, Morana and Beltratti (2008) investigated co-movements in four international stock markets (U.S., UK, Germany, and Japan) over the period 1973 to 2004. They show that the integration of the different stock markets under investigation induces to rising co-movements in prices, returns, correlation, and volatility. Menezes and Dionísio (2011) used a VECM model under structural breaks to investigate the long-run co-movements and globalization in G7 stock markets. They showed a significant long-run causal relationship across the process of G7 markets integration and driven in general by the U.S. stock market. Tsai (2014) investigated the spillover effect in the main five stock markets (U.S., UK, Germany, Japan, and France). He reported a net spillover effect in the U.S. stock market during the subprime mortgage crisis and Lehman Brothers bankruptcy from 2007 to 2008. Also, he showed that the fear index is a principal reason behind the increased correlation between markets. Using the DCC-GARCH methodology, Ahmad et al. (2014) investigated the contagion effects of U.S. and GIPSI stock markets on seven Eurozone and six non-Eurozone stock markets. They reported that Italy, Ireland, Portugal, and Spain are most contagious for Eurozone and non-Eurozone markets during the Eurozone crisis period among the GIPSI stock markets. However, France, Belgium, Austria, and Germany are strongly affected by the financial contagion shocks in the Eurozone. Výrost et al. (2015) used Granger causality networks to investigate the network between 20 developed stock markets. They found the existence of preferential attachment between stock markets and the degree of connectedness affect positively on the presence of spillover effects. Maghyereh et al. (2015) applied the methodology of Diebold and Yilmaz (2012) to investigate equity returns and volatility co-movement between a group of MENA and the U.S. stock markets before and after the global financial crisis. They reported that the relationship with the U.S. stock market is very weak in the period of pre-crisis and bound to a high level after the global financial crisis. Barunik et al. (2016) extended the methodology of Diebold and Yilmaz (2012) by allowing for negative and positive changes to quantify asymmetries in volatility spillovers. Their study reported that the connectedness across the U.S. stock intra – market rise greatly during the financial crisis.

More recently, Wang et al. (2017) examined contagion from the U.S. to the BRIC and the G7 (except for Japan) during the global financial crisis using multiscale correlation. They reported that the contagion of the stock markets during the global financial crisis is dependent on both the recipient country and the time scale. Jiang et al. (2017) applied the VAR model and Granger causality tests to explore the impact of the recent financial crisis on six major stock markets (US, Britain, Germany, Japan, China, and Hong Kong). Results show that the financial crisis has boosted the interdependence correlation of global stock markets. Mokni and Mansouri (2017) examined the relationship between major international stock markets using a long memory GARCH-copula model approach. They reported that the dependence structure rises during the European debt and global financial crises. Manopimoke et al. (2018) investigated the dynamic connectedness between Asian emerging markets and other international markets using a generalized Vector Autoregressive (VAR) model. They concluded that international stock markets are integrated, with a rising trend since the Asian financial crisis and a more important trend of increasing during the global financial crisis. Mensi et al. (2018) applied the methodology of Diebold and Yilmaz (2012, 2014) by implementing static and rolling-window methods to examine the connectedness between regional, global, and GIPSI stock markets. They reported that the financial contagion effect increases upwards during the crisis. Zhou et al. (2018) applied a CEEMDAN wavelet model to examine the contagion effect among stock markets (Asia, Europe, and America). They reported that shocks could be transmitted between different stock markets when irregular events and extreme events cause it. Gong et al. (2019) applied the transfer entropy method to investigate the network connectedness of global stock markets, suggesting that the total network connectedness rises during the crisis. Kanga et al. (2019) used a dynamic equicorrelation (DECO) model, and the spillover index of Diebold and Yilmaz (2012) investigated the dynamic spillover effects between ASEAN and world stock markets. They report directional spillovers for each one of the markets and the increase of return and volatility spillovers during financial crises. Su (2020) examined the volatility spillover behaviors in G7 stock markets using a spectral representation of variance decompositions to distinguish between short, medium, and long-term volatility spillovers components. He reports the crisis sensitive of the volatility spillovers across G7 stock markets.

Fig.1: daily spot prices of stock markets considered for the period running from 01/01/2015 to 05/18/2020. The shaded area indicates the period of the COVID-19 pandemic.

From its appearance, the novel coronavirus (COVID-19) effects are frequently assimilated to the Global Financial Crisis of 2008. In recent studies, the effects of COVID-19 pandemic on stock markets are exanimated using different approaches. For example, Salisu and Vo (2020) investigate the relevance of health-news obtained through Google searches in the predictability of stock returns using data for top-20 affected countries and most deaths reporting countries. They report that embodying health-related information in the valuation of stocks improves forecast accuracy. Also, the forecast performance is improved by adjusting for macroeconomic factors and accounting for the "asymmetry" effect of good and bad health news. Al-Awadhi et al. (2020) examine the effect of the COVID-19 contagious infectious disease on the Chinese stock market by applying panel testing while controlling for firm-specific characteristics. They found significant negative effects on stock returns caused by COVID-19 across all companies.

Sharif et al. (2020) used the wavelet-based Granger causality and the coherence wavelet tests to investigate the time-frequency relationship between oil price, COVID-19 outbreak, economic uncertainty, geopolitical risk, and U.S. stock market. They showed that the effect of the COVID-19 on the geopolitical risk substantially higher than on the U.S. economic uncertainty. Using the DCC-GARCH methodology, Corbet et al. (2020a) examined the effects of the term “corona” on the behavior of stocks during the COVID-19 pandemics. They show a negative effect of the companies with related names to the coronavirus pandemic.

Azimli (2020) investigated the effect of the COVID-19 pandemic on the degree and structure of risk-return dependence in the U.S. using quantile regression. He reported the increase of dependence among returns and market portfolio in the higher quantiles. Corbet et al. (2020b) investigated the contagion between Chinese stock markets during the COVID-19 pandemic. The results display that COVID-19 has a significant strong positive impact on the volatility of the Shanghai and Shenzhen Stock Exchanges. Also, they report a strong positive correlation between WTI and Chinese stock markets.

3. Data and econometric framework

3.1. Data

The abnormal situation developed by COVID-19 offers us an opportunity to assess the pandemic's impact on the stock markets of the most affected nations due to this unforeseen and feared disease. In this paper, we investigate the impact of the COVID-19 pandemic in the connectedness between the major affected nation's stock markets as measured by their leading stock indices. We use data of daily stock indices’ closing prices in China, France, Germany, Italy, Russia, Spain, the UK, and the US. over the period spanning from 01/01/2015 to 05/18/2020 including the period of COVID-19 pandemic, covering the part related to the year 2020.

Fig.1 depicts the daily spot prices of the stock market's indices of the considered countries in this study. As we can see, all the considered stock market indices exhibit a sudden and abnormal decline within the onset of the COVID-19 pandemic. Regarding China's stock market, we can see from the patterns that prices register a weak decline from a 3000 point to around 2500 points. While the European stock markets, as well as the American and the British stock markets, are the most affected by the recent spread of the new infectious shock and register an unprecedented shut down of their indices spot prices. For Italy, just before the pandemic outbreak, the index daily spot prices are situated at over 27000 points and fall to under 17000 points with the onset of a pandemic. For the USA, the index daily spot prices reach a pic of more than 3300 points before the COVID-19 pandemic outbreak and fall under 2300 points with the announcement of the new pandemic. These results highlight the fast responses of the stock markets worldwide to bad news related to the outbreak of the COVID-19 pandemic, which increases risk and uncertainty around the world and affects the investor's sentiments and decisions, which in turn affect stock markets prices.

