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Do the Political Uncertainty and Geopolitical Risk Indexes in the G-7 Countries Relate to Stock Prices? Fourier Causality Test Evidence

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ABSTRACT
This study aims to examine the reciprocal effects of the Economic Policy Uncertainty (EPU) and the Geopolitical Risks (GPR) on the stock markets (SP) of the G-7 countries. The findings of the study will allow us to answer the following questions: Do risk and uncertainty conditions in other G-7 countries affect their stock markets as much as those in the country itself? Which affects G-7 stock markets more, EPU or GPR? In addition to previous research in the field, this study conducts a comparative analysis of the effects of the EPU and GPR on the SP of G-7 countries. Therefore, we used the linear VAR Granger, Fourier and Fourier Fractional Frequency Granger Causality tests. We found that the EPU indices of the United States, United Kingdom, and Germany had the greatest impact on the stock markets of their respective countries and other G-7 countries, and the conclusion that G-7 stock markets were influenced by economic uncertainties in other member countries was added to the literature. It has also been found that the G-7 stock markets have a broad influence on the EPU index.

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1. Introduction

Increasing real and financial market integration as a result of globalization has made countries more sensitive to crises all over the world and the associated risks and uncertainties (Tissot, 2016). Measuring and predicting stock market volatility is an important phenomenon for economists and investors (Mei et al., 2018; Poon & Granger, 2003; Su et al., 2019). In the last two decades, uncertainty and risk have been an important research topic in the empirical literature on stock markets, especially after the 2008 crisis (Antonakakis et al., 2013; Bansal et al., 2005; Bekiros et al., 2016; Chang et al., 2015; Yao & Sun, 2018). The concept of uncertainty, which can be expressed as the inability of policymakers, investors, and consumers to accurately predict possible future realities, is related to macroeconomic and microeconomic phenomena, as well as non-economic phenomena such as war and epidemic climate change (Bloom, 2014). The concept of uncertainty can be

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evaluated in two distinct categories: economic policy uncertainty and uncertainty resulting from geopolitical threats (Agoraki et al., 2022).

Economic policies have a substantial impact on the investment decisions made by market participants in global financial markets (Dash et al., 2021). Prior research indicates that policy uncertainty and geopolitical risk, have a substantial impact on investor sentiment and play a crucial role in financial markets (Bossman et al., 2023a, 2023b; Mensi et al., 2023; Naeem et al., 2021). Investors' risk perception and market volatility may be elevated by both economic uncertainties and geopolitical risks. In this scenario, asset prices may experience abrupt and substantial fluctuations (Costola et al., 2022). The decision-making processes of companies and investors may be impeded by these risks and uncertainties. Particularly, the planning and evaluation of long-term investments can be conducted with greater precision. Simultaneously, economic uncertainties and geopolitical risks may also influence the policy decisions of governments and central banks. The overall movement of markets and investor sentiment can be significantly influenced by these decisions. In addition, the risk and uncertainty environment also impacts investor psychology. In situations of increased uncertainty, investors may make decisions based on emotional reactions, which can result in significant and rapid price fluctuations in the markets. For similar reasons, stock market efficiency can be impacted by economic uncertainties and geopolitical concerns (Agoraki et al., 2022).

The Economic Policy Uncertainty index, developed by Baker et al. (2012) based on disagreements in newspaper articles referring to economic uncertainty, tax regulations that will expire, expected future inflation, and government expenditures, is the leading index in this field. In the developed index, retrospective calculations were performed through 1985, and substantial rises in the index were identified during the time of important elections, wars, the September 11 terrorist assault, and the 2008 global financial crisis (Baker et al., 2012). Considering its ability to quantify risk and uncertainty, the EPU is frequently used in the literature to evaluate stock markets (Arouri et al., 2016; Kang & Ratti, 2013; Kundu & Paul, 2022; Li & Peng, 2017; Liu & Zhang, 2015; Ma et al., 2018; Yu et al., 2018; Zhou & Jiang, 2020).

While the empirical literature shows that the EPU is an effective indicator for explaining the effects of economic uncertainty on the stock market, non-economic factors such as wars (Umar et al., 2022), terrorist attacks (Balcilar et al., 2018b), and epidemics are (Sharif et al., 2020) also being investigated (Hasan et al., 2020). At present, the Geopolitical Risk Index, developed by Caldara and Iacoviello (2018) to evaluate adverse geopolitical events and risk circumstances, is a useful instrument for analyzing the consequences of war and terrorist attacks on economic indicators. The index is generated for 43 countries based on 10 major newspapers' coverage of eight categories: threats of war, threats of peace, military structures, nuclear threats, terrorist threats, the onset of war, the escalation of war, and terrorist acts (Caldara & Iacoviello, 2022). In recent years, with the impact of GPR factors such as the COVID-19 epidemic (Sansa, 2020; Zhang et al., 2020) and the Russia–Ukraine war (Boungou & Yatié, 2022; Tajaddini & Gholipour, 2023), the GPR index's impact on the stock market has been an important topic of empirical research (Apergis & Apergis, 2016; Bouras et al., 2019; Hassan et al., 2022; Hoque & Zaidi, 2020; Jung et al., 2021; Lee, 2023; Şahin & Arslan, 2021).

The purpose of this study is to examine the effects of economic uncertainty and geopolitical risks on national stock markets using a panel causality analysis based on the EPU and

GPR for the G-7 countries in the period 2001:01–2022:11. In examining the relationship between the EPU and GPR and the stock markets of the G-7 countries, we conducted a cross-country analysis to determine the impact of each country's EPU and GPR values on the stock markets of other nations. There are numerous reasons to examine the G-7. First, according to the IMF's report (2022), the G-7, which made up 30.7% of the global economy in 2021, accounted for 79% of the total value of the global stock market in 2022 (Dimson et al., 2022). According to the financial globalization index, which is a subcomponent of the globalization index calculated by the KOF Swiss Institute of Economics, the globalization level of the G-7 countries in 2022 (Canada: 83, Germany: 83, France: 85, England: 89, Italy: 73, Japan: 78, and America: 80) will be significantly higher than the world average index value of 60.7. G-7 with a high degree of financial globalization are likely to influence the global conjuncture and be influenced by it. In this context, it is essential for the global financial market to measure and model the impact of uncertainty and risk factors on G-7 stock markets.