Table 1: Descriptive statistics and preliminary tests on the data

	China	France	Germany	Italy	Russia	Spain	UK	U.S.
Mean	0.002	0.034	0.029	0.03	0.032	0.000	0.010	0.035
Variance	2.193	1.546	1.649	2.082	3.398	1.739	1.129	1.375
Skewness	-1.139***	-1.344***	-0.871***	-2.126***	-0.849***	-2.202***	-0.988***	-1.087***
Kurtosis	7.036***	15.402***	14.281***	26.074***	8.802***	25.231***	17.225***	24.133***
JB p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ERS	-11.138***	-5.272***	-10.716***	-8.481***	-2.908***	-3.252***	-3.708***	-3.031***
Q(20)	22.303***	16.165*	14.064	27.328***	13.041	21.215***	26.420***	116.391***
Q2(20)	101.408***	20.766**	98.182***	1.716	188.782***	6.79	70.659***	301.223***
LM(20)	119.824***	193.533***	236.167***	39.210***	208.550***	89.173***	237.360***	480.568***
Correlation matrix								
CHINA	1							
FRANCE	0.219	1						
GERMANY	0.207	0.942	1					
ITALY	0.15	0.866	0.845	1				
RUSSIA	0.183	0.552	0.515	0.493	1			
SPAIN	0.179	0.889	0.851	0.888	0.521	1		
UK	0.223	0.866	0.829	0.753	0.583	0.784	1	
US	0.179	0.605	0.583	0.551	0.384	0.581	0.601	1

Notes: This table reports the descriptive statistics of the considered stock market returns. J.B. is the Jarque-Bera normality test statistics. ERP is the Elliot-Rothenberg- Stock unit root tests. Q(10) and Q2(10) are the Ljung-Box tests for 20th order serial correlations for returns and squared returns, respectively. L.M. (20) is the L.M. heteroscedasticity test at order 20. (***), (**), and (*) indicate the statistical significance, respectively, at the 1%, 5%, and 10% levels.

Table 1 reports descriptive statistics on the log-returns of the stock index for the countries selected in this study. We remark that China, Spain, and the U.K. present the lowest index prices average, while the USA, France, Russia, and Italy exhibit the highest average returns, and the three countries exhibit close mean returns around 0.03. Also, Russia has the riskiest stock market as measured by the variance, followed by China and Italy. Whereas, the British stock market presents the lowest risk average, followed by the stock markets of the USA and France. All the series considered are skewed to the left, as indicated by the significant negative values of the skewness. They are characterized by excess kurtosis, suggesting a leptokurtic distribution with fat tails, and the null hypothesis of normality is rejected for all series at the 1% level, as indicated by the Jarque-Bera test.

To test for the existence of unit root in the return's series, we conduct the Elliot-Rothenberg-Stock (ERS) tests. Results presented in table 1 show that all series are integrated of order zero. Moreover, the results suggest that all series are autocorrelated (except Spain and Italy) and exhibit ARCH errors, which support choosing the TVP-VAR model with time-varying covariances. Regarding the correlation matrix, we can see that all selected stock markets are correlated during the sample period. The Chinese stock market exhibit the lowest correlation with all other stock markets, while all other stock markets are highly correlated with a range between 0.5 and 0.95.

3.2. Methodology

3.2.1. TVP-VAR-based dynamic connectedness approach

To explore the time-varying connectedness between international stock markets during a period, including the COVID-19 pandemic, we follow the methodology of Antonakakis and Gabauer (2017) and Antonakakis, et al. (2019). This methodology employs the TVP-VAR methodology of Koop and Korobilis (2014), which combined with the connectedness approach of Diebold and Yılmaz (2014)[2].

Let Y_t be a $(N \times 1)$ vector of N stock market returns. The TVP-VAR model can be represented by the following set of equations:

$$Y_t = \Phi_t Y_{t-1} + u_t; \quad u_t \backslash \Omega_{t-1} \backsim N(0, S_t) \tag{1}$$

[2] This methodology is employed in our study to overcome some limitations with the rolling-window procedure related to the window size choice, leading to erratic or flattened parameters, and loss of valuable observations Antonakakis & Gabauer, 2017; Antonakakis et al., 2018; Antonakakis et al., 2019; Gabauer and Gupta, 2018; Korobilis and Yilmaz, 2018).

$$\Phi_t = \Phi_{t-1} + v_t; \;\; v_t \backslash \Omega_{t-1} \backsim N(0, R_t) \tag{2}$$

where Ω_{t-1} denotes the set of information available at $t-1$. Y_{t-1} is a lagged vector of the dependent variables. Φ_t is an $(N \times Np)$ matrix of coefficients, which is supposed to be time-varying. u_t and v_t are two $(N \times 1)$ vectors of the error terms. S_t and R_t are $(Np \times Np)$ matrices that denote the time-varying variance-covariance matrices of the error terms u_t and v_t, respectively.

After estimating the time-varying parameters and variances using the TVP-VAR, this model can estimate the generalized connectedness procedure of Diebold and Yılmaz (2014) based on the generalized impulse response functions (GIRF) and the generalized forecast error variance decompositions (GFEVD) after transforming the VAR to its vector moving average (VMA) (Koop et al., 1996; Pesaran and Shin, 1998) of Eq. (2) as follows:

$$Y_t = \Phi_t Y_{t-1} + u_t = A_t u_t \tag{3}$$

where $A_t = (A_{1,t} \quad A_{2,t}, \quad \dots \quad A_{p,t})'$ is an $(N \times N)$ matrix of parameters verifying $A_{i,t} = \sum_{k=1}^{p} \Phi_{1,t} A_{i-k,t} \;\; if \; i \neq 0$, and I_N otherwise. Therefore, the generalized impulse response functions (GIRF) can define the responses of all variables following a shock in variable *i*.

Antonakakis and Gabauer (2017) compute the differences between a J-step-ahead forecast once variable *i* is not shocked. Formally, let J be the forecast horizon and $\delta_{j,t}$ be the selection vector equal to 1 on the j^{th} position, and 0 otherwise, the GIRF, denoted by $\Psi^{g}_{j,t}(J)$, can be calculated by:

$$GIRF(J, \delta_{j,t}, \Omega_{t-1}) = E(Y_{t+J} \backslash u_{j,t} = \delta_{j,t}, \Omega_{t-1}) - E(Y_{t+J} \backslash \Omega_{t-1}) \tag{4}$$

$$\Psi^{g}_{j,t}(J) = S_{jj,t}^{-\frac{1}{2}} \;\; A_{J,t}\, S_t u_{j,t} \tag{5}$$

Also, the GFEVD for the horizon J, denoted by $\Pi^{g}_{j,t}(J)$, can be calculated by:

$$\Pi^{g}_{j,t}(J) = \frac{\sum_{t=1}^{J-1} \Psi^{2,g}_{ij,t}}{\sum_{j=1}^{N} \sum_{t=1}^{J-1} \Psi^{2,g}_{ij,t}} \tag{6}$$

$\Pi^{g}_{j,t}(J)$ can be interpreted as the variance share one variable has on others[3]. The GFEVD verifies $\sum_{j=1}^{N} \Pi^{N}_{j,t}(J) = 1$ and $\sum_{i,j=1}^{N} \Pi^{N}_{j,t}(J) = N$.