It aims to contribute to the literature by utilizing the empirical findings of our study. First, while the effects of the EPU and GPR, as well as economic uncertainty and geopolitical risk, on the stock market have been studied separately, there are few studies that compare the effects of both indices (Adebayo et al., 2022; Agoraki et al., 2022; Das et al., 2019; Kannadhasan & Das, 2020). The EPU reflects the impact of economic uncertainty and risks on stock markets, whereas the GPR reflects the impact of geopolitical factors such as war and terrorist attacks. In terms of making predictions and building models for the markets, it is essential to determine which factors have the greatest impact on the stock markets of various countries. A further consideration is that liberalized stock markets are susceptible to internal and external shocks (Asgharian & Nossman, 2013), which means that the impact of the EPU and GPR in other countries is unavoidable. We will investigate the effects of risk and uncertainty in each of the G-7 with a high level of financial globalization on the stock markets of other G-7 countries, as well as the extent to which countries are affected by external shocks and uncertainties. Thus, we will obtain comprehensive results by determining which of the economic and geopolitical conditions of each G-7 country has the greatest impact on the stock markets of the G-7 countries. Therefore, we will be able to answer the following questions based on the study's findings: Do the risk and uncertainty conditions experienced in other G-7 countries have a similar impact on the stock markets of those countries as the risks and uncertainties experienced within the country itself? Which factor exerts a greater influence on the stock markets of the G-7 nations, EPU or GPR?

Our study proceeds as follows. In the second part, we examine the sample literature to determine the relations between EPU and GPR on stock markets. In the third part, we present the dataset and model that we use in our empirical analysis. In the fourth part, we present the empirical findings. In the fifth and final part, we offer conclusions and recommendations by interpreting the empirical findings.

2. Literature Review

The EPU, which was introduced to the literature by Baker et al. (2012), has been a topic of discussion for many years. According to the authors,

> … Uncertainty about who will make economic policy decisions, what economic policy actions will be undertaken and when, and the economic effects of policy actions (or inaction) –

> including uncertainties related to the economic ramifications of 'noneconomic' policy matters, e.g. military actions … (Baker et al., 2016, p. 1598)

Based on this index, they found negative impacts of the EPU on investments. Since that study, many studies have examined the relationship between the stock, which is an investment tool, and the EPU. Baker et al. (2016) developed news-based EPU while Caldara and Iacoviello (2018) developed the GPR. However, earlier studies on the effects of the EPU and GPR are mostly related to inflation, investment, employment, and economic growth. It began to be studied in detail in the form of the GPR–EPU and stock market performance (represented by the stock market price or stock return), especially after the last global financial crisis in 2008 (Li et al., 2016, p. 675).

The studies in the literature can be divided into three groups for examination (Tables 1 and 2). The first category includes studies of the role of a single EPU on the stock markets. The second category encompasses studies of the role of a single GPR on the stock markets. The third category considers the role of a combined EPU and GPR on the stock markets.

When we look at the studies on the relationship between SP and EPU, it is seen that there are quite interesting and different results. In particular, the most striking studies are Chang et al. (2015) and Wu et al. (2016). Although they use a similar time period and the same analysis method, the results obtained in both studies differ. A similar situation is observed in Kundu and Paul (2022) and Khojah et al. (2023). Although both studies are analyzed within the scope of G-7 countries and with a similar data set, the results obtained differ. In this case, evaluating the data on a monthly and/or annual basis shows that the results may differ.

It is seen that the studies investigating the relationship between GPR and SP are limited in the literature. The results obtained from the studies generally show that there is a negative relationship between GPR and SP. In this case, the geopolitical uncertainties of the countries have a negative impact on the stock prices of the countries, and these results can be considered quite normal.

In particular, if we consider the effects of EMU and GPR on the SP, it is possible to say that GPR and EMU are highly significant on the SP. Economic uncertainties in countries affect investor decisions directly or indirectly, leading to a decrease in investment volumes and a depreciation of the stock market. Likewise, an increase in geopolitical risk causes investors to abandon their investment decisions in the stock market and the stock market is negatively affected.

Lastly, when the literature is examined, there are a few studies about the effects of GPR and EPU on the SP (Adebayo et al., 2022; Das et al., 2019). Das et al. (2019) utilized nonparametric causality-in-quadratics tests for the period 1997–2018 for 24 emerging economies. The result of the analysis shows that the relationship between the variables varies among countries and is not the same for each country. Moreover, Adebayo et al. (2022) investigated the relationship for South Korea using the same tests for the period 1997–2021, and found that there is a causal relationship from the GPR and the EPU to the SP.

Our paper presents several main contributions to the literature. First, there is a limited number of research examining the impact of the EPU and GPR on stock market prices in conjunction. Second, there are no studies examining the causality relationship between EPU–GPR and stock prices in the context of G-7 countries. However, G-7 countries have important roles in the international market, which roles can cause uncertainty and risk in

Table 1. Literature summary on the relationship between the EPU and the SP.