Using the GFEVD, we can construct different connectedness indices. The first index is related to the *total connectedness,* which shows how a shock in one variable spills over to other variables and defined by:

$$H^{g}_{t}(J) = \frac{\sum_{i,j=1,i\neq j}^{N} \Pi^{g}_{ij,t}(J)}{N} \times 100 \tag{7}$$

Second, we calculate the directional connectedness variable i receives from variables j, called *total directional connectedness from others*, is defined as:

$$H^{g}_{i\leftarrow j,t}(J) = \frac{\sum_{i,j=1,i\neq j}^{N} \Pi^{g}_{ij,t}(J)}{\sum_{j=1}^{N} \Pi^{N}_{ij,t}(J)} \times 100 \tag{8}$$

Similarly, we compute the directional connectedness variable i transmits its shock to all other variables j, called *total directional connectedness to others*, defined by:

$$H^{g}_{i\rightarrow j,t}(J) = \frac{\sum_{i,j=1,i\neq j}^{N} \Pi^{g}_{ji,t}(J)}{\sum_{j=1}^{N} \Pi^{N}_{ji,t}(J)} \times 100 \tag{9}$$

Finally, we define the so-called *net total directional connectedness* as the difference between the two later indices:

$$H^{g}_{i,t}(J) = H^{g}_{i\rightarrow j,t}(J) - H^{g}_{i\leftarrow j,t}(J) \tag{10}$$

This index examines the '' power" of variable i, or its influence on the whole variables' network. If $H^{g}_{i,t}(J) > 0$, the variable i influences the network more than being influenced by that. If $H^{g}_{i,t}(J) < 0$, it means that variable i is driven by the network.

3.2.3. EPU and dynamic connectedness between stock markets

[3] These variance shares are normalized in the sense that each row sums up to 1. This means that all variables together explain 100% of *variable* i *'s* forecast error variance (Antonakakis and Gabauer, 2017).

Several recent studies argue that the relationship between financial markets, especially stock markets, is affected by economic policy uncertainty (Li et al., 2015; Li and Peng, 2017; Fang et al., 2017; Fang et al., 2017; Badshah et al., 2019; Fang et al., 2019; Matkovskyy et al., 2020). Almost all of these studies argue that EPU negatively impacts the correlations between these variables. Therefore, one can argue that economic policy uncertainty is a potential factor that drives the connectedness between the stock returns.

After computing the different time-varying spillover indices based on the TVP-VAR model, we can examine whether the economic policy uncertainty (EPU) drives this connectedness between stock market returns. To this end, we estimate the following equation:

$$H_t = \theta_0 + \theta_1 EPU_t + \varepsilon_t \tag{11}$$

where H_t represents the total and net connectedness measures, as reported in Eqs. (7) and (10) between stock market returns. EPU_t refers to changes in the U.S. economic policy uncertainty index developed by Baker et al. (2016).

4. Results and discussions

4.1. Dynamic spillover results

Table 2 summarizes the estimation results of the average dynamic connectedness measures for each stock market considered, issued from the TVP-VAR model. We observe that own-country stock market spillovers explain the highest share of forecast error variance, as the diagonal elements receive higher values compared to the off-diagonal elements. Also, the total connectedness index (TCI) measures the average influence all variables have on one variable's forecast error variance throughout time. The TCI in all markets is 65.43%. This result indicates that international stock markets are not independent of each other; the average influence of a stock market is approximately 66%. This large value shows that the transmission of international stock market spillovers is an important source of domestic stock market fluctuations. Moreover, results show that France contributes to the forecast error variance of all other markets considered by transmitting the highest index of 97.48%, followed by Germany 88.83%, Spain 84.55%, and Italy 82%. Further, these countries receive the highest spillovers from others, France 77.9%, Germany 76.63%, and Spain and Italy around 75%. However, the contributions of

China, Russia, the US, and the UK to others are the lowest with 8.83%, 29.89%, 53.83%, and 77.32, respectively. Besides, we notice that China, Russia, and the US receive more spillovers than they transmit with 30.7%, 51.4%, and 61.76%, respectively. The bottom line in table 2 shows the total net spillovers for each country, and the results show that China, Russia, and the US are net receivers of spillover from all others. In contrast, all other considered countries are net transmitters for all others.

Table 2: Dynamic connectedness measures between stock returns

	China	France	Germany	Italy	Russia	Spain	UK	US	From
CHINA	69.304	4.609	4.442	3.614	2.936	4.179	4.797	6.118	30.696
FRANCE	1.106	22.099	18.598	15.393	4.371	15.944	14.243	8.247	77.901
GERMANY	1.101	19.693	23.364	15.263	3.749	15.359	13.306	8.165	76.636
ITALY	0.858	17.194	16.099	24.878	3.976	18.076	11.794	7.124	75.122
RUSSIA	1.982	9.146	7.421	7.449	48.6	7.613	10.332	7.457	51.4
SPAIN	0.932	17.463	15.878	17.761	4.061	24.426	11.999	7.48	75.574
UK	1.344	16.886	14.854	12.518	5.752	13.083	26.322	9.242	73.678
US	1.512	12.432	11.543	10.064	5.046	10.305	10.858	38.24	61.76
Contribution to others	8.835	97.423	88.835	82.063	29.892	84.559	77.327	53.833	522.767
Contribution including own	78.14	119.522	112.199	106.941	78.491	108.985	103.649	92.074	TCI
Net spillovers	-21.86	19.522	12.199	6.941	-21.50	8.985	3.649	-7.926	65.346

Note: This table reports the variance decompositions for the estimated TVP-VAR model addressing different stock market returns. Variance decompositions are based on 10-step-ahead forecasts and a TVP-VAR lag length of order 1.

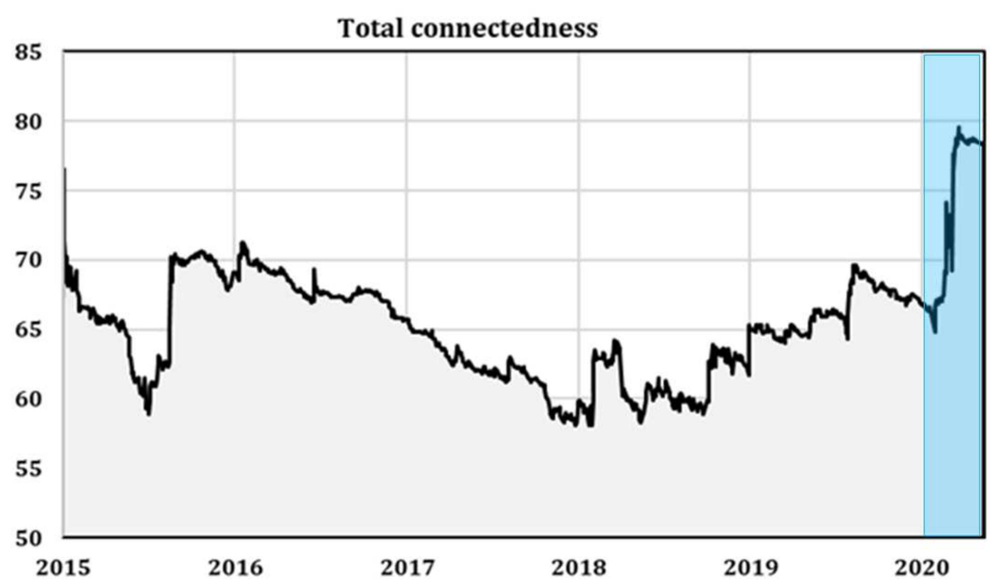

Fig. 2: Total connectedness measure (the shaded blue area indicates the period of the COVID-19 pandemic)

In order to see if the average of connectedness between stock markets varies through time and how it is affected by the new Pandemic Covid-19, we proceed to the estimation of the different time-varying connectedness measures. Fig.2 presents the results for the dynamic total connectedness index (TCI). We observe large variations on the total connectedness index during the full sample period. Moreover, the total connectedness index is relatively high during the entire period. It exceeds the level of 60% in mid-2015, and in the first quarter of the year 2018, the TCI reached its lowest level with approximately 57% and 55%, respectively. However, the dynamic spillovers reached unprecedented heights during the COVID-19 pandemic outbreak in the first quarter of the year 2020 with a level close to 80%. This result is not surprising in the sense that it's well known that stock markets are interlinked and interdependent (Morales and Andreosso, 2012) and that crisis periods increase the global stock market's interdependence. This result may be explained by the fact that the outbreak of the coronavirus pandemic and its fast-spreading around the world may bring down economic trends and induces negative changes in investor's sentiments that strongly affect their investment decisions and, consequently, stock market prices. Such external and unexpected shock worldwide turns investors more pessimistic about future returns and therefore tends to take fewer risks. According to Bai (2014), Baker et al. (2012), investors may feel pessimistic about investment prospects in a given market, selling off that market's stocks under an infectious disease outbreak.

This dynamic provides evidence that static TCI may mask specific periods (e.g., financial and economic events) that are likely to impact, differently, its interconnectedness. Therefore, it's crucial to consider the time-varying behavior of connectedness measures when analyzing the transmission of spillovers mechanism between stock markets to better understand the details of these spillovers, especially during critical periods.

In this line, we analyzed the total directional dynamic spillovers for each country and from all stock markets in each country, as reported in Fig .3 and Fig.4, respectively. According to these two figures, the total dynamic spillovers from/to each series range are bidirectional and range between 0.2% and 13%. Fig.3 depicts the amounts of spillovers received by each country from all other countries. We observe that China, Russia, the UK, and the US. show significant time-varying transmission patterns. For China and Russia, we see that the transmission of spillovers to stock markets of these countries, from all others, increased significantly during the first quarter of the year 2020 which coincide with the outbreak of the COVID-19 pandemic reaching a peak of 3.2% and 8% in China and Russia, respectively. For the UK and the US, a weak dynamic transmission pattern compared to China and Russia was observed. In fact, for these two countries, we register high spillovers level that ranges between 12% and 6% from all others to the UK and the US, but these spillovers are less dynamic.

Regarding the Euro area zone, we remark that the stock markets of these countries are less impacted by the transmission of spillovers from all others. For France, the transmission patterns are almost static during the spanning period, with no changing of the transmission of spillovers to the stock market of France during the COVID-19 pandemic outbreak. For Germany, Italy, and Spain, the total dynamic spillovers to stock markets of these countries are significant and, a little bit, time-varying compared to France. However, similar to the French stock market, the total dynamic spillovers to stock markets of Germany, Italy, and Spain, from all others, didn't vary during the pandemic period. These results may be explained by the fact that, following China, the pandemic broke out to Europe and dampens economic activity. Consequently, European countries experience downturns after the announcement of the outbreak of the COVID-19 in the international media. Thus, stock markets are suffering a large decline and didn't react anymore to bad news related to the recent health crisis or different country's policies as responses to the rapid spread of the COVID-19 the pandemic.

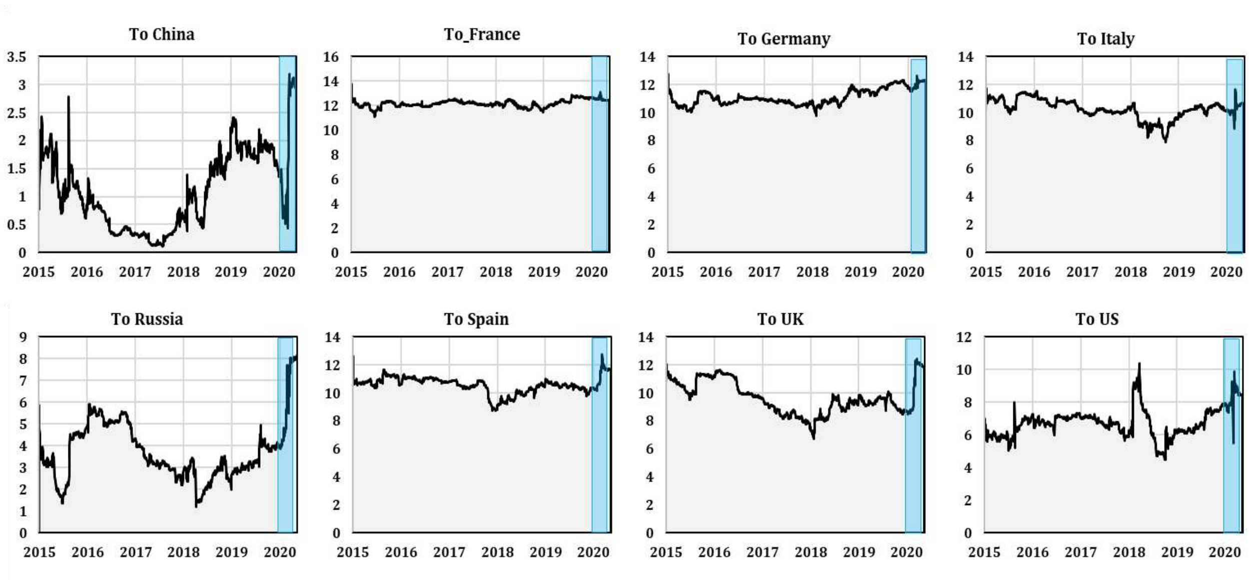

Fig. 3: Dynamic spillover to the stock market in each country (the shaded blue area indicates the period of the COVID-19 pandemic)

Fig. 4 depicts the amount of spillovers transmitted by each country to all other stock markets. As we can see, China, Russia, France, Germany, and Spain are the most transmitters of spillovers to all other stock markets. From these countries, the dynamic transmission patterns are significant time-varying with increased transmission of spillovers to all others, especially during the COVID-19 pandemic outbreak. For China, the transmission of spillovers jumps from 4% before the pandemic onset to close to 9%, during the outbreak of the pandemic. For Russia, the dynamic transmission of spillovers from this country to all other stock markets have also increased during the pandemic period and jumped from 7% before the Covid-19 pandemic period to close with10%.

Regarding the Euro area zone, the figure shows that the dynamic spillovers from these countries (France, Germany, and Spain) behave rather heterogeneously over time and follow a similar transmission pattern to all other stock markets. Moreover, we register increased dynamic spillovers from these countries during the recent COVID-19 pandemic period, which jump from an average of 9.5% before the outbreak of pandemic to nearly 10.5% after the pandemic outbreak. For Italy, the total directional spillovers from this country to all stock markets are almost static and didn't vary during the spanning period. For the UK and the US, the figures show that the total directional spillovers from these countries to all others are less dynamic and rather static over time with very weak variations during the sample period. Nevertheless, the dynamic spillovers from these countries have increased slightly during the pandemic period and pass from 9% (7%) for the UK (the US) before the pandemic outbreak to close to 10% for both.

Comparing the results of the dynamic spillover, we remark that the European stock markets transmit more spillovers to all other stock markets more than they receive (except for Italy), and this role becomes more pronounced during the outbreak of the COVID-19 pandemic. A plausible explanation is that the announcement of the worldwide pandemic may changes the way market participants perceive risk and started to expect higher levels of bad shocks transmission. Therefore, markets under pressure tend to transmit risks higher than in normal periods, and investors become less confident in predicting risks, which in turn increases spillovers of bad news (shocks).