Author/s	Period	Country/unit	Method	Result
Sum (2012a)	1993–2012	European Union (EU), 6 Non-EU countries	OLS	$EPU \rightarrow SP^{-,EU}$ $EPU \neq SP^{Non-EU}$
Sum (2012b)	1993–2012	Eurozone countries	OLS, VECM	$EPU \rightarrow SP^{+}$
Antonakakis et al. (2013)	1985–2013	The USA	DCC, DCC-GARCH	$EPU \rightarrow SP^{-}$
Kang and Ratti (2013)	1985–2011	The USA	VAR Model	$EPU \rightarrow SP^{-}$
Ajmi et al. (2015)	1985–2013	The USA	Granger causality, Time-varying causality	$SP \leftrightarrow EPU$
Alexopoulos and Cohen (2015)	1985–2007	The USA	VAR, GARCH, E-GARCH Model	$EPU \rightarrow SP^{-}$
Chang et al. (2015)	2001–2013	OECD countries	Kónya Panel causality	$EPU \rightarrow SP^{-,ItalyandSpain}$ $EPU \neq SP^{othercountries}$
Wu et al. (2016)	2003–2014	OECD countries	Kónya Panel causality	$SP \rightarrow EPU^{-,India,Italy,andSpain}$ $EPU \rightarrow SP^{+,theUK}$
Arouri et al. (2016)	1900–2014	The USA	Regime Switching Model	$EPU \rightarrow SP^{-}$
Li et al. (2016)	1995–2013	China, India	Time-Varying causality	$SP \rightarrow EPU$
Li and Peng (2017)	1993–2015	China	ADCCX Model	$EPU \rightarrow SP^{-}$
Christou et al. (2017)	1998–2014	Australia, Canada, China, Japan, Korea and the US	Panel – VAR	$SP \rightarrow EPU^{-}$
Phan et al. (2018)	1085–2016	16 countries	Panel Data Analysis	Mixed results
Das and Kumar (2018)	1998–2017	11 developed countries, 6 emerging countries	Multiple and Partial Wavelet Approach	Mixed results
Karacaer Ulusoy and Pirgaip (2019)	2005–2019	21 countries	Panel Granger Causality	Mixed results
Bahmani-Oskooee and Saha (2019)	1985–2016	Canada, Japan, Korea, the UK and the USA	ARDL Bounds test,	$EPU \rightarrow SP^{-,Canada,Japan,theUK}$
Chen and Chiang (2020)	1900–2019	China	the GED-GARCH Model	$EPU \rightarrow SP^{+}$
Li et al. (2020)	2005–2017	China	GARCH-MIDAS, MCS	$EPU \rightarrow SP^{-}$
Zhou and Jiang (2020)	2005–2020	China	Johansen cointegration, Granger causality, Multivariate portmanteau test	$EPU \rightarrow SP^{-}$
Škrinjarić and Orlović (2020)	Mixed periods	Bulgaria, Czech Republic, Estonia, Hungary, Lithuania, Poland, Croatia, Slovakia and Slovenia	VAR Model	$EPU \rightarrow SP^{CzechRepublic,Lithuania,Slovenia,Poland}$
Liang et al. (2020)	2000–2017	11 Asian countries	NARDL	$EPU \rightarrow SP^{-}$
Hua et al. (2020)	1997–2016	China	GARCH-MIDAS	$EPU \neq SP$
Erdoğan et al. (2022)	1997–2019	Turkey	NARDL	$EPU \rightarrow SP^{-}$
Gemici (2020)	1997–2019	G-7 countries	Panel cointegration, CCE	$EPU \rightarrow SP^{-}$
Si et al. (2021)	2001–2020	China	VAR	$EPU \rightarrow SP$
Aydın et al. (2021)	2003–2021	BRIC countries	Asymmetric frequency domain causality	$EPU \leftrightarrow SP^{Brazil,India}$ $EPU \neq SP^{China}$
Darsono et al. (2022)	2015–2020	12 countries	ARDL Model	$EPU \rightarrow SP^{-}$
Zeng et al. (2022)	1985–2021	An overall economy	Portfolio performances	$EPU \rightarrow SP$
Kundu and Paul (2022)	1998–2018	G-7 countries	Markov switching VAR model	$EPU \rightarrow SP$
Albrecht et al. (2023)	1985–2021	the USA, the UK, Japan, Germany	Wavelet analysis	$EPU \rightarrow SP$
Ghani and Ghani (2023)	2010–2020	Pakistan	GARCH-MIDAS model	Mixed results
Khojah et al. (2023)	1998–2020	G-7 countries	Panel Threshold approach	$EPU \rightarrow SP^{anintervedUshape}$
Zeng et al. (2023)	2000–2022	the USA	MS-MIDAS model	Mixed results

Note: $\rightarrow$; indicates the causal relationship and the direction of causality, $\neq$; indicates that there is no relationship between the variables, $+$; indicates the positive relationship, $-$; indicates the negative relationship.

Table 2. Literature summary on the effects of GPR on the SP.

Author/s	Period	Country/unit	Method	Result
Apergis and Apergis (2016)	2015 (daily data set)	France	AARs, CAARs	GPR→SP
Balcilar et al. (2018a)	1985–2016	BRICS countries	Causality-in-quantiles test	Mixed results
Şahin and Arslan (2021)	Different starting time-2018	18 developing countries	Nonparametric Causality-in-Quantiles test	Mixed results
Hassan et al. (2022)	2022 (daily data set)	17 Africa countries	Wavelet analysis	GPR→SP^{+}
Boungou and Yatié (2022)	2022 (daily data set)	94 countries	Panel data analysis	GPR→SP^{-}
Zhang et al. (2023)	2017–2022	32 countries	Panel data analysis	GPR→SP^{-}

Note: →; indicates the causal relationship and the direction of causality, ≠; indicates that there is no relationship between the variables, +; indicates the positive relationship, −; indicates the negative relationship.

Table 3. Descriptive statistics.

Variables	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
CAN_{SP}	13426.16	13429.95	22186.52	6180.42	3913.23	0.16	2.45	4.66
GER_{SP}	8773.08	7785.50	18119.93	2423.00	3881.35	0.38	2.00	18.27
FRA_{SP}	4737.28	4575.26	8195.65	2618.46	1184.64	0.60	2.89	17.06
ITA_{SP}	24875.08	22672.94	45067.21	12873.84	7129.23	0.85	2.95	33.40
JAP_{SP}	16707.58	15540.55	40696.50	7568.42	7005.12	0.83	3.02	32.34
UK_{SP}	6092.10	6149.48	8151.36	3567.40	1091.80	−0.33	2.20	12.44
USA_{SP}	2041.75	1490.24	5254.33	735.09	1127.72	1.06	2.95	52.48
CAN_{EPU}	193.83	174.77	678.82	40.44	114.82	0.96	3.90	52.04
GER_{EPU}	201.82	148.22	844.85	28.43	164.42	1.97	6.48	323.09
FRA_{EPU}	205.82	206.67	574.63	30.62	101.23	0.52	3.16	13.01
ITA_{EPU}	114.13	108.45	279.39	31.70	40.29	0.78	3.97	39.39
JAP_{EPU}	107.56	104.27	239.02	48.40	31.34	1.03	4.95	94.14
UK_{EPU}	223.66	198.98	1141.80	30.47	148.98	1.67	8.55	489.71
USA_{EPU}	141.17	128.60	503.96	44.78	64.95	1.86	8.86	562.08
CAN_{GPR}	0.23	0.18	1.72	0.06	0.17	4.58	33.78	12028.59
GER_{GPR}	0.44	0.36	2.66	0.09	0.31	3.40	20.60	4153.86
FRA_{GPR}	0.56	0.49	2.80	0.19	0.34	2.98	15.40	2207.87
ITA_{GPR}	0.15	0.12	0.65	0.03	0.10	2.16	9.34	686.82
JAP_{GPR}	0.25	0.20	1.24	0.06	0.17	2.22	9.65	746.19
UK_{GPR}	1.15	0.99	5.99	0.40	0.70	3.98	24.13	5946.95
USA_{GPR}	2.50	2.15	13.23	1.02	1.36	4.49	31.48	10400.38

Note: Author's calculation.

the markets. Thus, we examine the relationship between variables for G-7 and fill the gap in the literature. Third, to our knowledge, most relevant studies were based on panel tests, and they did not take structural change into account. In contrast, to address the gap in the literature, we applied a time-series analysis and considered structural change in our examination of the relationship between variables. Hence, we employed linear VAR Granger, Fourier Granger Causality and Fourier Fractional Frequency Granger Causality to be able to compare the impact of structural change. The last contribution of our study is that almost all past studies have dealt with the relationship between the variables in one direction only (from EPU and/or to SP). We focus on bidirectional causality, not just the effects of a source country but also the effects of other countries.