A similar picture emerges when looking at the net dynamic total directional connectedness, which is depicted in fig. 5. We see that China and Russia are mostly net receivers of spillovers during the sample period. The US act as a net transmitter of spillovers during the first half of the year 2018 while a net receiver of spillovers during the remaining periods. The countries of the Euro area zone are net transmitters of spillovers to all other countries. Finally, the UK acts as a net receiver of spillovers from other countries during the period running from the year 2017 to the first quarter of the year 2018. It turns to the transmitter ends during the remaining periods.

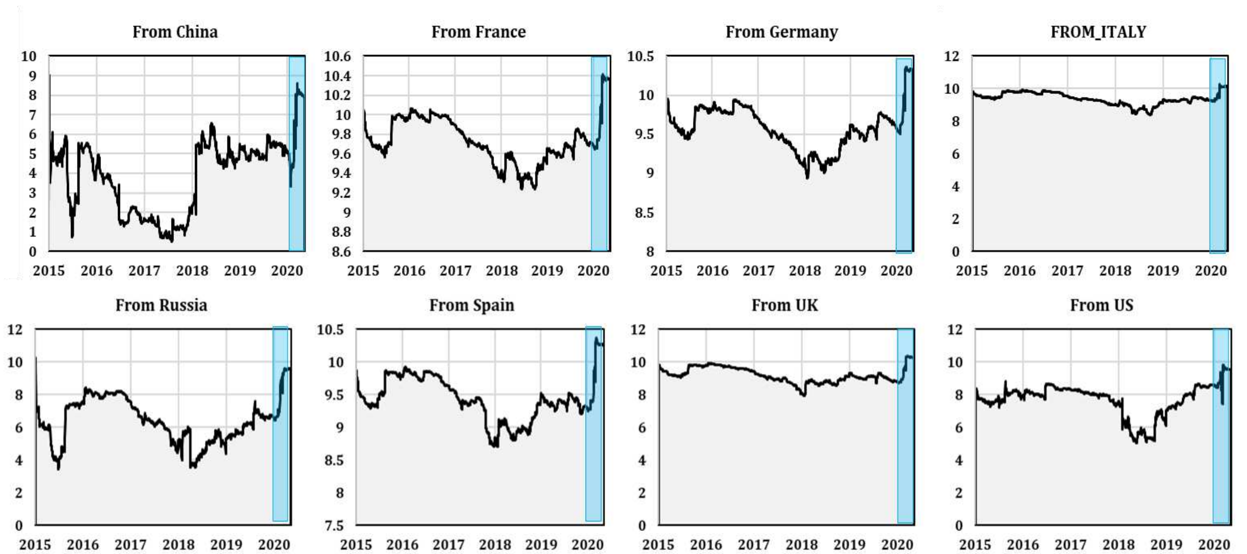

Fig. 4: Dynamic spillover from the stock market in each country (the shaded blue area indicates the period of the COVID-19 pandemic)

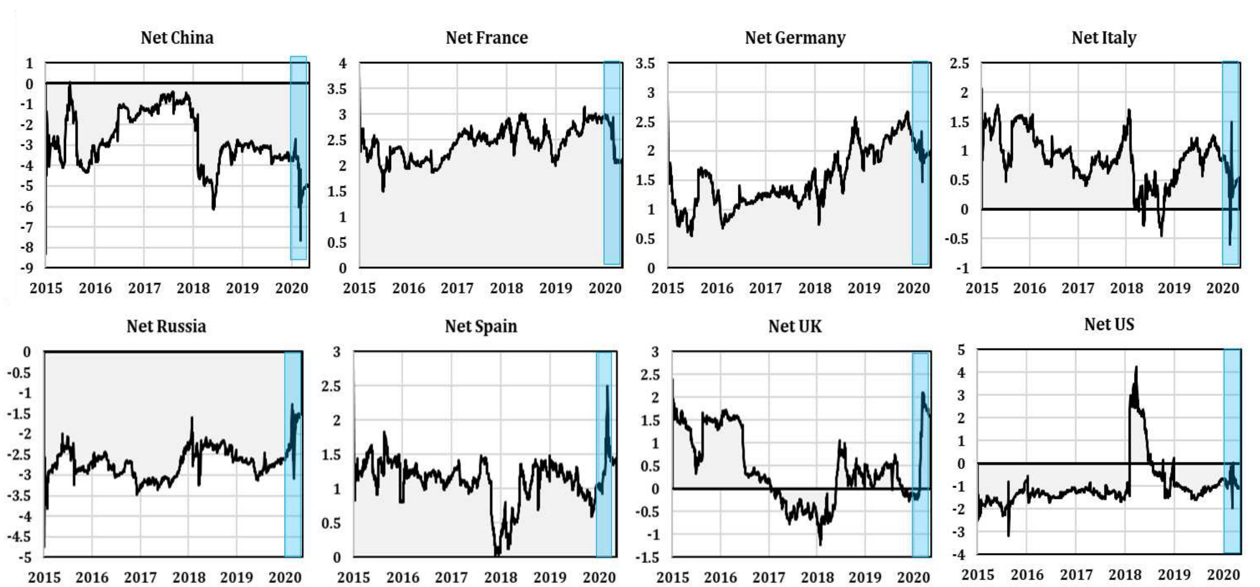

Fig. 5: Net dynamic spillover of the stock market in each country (the shaded blue area indicates the period of the COVID-19 pandemic)

4.2. Dynamic spillover and EPU

The rapid spread of the COVID-19 pandemic to different countries worldwide, causing unprecedented effects on the global financial stock market risks and increasing remarkably geopolitical risks and economic policy uncertainty (EPU). In this section, we aim to investigate the effect of EPU on the connectedness between the eight considered stock markets. For comparison, we investigate the effect of the EPU during the whole period, before, and after the outbreak of the COVID-19 pandemic. In this line, the sample period is divided into two sub-periods (1) 01/01/2015 – 12/23/2019 (pre-COVID-19 outbreak). The second sub-period covers 12/24/2019 – 05/18/2020 (COVID-19 outbreak).

Table 3: Effect of the EPU on the connectedness between the stock market before and after COVID-19 pandemic

	Total connect	Net connectedness							
		China	France	Germany	Italy	Russia	Spain	UK	U.S.
Panel A: Full period									
θ_0	63.0278***	-2.3180***	2.4566***	1.3867***	0.9731***	-2.8318***	1.0697***	0.3039***	-1.0401***
	(0.1716)	(0.0626)	(0.0151)	(0.0233)	(0.0200)	(0.0173)	(0.0158)	(0.0363)	(0.0479)
θ_1	0.0239***	-0.0042***	-0.0002	0.0014***	-0.0011***	0.0015***	0.0006***	0.0016***	0.0005
	(0.0013)	(0.0005)	(0.0001)	(0.0002)	(0.0002)	(0.0001)	(0.0001)	(0.0003)	(0.0004)
Panel B: Before COVID-19									
θ_0	64.9779***	-2.6990***	2.3216***	1.2773***	0.9872***	-2.6534***	1.1577***	0.6811***	-1.0726***
	(0.2402)	(0.0898)	(0.0212)	(0.0339)	(0.0293)	(0.0231)	(0.0224)	(0.0512)	(0.0717)
θ_1	-0.0027	0.0012	0.0014***	0.0026***	-0.0012***	-0.0010***	-0.0007***	-0.0032***	0.0008
	(0.0026	(0.0010)	(0.0002)	(0.0004)	(0.0003)	(0.0002)	(0.0002)	(0.0006)	(0.0008)
Panel C: COVID-19 period									
θ_0	65.9934***	-3.7050***	2.9934***	2.1246***	0.6737***	-2.4235***	1.2975***	-0.1945**	-0.7658***
	(0.4656	(0.1382)	(0.0320)	(0.0242)	(0.0761)	(0.0791)	(0.0684)	(0.0920)	(0.0685)
θ_1	0.0241***	-0.0029***	-0.0017***	-0.0004***	-0.0005**	0.0014***	0.0004**	0.0038***	-0.0002
	(0.0013)	(0.0004)	(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)

Notes: This table provides the parameter estimates of the model in Eq. (11). Numbers between parenthesis denote the estimated standard error. (***), (**), and (*) indicate the parameters significance at 1%, 5%,, and 10%, respectively.

Table 3 reports the estimation results of the effect of the Economic policy uncertainty (EPU) on the total connectedness between stock markets and on the net connectedness for each country's stock market, as described in Eq. (11). In Panel (A), we report the effect of the EPU during the whole sample period. Results show that the effect of the EPU on the total connectedness is significantly positive. Also, the effect of the EPU on the net connectedness for each country is significantly affected by the EPU excepting the cases of France and the US. Moreover, we notice that China and Italy net connectedness are negatively affected by the EPU, while a positive connectedness is reported for all other markets.

Panel (B) and (C) report the effect of the EPU on the total connectedness between stock markets and the net connectedness for each country before and during the onset of the COVID-19 pandemic. Results highlight that the effect of the EPU on the total connectedness was insignificant before the pandemic outbreak, but turns to significantly positive following the announcement of the infectious disease. This result proves, again, that global financial stock markets tend to co-move in the same direction during periods of pressure and high economic uncertainty. Thus, what is good for one market is also good for all other markets and vice versa.

Regarding the effect of the EPU on the net connectedness for each country, the EPU has a significant effect for all stock markets before the onset of the COVID-19 pandemic, excepting China and the US. Notice that, the EPU affect the net connectedness positively for France and Germany's stock markets, while affect negatively the cases of Italy, Spain, Russia and the UK. Within the outbreak of the COVID-19 pandemic, results are slightly different. In fact, we observe a significant net connectedness of all considered stock markets affected by the EPU and caused by the outbreak of the new infectious disease, excepting the US. Also, we report that the sign of the EPU's effect changes before and during the outbreak of the pandemic. The effect of the EPU on the net connectedness of stock markets of France and Germany turns to be significantly negative but significantly positive for Russia, Spain, and the UK. However, the net connectedness for the stock market of Italy is significantly negative before and during the onset of the COVID-19 pandemic. These results underscore the existence and strong linkage between the economic policy uncertainty and the net connectedness of stock markets on countries worldwide.

The changing sign of the effect of the EPU on net connectedness before and during the onset of the pandemic, show that information spillovers from a given market may be seen as good or bad news for other markets, given the economic situation prevailing. For example, during the normal economic situation (before the COVID-19 outbreak), the net connectedness from the stock markets of china didn't respond to the economic uncertainty. In contrast, within the onset of the pandemic (high economic uncertainty state), the bad news spillovers from these stock markets to other markets are significantly affected by the high economic uncertainty prevailing. Regarding the responses of other stock markets, net connectedness's to the economic uncertainty environment, the changing sign of the EPU effects show that the dynamic transmission of spillovers from a given market depends on whether the economic state is normal (low levels of uncertainty) or is under pressure (high uncertainty level). Thus, the bad news coming from China during the outbreak of the

COVID-19 pandemic and the different Chinese authorities' policy's to react to the new pandemic may be considered as bad or good news to other countries around the world.

On the other hand, Europe was the second center of the coronavirus spread, especially Italy then followed by Spain, France, and Germany. In this short period, European countries have not large experience about how to react to the pandemic spread and have not yet plans and policies to take in order to protect their economies and stock markets. Therefore, bad news coming from China is considered bad news for European stock markets. While other countries such as the US, the UK, and Russia, lately affected, are better informed about the risk related to the pandemic spread. Consequently, these countries profit from the time interval and other countries' experience to mitigate the risk.

5. Conclusion and policy implications

The public health emergency could transmit the effect to the economy as the stock market serves as the barometer of investors' expectations and faith in economic prospects (Bai, 2014; Baker et al., 2012). The spread of the COVID-19 pandemic intensifies uncertainties worldwide, increases stock investors' fear, and creates pessimistic sentiments on future returns. In this study, we analyze the dynamic connectedness between the major stock markets affected by the coronavirus pandemic. Moreover, we analyze the effect of the economic policy uncertainty on the dynamic directional connectedness between the stock markets considered before and during the onset of the outbreak of the COVID-19 pandemic, using the TVP-VAR model recently proposed by Antonakakis and Gabauer (2017). This methodology substantially improves the connectedness approach of Diebold and Yelmaz (2014). It also overcomes the burden of the often arbitrarily chosen rolling-window-size, which could lead to very erratic or flattened parameters as well as a loss of valuable observations.

Using daily data for the eight stock markets, results reveal an unprecedented sensitivity of stock market connectedness to the rapid spread of the COVID-19 pandemic. Results show that the total connectedness between stock markets, as well as the net connectedness for each stock market, vary across time and depending on the economic uncertainty state.

Our findings reveal different regularities. First, the total dynamic connectedness between stock markets understudy has increased considerably and reaches unprecedented levels during the COVID-19 pandemic outbreak. This result confirms previous findings suggesting that stock market linkages become more pronounced during crisis periods. According to Gormsen and Koijen (2020), such dramatic movement cannot simply because, at long-term expectations, it is almost certain that sentimental factors play important roles. Broadstock and Zhang (2019), show that the market sentiment in response to the outbreak can be quickly amplified through social media, which then stimulate trade activities and cause extreme price movements

Second, results show that China and Russia act as net receivers of dynamic spillovers during the whole sample period, and the US stock market acts as a net receiver for the majority of the time. The European stock markets are net transmitters of spillovers for all other markets, and the US stock market's acts, mostly, as a transmitter. Furthermore, we find that, during the outbreak of the coronavirus pandemic, European stock markets, except Italy, as well as the stock market of the UK, transmit spillovers more than they receive. This result suggests that, in crisis periods, stock markets are more likely to transmit risks (bad volatility), negative spillovers suggest that uninformed traders dominate the whole system, and bad spillover tends to transmit at a larger magnitude (Ben Saida (2019)).

Third, we have analyzed the effect of the economic policy uncertainty (EPU) on the total directional connectedness and the net connectedness for each stock market. Results show a significant positive effect of the EPU on the total dynamic spillover during the whole sample period and the coronavirus outbreak. Concerning the net connectedness for each stock market, results report different regularities. First, for the considered full period, the EPU significantly impacts the net connectedness for all stock markets considered, except France and the US. To analyze further the effect of the EPU on the net connectedness along with the outbreak of the COVID-19, we have divided the sample period into two sub-periods before and during the pandemic outbreak. Comparing the results for each period, we find that: (i) before the outbreak of the pandemic, the net connectedness for each stock market is significantly affected by the economic uncertainty, except for China and the US.