3. Methodology

3.1. Fractional Fourier ADF Unit Root Test

The impact of shocks is realized more smoothly on macroeconomic variables (Enders & Lee, 2012). Trigonometric terms are used in Fourier techniques to analyze this smooth

Table 4. FFADF unit root test results.

Variables	Optimal freq.	*F* stat.	Optimal Lag length	FADF test stat	ADF test stat
CAN_{SP}	0.1	4.61	1	−2.97	−0.25
GER_{SP}	0.1	6.83**	3	−3.63*	–
FRA_{SP}	0.1	8.89**	9	−4.05**	
ITA_{SP}	2.6	2.87	9	−2.14	−2.61
JAP_{SP}	0.1	4.45	1	−2.18	1.68
UK_{SP}	0.1	5.79	2	−3.38	−1.21
USA_{SP}	0.1	11.99***	9	−4.21**	–
CAN_{EPU}	0.8	7.38*	5	−4.57***	–
GER_{EPU}	0.7	15.17***	1	−7.27***	–
FRA_{EPU}	0.1	10.47**	1	−5.46***	–
ITA_{EPU}	2.5	6.29*	8	−5.07***	
JAP_{EPU}	2.4	3.95	4	−4.48	−6.65***
UK_{EPU}	0.9	6.84*	7	−4.54***	–
USA_{EPU}	2.3	3.93	8	−2.81	−4.78***
CAN_{GPR}	0.1	6.29*	10	−4.68***	–
GER_{GPR}	2.1	2.11	9	−3.8	−8.52***
FRA_{GPR}	0.7	6.35	8	−5.11***	
ITA_{GPR}	0.5	4.79	9	−5.38	−8.4***
JAP_{GPR}	1.3	4.94	9	−4.94	−7.22***
UK_{GPR}	0.1	6.57*	10	−4.8***	
USA_{GPR}	0.1	2.91	14	−2.71	−6.57***

Note: *, **, and *** denote significance at 1%, 5%, and 10% levels, respectively. For critical values of the *F* Stat and FADF unit root test stat, please see Enders and Lee (2012), and Bozoklu et al. (2020), respectively.

Table 5. Summary results.

	CAN_{SP}			GER_{SP}			FRA_{SP}			ITA_{SP}			JAP_{SP}			UK_{SP}			USA_{SP}		
Variables	GC	FGC	FFGC	GC	FGC	FFGC	GC	FGC	FFGC	GC	FGC	FFGC	GC	FGC	FFGC	GC	FGC	FFGC	GC	FGC	FFGC
CAN_{EPU}	↔	←	←	↔	↔	↔	↔	←	←	←	←		↔	↔	↔	←	←	←	↔	↔	
GER_{EPU}	←	←	←	↔	↔	↔	↔	↔	↔	↔	←	←	→	↔	↔	←	↔	↔	←	←	←
FRA_{EPU}	←	←	←	↔	↔		←	←	←	←	←	←	↔	↔	↔	←	←	←	←	←	
ITA_{EPU}	←	←	←	↔	↔	←	←	↔	←	←	←	←		→	→	←	←	←	↔	↔	↔
JAP_{EPU}	←	←	←	←		←	←	←	←	←	←	←	←		←	←	←	←			
UK_{EPU}			←	↔	→	↔	↔	↔	↔	←	←	←	↔	↔	↔	←	←	←			←
USA_{EPU}	←	↔	←	↔	↔	↔	↔	↔	↔	↔	↔	↔	↔	↔	↔	←	↔	←	↔	↔	↔
CAN_{GPR}										→			←			←					
GER_{GPR}				←			←							←	←				↔	↔	↔
FRA_{GPR}					←			←						↔							
ITA_{GPR}							←						←	←	←	←	←	←	←		
JAP_{GPR}		←	←		←	←	→	↔	↔	→	→	→		←	←					←	←
UK_{GPR}										→		→		←	←	←	←	←			
USA_{GPR}					→	←		→		→		→	←	←	←	←	→	←		←	←

Note: ←, →, and ↔ indicate that there is unidirectional causality from the variable in the row to the variable in the column, unidirectional causality from the variable in the column to the variable in the row, and bidirectional causality between the variables in the row and column, respectively.

effect. The Fourier approach does not need prior knowledge of the number, dates, and shapes of breaks, and it captures structural changes using a small number of low-frequency components (Banerjee et al., 2017). In addition, Omay (2015) found that a test that takes into account the Fourier approximation is robust for problems of nonlinearity in both deterministic and stochastic components at the same time. Enders and Lee (2012) defined the Fourier expansion as follows:

$$d(t) = a_0 + \sum_{k=1}^{n} a_k \sin\left(\frac{2\pi kt}{T}\right) + \sum_{k=1}^{n} \beta_k \cos\left(\frac{2\pi kt}{T}\right), n \leq \frac{T}{2}$$

where n is the number of frequencies, T is the sample size, t is the trend, $\pi = 3,14416$. On a side note, k shows the frequency for the approximation, which is calculated between 1 and 5, that minimizes the sum of residual squares. If $a_1 = \beta_1 = \ldots = a_n = \beta_n = 0$ is valid, the traditional unit root test needs to be used. Otherwise, there is a break or a non-linear slope, and the data generating process must include at least one Fourier frequency.

k emphasizes that the effect of structural breaks at integer frequencies is temporary, while fractional frequencies represent permanent breaks. The forms of frequencies determine whether the impacts of structural breaks on variables are temporary. Christopoulos and Leó'n-Ledesma (2010) stated that when k is not a fraction, using integer values of k will result in temporary breaks. Omay (2015) developed a fractional FADF unit root test that allows the frequency number to be estimated between 0.1 and 2 based on the FADF unit root test. The frequency range was improved by Bozoklu et al. (2020) to 0–5. Hence, the following equation can be used to determine whether a unit root exists:

$$\Delta y_t = \rho y_{t-1} + c_1 + c_2 t + c_3 \sin\left(\frac{2\pi k^{fr} t}{T}\right) + c_3 \cos\left(\frac{2\pi k^{fr} t}{T}\right) + e_t$$

In difference to the last equation, k^{fr} is added to this equation to represent a fractional frequency value between 0 and 5 that minimizes the sum of residual squares. Critical values for the test statistic are in Bozoklu et al. (2020). This test's asymptotic specification is identical to that of Enders and Lee (2012). As with the FADF unit root test, the critical values for testing the null hypothesis differ as to the frequency and sample size. The coefficients of the Fourier function and other deterministic terms do not affect the asymptotic distribution.

3.2. Fourier Granger Causality

Granger causality was one of the first tests developed in the literature on causality tests. This test is based on the Vector Autoregressive (VAR) system.

$$y_t = a_o + \sum_{i=1}^{n} \beta_i y_{t-i} + \varepsilon_t$$

In the above equation, y_t takes place endogenous variables, a_o is a vector of intercept terms, β are coefficient matrices, and, ε_t are white-noise residuals. Nevertheless, no structural changes are accounted for in Granger causality. Recent studies show that structural changes play an important role in causality analyses (Enders & Jones, 2016; Nazlioglu et al., 2016; Yilanci & Gorus, 2020). Enders and Jones (2016) showed using Monte Carlo simulations that the results of Granger causality analysis can be misspecification errors if structural breaks in the VAR model are ignored or not modelled. This can lead to rejecting the null hypothesis. These results not only highlight the significance of taking into account any structural changes, but they also call for careful consideration of how breaks are recorded.

Traditional approaches taking structural changes into account assume that the change is sharp and analyse it using dummy variables. Those approaches, however, cause significant challenge in determining the VAR model. Therefore, Enders and Jones (2016) suggested the Fourier approach that allows a smooth transition to control structural change. Thus, they developed the Fourier Granger causality test by adding Fourier terms to the standard VAR model in equation (1). Equation (4) express this.

$$y_t = a_o + a_1 sin\left(\frac{2\pi kt}{T}\right) + a_2 cos\left(\frac{2\pi kt}{T}\right) + \sum_{i=1}^{n} \beta_i y_{t-i} + \sum_{i=1}^{n} \gamma_i x_{t-i} + \varepsilon_t$$

where $sin\left(\frac{2\pi kt}{T}\right)$ and $cos\left(\frac{2\pi kt}{T}\right)$ are Fourier terms controlling smooth transition. Integer frequencies, according to k, indicate that the impacts of structural breaks are temporary, whereas fractional frequencies indicate that the impacts of structural breaks are permanent. Based on Christopoulos and Leó'n-Ledesma (2010), we added a fractional frequency to the Fourier Granger causality test, which equation can be written as follows:

$$y_t = a_o + a_1 \sin\left(\frac{2\pi k^{fr} t}{T}\right) + a_2 \cos\left(\frac{2\pi k^{fr} t}{T}\right) + \sum_{i=1}^{n} \beta_i y_{t-i} + \sum_{i=1}^{n} \gamma_i x_{t-i} + \varepsilon_t$$

Different from Fourier Granger causality, k^{fr} is added to above equation to represent a fractional frequency value between 0 and 5 that minimizes the sum of residual squares.

Enders and Jones (2016) asserted that changes in the way variables relate to each other are more likely to have happened over time than to be modelled as sharp shifts. They calculated that the flexible Fourier form has a reasonable size and power properties in the test of smooth structural change in the VAR model. Critical values are obtained by a bootstrap technique in order to increase the power of the test statistic.

In this study, structural changes and the application of Fourier approaches are taken into consideration for several reasons. Firstly, economic uncertainty and geopolitical risks arise from sudden changes in the country's security environment. In addition, the G-7 countries' SP values are highly volatile (Aydoğan et al., 2022; Chiang, 2019), COVID-19, in particular, has increased this volatility (Awan et al., 2021). It is therefore important to consider structural changes when investigating the relationship between variables. The reason for analysing these changes with Fourier functions, in addition to the previously mentioned advantages, is that it allows the significance of the structural change to be tested, and, unlike other tests, there is no restriction on the number of breaks.[1] Furthermore, Enders and Jones (2016) stress that the null hypothesis may be rejected and unreliable results may be found if breaks are not appropriately modelled, even in cases when a causal relationship exists.

On the other hand, this study analyses G-7 countries using time series techniques rather than panel data analyses. The main reason for this is that a change in any country affects the results of the panel. In this study, it is aimed at comparing the findings obtained by utilizing the individual characteristics of the countries and making more effective policy recommendations.

4. Data

We aim to investigate the relationship between stock market prices (SP), economic policy uncertainty and geopolitical risks of G-7 countries (Canada, Germany, France, Italy,

[1] The G-7 countries experienced numerous acts of terrorism, tensions, etc., as well as various economic and financial crises, such as the Mortgage crisis in 2001–2024.

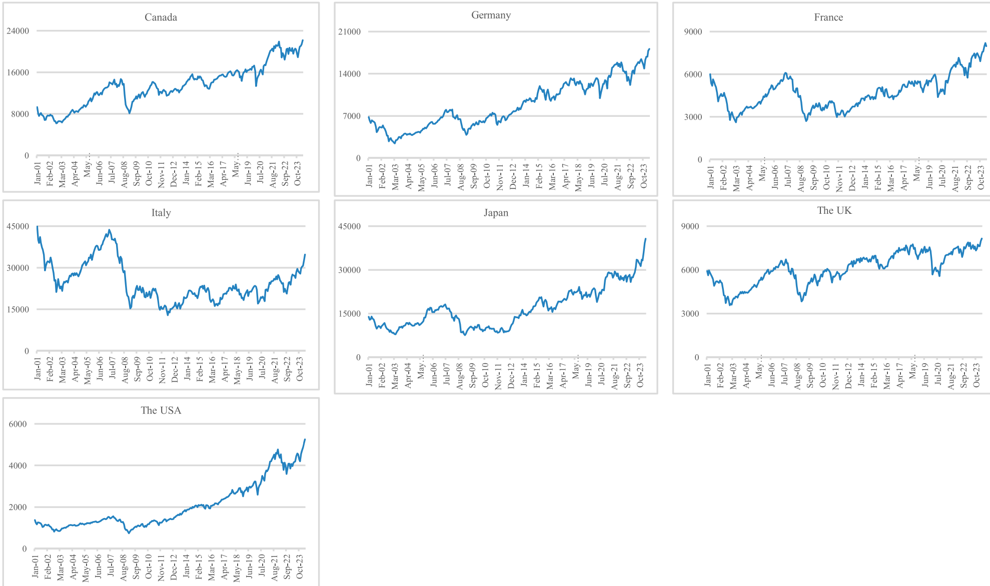

Figure 1. The stock market prices. Source: www.investing.com.