While during the pandemic outbreak, all stock markets net connectedness's are significantly affected by the EPU. (ii) The effect of the EPU on the net connectedness, before and during the COVID-19 outbreak, switches between negative and positive. Thus, what is good for a given market may be bad or good for other markets. (iii) The changing sign of the effect of the EPU on the net connectedness, before and during the onset of the new infectious disease, suggests that the responses of stock markets to news coming from a given market depends on the economic uncertainty states. Thus, during the COVID-19 outbreak, bad news coming from China may be considered as bad news for some countries which are rapidly affected by the new virus (Italy, Spain, and France). Whereas, some other countries who are latterly affected by the new coronavirus, are less sensitive to bad news coming from other countries and authorities have already implemented different policies to alleviate the impact of the bad news inherent to the spread of the coronavirus pandemic on their economies and stock markets.

Findings from this study offer some policy implications. The rapid spread of the new COVID-19 pandemic is causing a high level of dynamic connectedness between international stock markets, an unprecedented shutdown of stock market returns, and increasing economic uncertainty worldwide. Therefore authorities, central banks, and investment banks must implement efficient economic strategies and different policies to manage the COVID-19 crisis without triggering uncertainty. Similarly, government interventions should try to alleviate the panic mode of the financial stock markets and increases investor's confidence in future revenues and market recovery. Meanwhile, given the continuous spread of the COVID-19 pandemic worldwide, market participants and investors should learn how to manage stock market risk and panic.

As with all studies, our research presents some limitations. The most one is that we study the immediate and short-term effect of the COVID-19 outbreak on the dynamic connectedness between the major affected countries' stock markets due to the short event period and the evolving nature of the virus spread. Moreover, future research may consider the long-term effects of the infectious disease on the stock markets connectedness, investors' confidence inside and between foreign stock markets, as well as investor sentiment and uncertainty.

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Figures

Figure 1

Daily spot prices of stock markets considered for the period running from 01/01/2015 to 05/18/2020. The shaded area indicates the period of the COVID-19 pandemic.

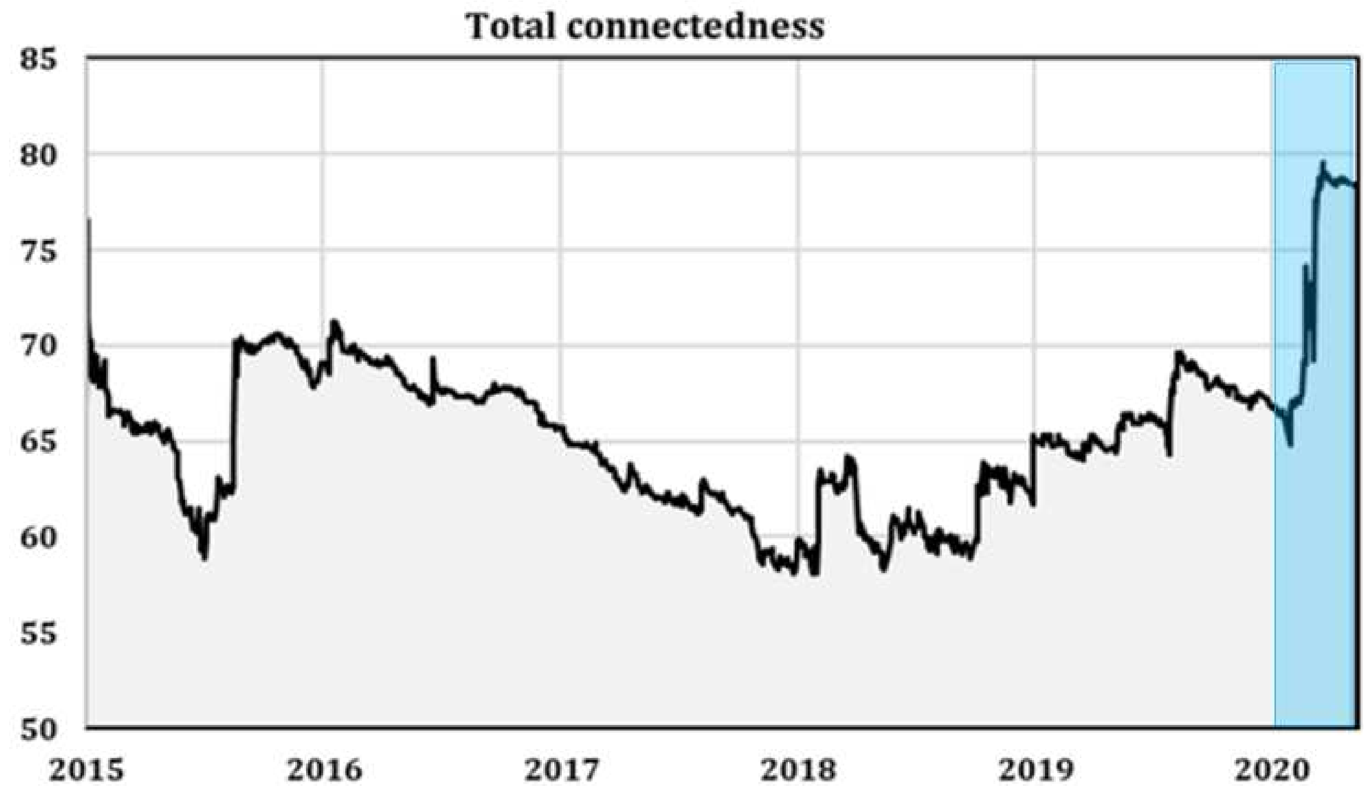

Figure 2

Total connectedness measure (the shaded blue area indicates the period of the COVID-19 pandemic)

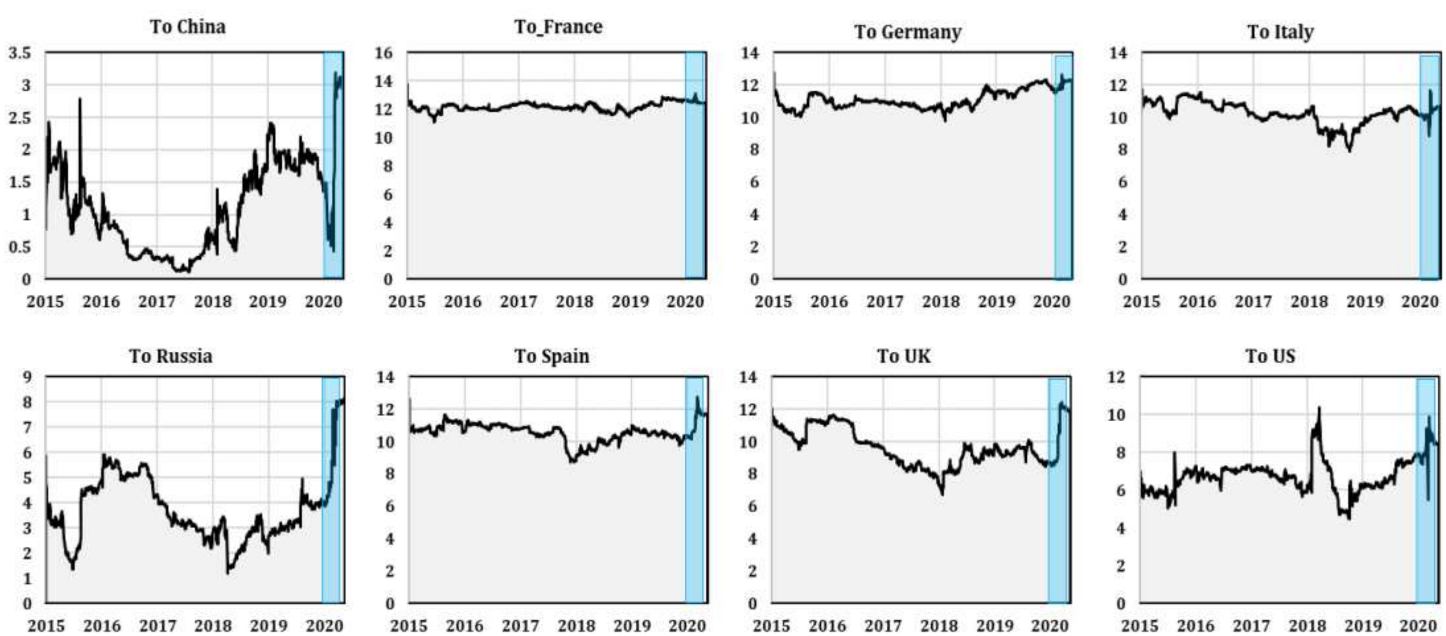

Figure 3

Dynamic spillover to the stock market in each country (the shaded blue area indicates the period of the COVID-19 pandemic)