Japan, UK, USA). This investigation covered the monthly data set from January 2001 to April 2024. The period starts on the date of the SP of the UK and ends on the date of the most recent published EPU. The closing prices of the countries are found on www.investing.com, which uses data from the SP/TSX Composite for Canada, the DAX for Germany, the CAC 40 for France, the FTSE MIB for Italy, the NIKKEI 225 for Japan, the FTSE 100 for the UK, and the S&P 500 for the USA. The EPU and GPR were collected from www.policyuncertainty.com Diagnostic statistics are tabled in Table 3.

When we examine the diagnostic statistics in Table 3, we find that Italy has the highest SP value, while the USA has the lowest; the UK has the highest EPU value, while Japan has the lowest; on average, the USA has the highest GPR, while Italy has the lowest. When the standard deviation value is considered, for the SP, EPU, and GPR, the countries with the highest variability are Italy, Germany, and the USA, whereas the lowest are the UK, Japan, and Italy. Moreover, Skewness value is analysed, the other variables have positive asymmetry, except the UK_{SP}. On the other hand, CAN_{SP}, GER_{SP}, FRA_{SP}, ITA_{SP}, JAP_{SP}, the UK_{SP}, and the USA_{SP} have a playkurtic distribution, whereas the other series has a leptokurtic distribution, as shown by the kurtosis coefficients. Finally, according to the JB test statistic, all variables are normally distributed. The SP of the countries are shown in Figure 1.

Consideration of the SP in Figure 1 reveals that Italy and Japan have the highest values, while the United States has the lowest. It is clear that the global financial crisis and the COVID-19 epidemic had an effect on the SP of most countries. When the GPR of each country in Figure 2 is examined, we see that the United States and the UK are the countries with the highest risk, while Italy and Canada are the countries with the lowest risk. We additionally observed that the geopolitical risks for the G-7 nations abruptly increased in March 2003, when the Iraq War began, and also after the September 11 attacks. Moreover,

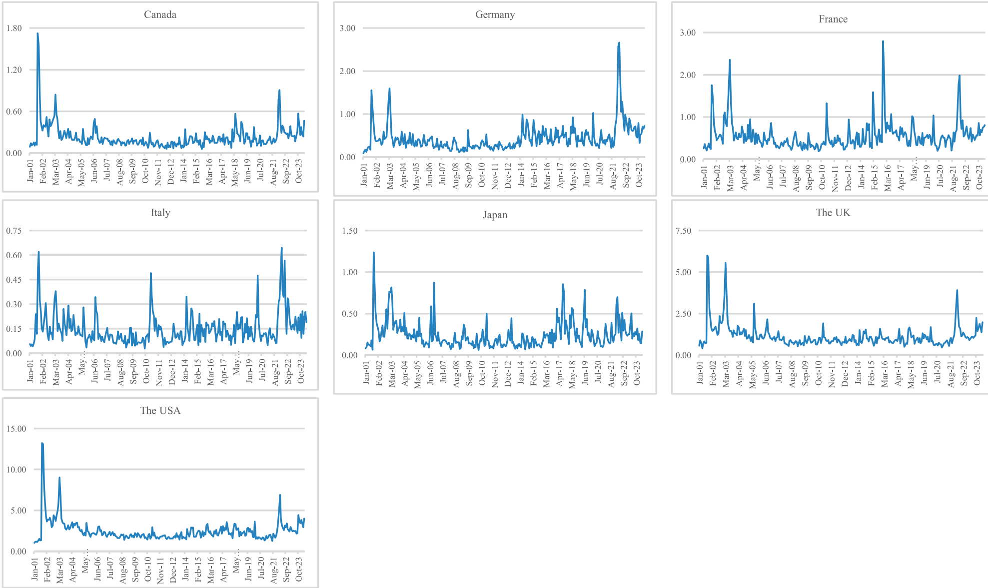

Figure 2. The geopolitical risk index. Source: www.policyuncertainty.com.

an increase has only been noticed in the United States since the Russia–Ukraine war. Examining of the EPU in Figure 3 demonstrates that, among the G-7 economies, Italy and Japan have the lowest level of uncertainty, while the UK and France have the highest levels. After the Brexit vote of the UK in 2016, it is apparent that the EPU has increased. The GPR and EPU showed a similar influence during COVID-19; both increased. It has been noticed that countries' economic uncertainty has been getting worse over the past few years. This is likely caused by the impact of the worldwide economic crisis.

5. Results

We used panel Fourier and Fractional Frequency Fourier Granger causality tests to investigate the causal relationship between the variables. Since these tests are primarily based on the Granger causality test, the variables are examined at their stationary level. In this context, we used the fractional Fourier unit root test to figure out the level of stationarity of the variables. The results obtained from the FFADF unit root test are given in Table 4.

In order to apply the FFADF unit root test, the trigonometric terms must be statistically significant. According to the results of the F statistics, since the trigonometric terms in GER_{SP}, FRA_{SP}, USA_{SP}, CAN_{EPU}, FRA_{EPU}, GER_{EPU}, ITA_{EPU}, UK_{EPU}, and CAN_{GPR} and UK_{GPR} variables were statistically significant, these variables were run by the FFADF unit root test. When trigonometric terms are statistically insignificant, the ADF unit root test is applied. Based on the results of the unit root test, we determined that CAN_{SP}, ITA_{SP}, JAP_{SP}, and UK_{SP} were stationary at the first difference and at the level of the others. We conducted the examination of causality at the level at which the variables are stationary.

This study aims to investigate the multidirectional relationship between the SP, EPU, and GPR of the G-7 countries. Hence, we bidirectionally investigated the causation between

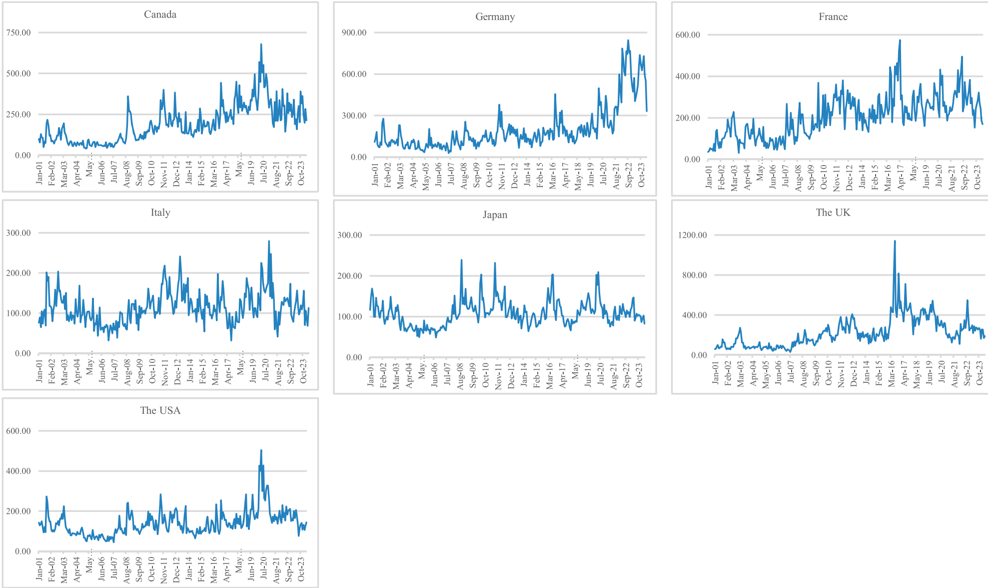

Figure 3. The economic policy uncertainty. Source: www.policyuncertainty.com.

each country's SP and its own and other countries' EPU and GPR. Linear VAR Granger, Fourier and Fractional Frequency Fourier Granger Causality test results for the G-7 countries are shown in the Tables 6–12 in the Appendix. Given the causality test results, the results of both Fourier tests and VAR Granger generally overlap with each other, especially the EPU. Furthermore, a unidirectional statistically significant causality from the SP of the countries to the EPU is more common. This causality runs in reverse from the UK_{EPU} to GER_{SP}, from ITA_{EPU} to JAP_{SP}, and from GER_{EPU} to JAP_{SP}.

Moreover, we discovered a statistically significant bidirectional causality between the SP and EPU values of some countries. We calculated bidirectional causalities between USA_{EPU} and SP of all countries and between GER_{EPU} and all countries except GER_{SP} and USA_{SP}. Moreover, CAN_{EPU} has bidirectional causalities between most countries' SP. The results obtained are in line with Ajmi et al. (2015). Although G-7 countries are evaluated in this study, changes in the economic, social and political structures of countries may affect the impact processes and directions in different ways. For this reason, the fact that the results obtained in our study differ across countries is similar to Phan et al. (2018), Das and Kumar (2018), Karacaer Ulusoy and Pirgaip (2019) and Bahmani-Oskooee and Saha (2019).

According to Table 5, GER_{SP} has the most bidirectional relationship among other G-7, there is only a unidirectional relationship with JAP_{EPU}. Similarly in FRA_{SP} and JAP_{SP}, it has generally bidirectional relationship with EPU values. Unlike others SP, there is a bidirectional relationship from ITA_{EPU} to JAP_{SP}. The UK, on the other hand, is found to have a bidirectional relationship only with GER_{EPU} and a unidirectional relationship with other countries from UK_{SP} to other countries' EPU. USA_{SP} is the only country there is no relationship with JAP_{EPU}, has at least a one-way relationship other countries' EPU.

Examining how the geopolitical risk affects the price of stocks, we found no a similar kind of general causality direction like the EPU. Especially when tests with the Fourier term are taken into account, it is determined that the GPR values of Japan and the USA affect other countries' the SP. Based on our empirical results, it can be claimed that the relationship between geopolitical concerns of the countries and their SP differs depending on how that country is seen to be at risk.

Under structural change, there was no significant correlation between CAN_{GPR} and other countries and JAP_{GPR} is affected by JAP_{SP} and USA_{SP}. CAN_{SP} has the least relationship with the GPR of other countries. This indicates that the relationship between the Canadian stock market and the risks in other countries is a weak. On the other hand, while JAP_{SP} is the value that affects on other countries' GPR the most, ITA_{SP} is the country most affected by the GPR of other countries. In these countries, the relationship between stock markets and risk levels is stronger affected by the GPR of other countries. Japan is the country with the highest stock price after Italy and more stable than Italy. Germany, on the other hand, is the country with the fastest rising GPR in recent periods.

The EPU and GPR can be compared, and it is clear that the former has a stronger impact on the SP. This is not surprising, as the G-7 is made up of countries that control the majority of total global capital, so they are also economically influenced by each other. Particularly, we found that the stock markets of G-7 countries had a significant impact on the economic policy uncertainty of themselves or of other countries. We observed similar results when we analysed geopolitical risk. In this context, it can be stated that the SP of countries have an impact on economic policy uncertainty and geopolitical risk. On the other hand, FGC and FFGC test results supported each other under the EPU, while we found reverse causality results when the EPU is considered.

6. Conclusions

The countries of the world are interconnected with each other due to the effect of globalization. It has become quite easy for economic, social, political and cultural changes in countries to spread to other countries. In 2008, the Mortgage Crisis in the US had repercussions on other countries of the world. Economic and political uncertainties, especially in developed countries, have a direct impact on the investment decisions of financial market traders, causing the usual course of the economy to change. Likewise, a change in a country's geopolitical position has the power to affect the financial market.

This paper tries to answer how the relationship between economic policy uncertainty, geopolitical risks, and stock markets changes. The G-7 countries are the highest proportion of the global financial market. For this purpose, we investigate the bidirectional relationship between the EPU and GPR variables with SP in this study. The main weaknesses of the existing empirical literature are that it examines the relationship in one direction only (from the EPU and GPR to the SP) and does not take into account these structural changes. The current period has experienced structural changes, including the 2008 global financial crisis and the COVID-19 pandemic. That is why considering structural changes plays an essential role in ensuring the reliability of empirical findings and the efficacy of policy suggestions.

The results of the linear VAR Granger causality tests are generally the same Fourier Causality tests. Fourier Causality test results can be summarized in three categories. First, the analysis of the relationship between EPU and SP revealed a causality, consistent with existing literature. Our results corroborate the research by Baker et al. (2016), Bahmani-Oskooee and Saha (2019), and Mei et al. (2018). We also note that the SP in G-7 countries had a stronger impact on the EPU of the host country and other countries. Second, we investigated how GPR and SP relate to one another. Our findings that the GPR had an impact on the SP are in line with previous research by Balcilar et al. (2018b), Boungou and Yatié (2022). Furthermore, we found a more robust causality relationship from the SP to the GPR. Third, the research findings indicate that the stock markets in G-7 nations are influenced not only by domestic risk and uncertainty factors but also by the risk and uncertainty factors prevalent in other G-7 countries. Fourth, in comparing the relationship between the SP and the EPU and GPR indicators, we determined similarly to Kannadhasan and Das (2020) that the connections between the EPU and the SP in G-7 were statistically stronger.