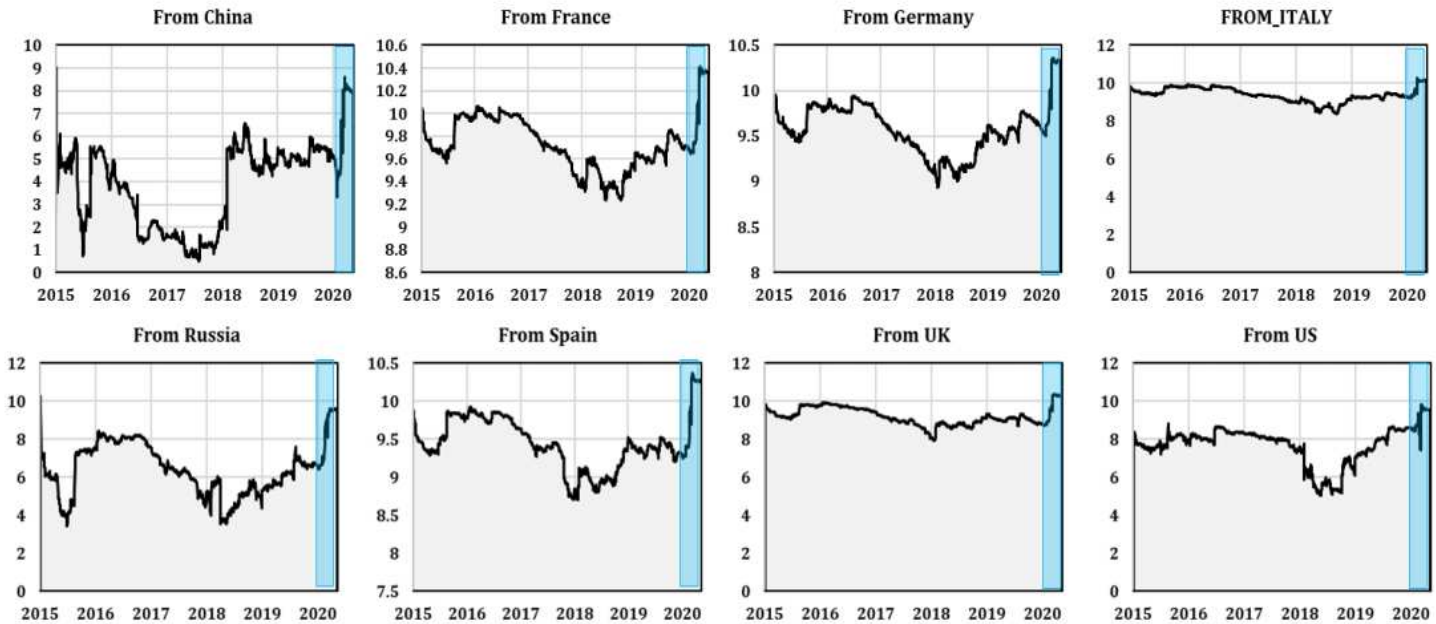

Figure 4

Dynamic spillover from the stock market in each country (the shaded blue area indicates the period of the COVID-19 pandemic)

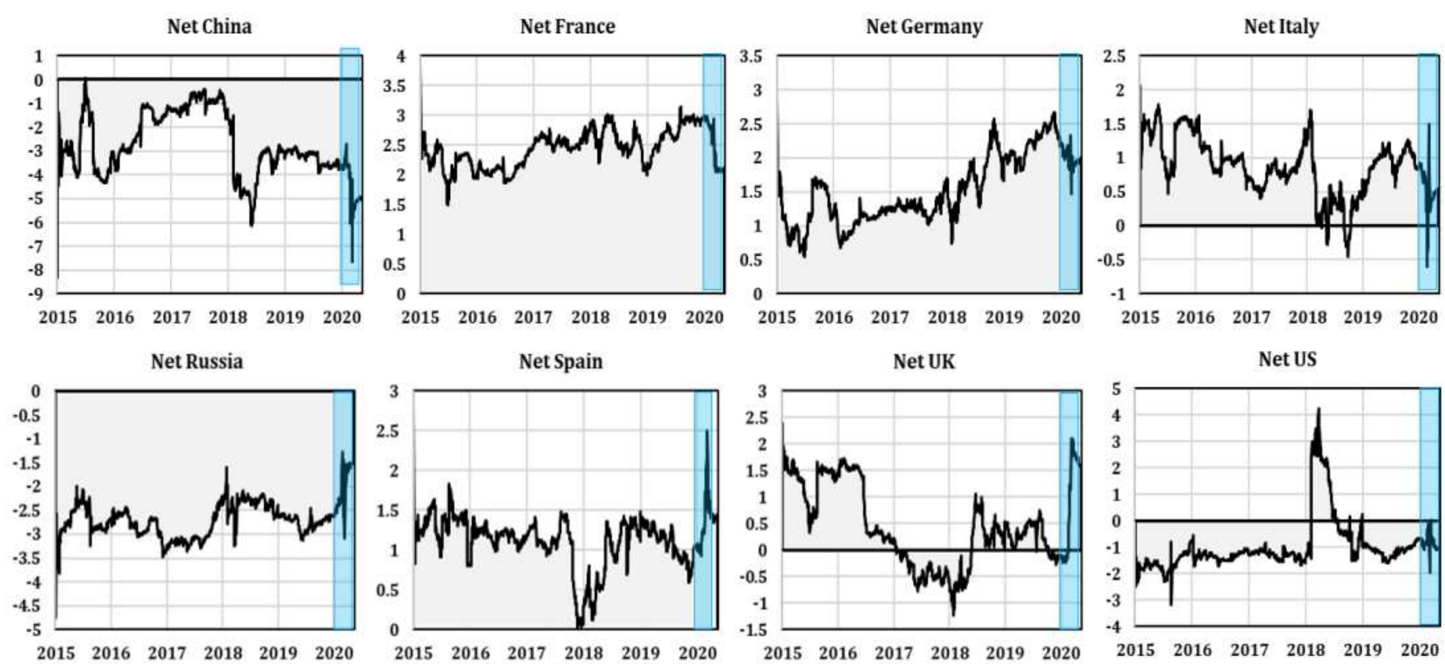

Figure 5

Net dynamic spillover of the stock market in each country (the shaded blue area indicates the period of the COVID-19 pandemic)

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- BASETotal.xlsx
- epu.csv