Our empirical findings show that a mutual influence between the stock markets of countries and the risk and uncertainty levels of other countries. The risk and uncertainty levels of countries are influenced by the stock markets of other countries and vice versa. Policymakers can reduce risks and uncertainties at both local and global levels by improving financial market strength and decreasing fragility.

Our study has some restrictions that should be understood. One is the time period. We aimed to encompass the relationship between the variables throughout the broadest period possible. Nevertheless, in some G-7 countries, available data are limited to the current period. Furthermore, given the results of our unit root tests, the variables under consideration did not comply with I(1) of the criteria, so we could not apply cointegration tests. For this reason, we could not determine the direction of the relationship. Potential future research can investigate both developed and developing financial markets using panel data analyses to ascertain which market type or structure is impacted by risks and uncertainties.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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References

Adebayo, T. S., Akadiri, S., & Rjoub, H. (2022). On the relationship between economic policy uncertainty, geopolitical risk and stock market returns in South Korea: A quantile causality analysis. *Annals of Financial Economics*, *17*(1), 1–19. https://doi.org/10.1142/S2010495222500087

Agoraki, M. E. K., Kouretas, G. P., & Laopodis, N. T. (2022). Geopolitical risks, uncertainty, and stock market performance. *Economic and Political Studies*, *10*(3), 253–265. https://doi.org/10.1080/20954816.2022.2095749

Ajmi, A. N., Aye, G. C., Balcilar, M., El Montasser, G., & Gupta, R. (2015). Causality between US economic policy and equity market uncertainties: Evidence from linear and nonlinear tests. *Journal of Applied Economics*, *18*(2), 225–246. https://doi.org/10.1016/S1514-0326(15)30010-6

Albrecht, P., Kapounek, S., & Kučerová, Z. (2023). Economic policy uncertainty and stock markets' co-movements. *International Journal of Finance & Economics*, *28*(4), 3471–3487. https://doi.org/10.1002/ijfe.2603

Alexopoulos, M., & Cohen, J. (2015). The power of print: Uncertainty shocks, markets and the economy. *International Review of Economics & Finance*, *40*, 8–28. https://doi.org/10.1016/j.iref.2015.02.002

Antonakakis, N., Chatziantoniou, I., & Filis, G. (2013). Dynamic co-movements of stock market returns, implied volatility and policy uncertainty. *Economics Letters*, *120*(1), 87–92. https://doi.org/10.1016/j.econlet.2013.04.004

Apergis, E., & Apergis, N. (2016). The 11/13 Paris terrorist attacks and stock prices: The case of the international defense industry. *Finance Research Letters*, *17*, 186–119. https://doi.org/10.1016/j.frl.2016.03.002

Arouri, M., Estay, C., Rault, C., & Roubaud, D. (2016). Economic policy uncertainty and stock markets: Long-run evidence from the US. *Finance Research Letters*, *18*, 136–141. https://doi.org/10.1016/j.frl.2016.04.011

Asgharian, H., & Nossman, M. (2013). Financial and economic integration's impact on Asian equity markets' sensitivity to external shocks. *Financial Review*, *48*(2), 343–363. https://doi.org/10.1111/fire.12006

Awan, T. M., Khan, M. S., Haq, I. U., & Kazmi, S. (2021). Oil and stock markets volatility during pandemic times: A review of G7 countries. *Green Finance*, *3*(1), 15–27. https://doi.org/10.3934/GF.2021002

Aydın, M., Pata, U. K., & Inal, V. (2022). Economic policy uncertainty and stock prices in BRIC countries: Evidence from asymmetric frequency domain causality approach. *Applied Economic Analysis*, *30*(89), 114–129. https://doi.org/10.1108/AEA-12-2020-0172

Aydoğan, B., Vardar, G., & Taçoğlu, C. (2022). Volatility spillovers among G7, E7 stock markets and cryptocurrencies. *Journal of Economic and Administrative Sciences*, 1026–4116. https://doi.org/10.1108/JEAS-09-2021-0190

Bahmani-Oskooee, M., & Saha, S. (2019). On the effects of policy uncertainty on stock prices: An asymmetric analysis. *Quantitative Finance and Economics*, *3*(2), 412–424. https://doi.org/10.3934/QFE.2019.2.412

Baker, S. R., Bloom, N., & Davis, S. J. (2012). Has economic policy uncertainty hampered the recovery? *Becker Friedman Institute for Research in Economics, Working Paper*, *242*, 1–12.

Baker, S. R., Bloom, N., & Davis, S. J. (2016). Measuring economic policy uncertainty. *The Quarterly Journal of Economics*, *131*(4), 1593–1636. https://doi.org/10.1093/qje/qjw024

Balcilar, M., Bonato, M., Demirer, R., & Gupta, R. (2018a). Geopolitical risks and stock market dynamics of the BRICS. *Economic Systems*, *42*(2), 295–306. https://doi.org/10.1016/j.ecosys.2017.05.008

Balcilar, M., Gupta, R., Pierdzioch, C., & Wohar, M. E. (2018b). Terror attacks and stock-market fluctuations: Evidence based on a nonparametric causality-in-quantiles test for the G7 countries. *The European Journal of Finance*, *24*(4), 333–346. https://doi.org/10.1080/1351847X.2016.1239586

Banerjee, P., Arčabić, V., & Lee, H. (2017). Fourier ADL cointegration test to approximate smooth breaks with new evidence from crude oil market. *Economic Modelling*, *67*, 114–124. https://doi.org/10.1016/j.econmod.2016.11.004

Bansal, R., Khatchatrian, V., & Yaron, A. (2005). Interpretable asset markets? *European Economic Review*, *49*(3), 531–560. https://doi.org/10.1016/j.euroecorev.2004.09.002

Bekiros, S., Gupta, R., & Kyei, C. (2016). On economic uncertainty, stock market predictability and nonlinear spillover effects. *The North American Journal of Economics and Finance*, *36*, 184–191. https://doi.org/10.1016/j.najef.2016.01.003

Bloom, N. (2014). Fluctuations in uncertainty. *Journal of Economic Perspectives*, *28*(2), 153–176. https://doi.org/10.1257/jep.28.2.153

Bossman, A., Gubareva, M., & Teplova, T. (2023a). EU sectoral stocks amid geopolitical risk, market sentiment, and crude oil implied volatility: An asymmetric analysis of the Russia–Ukraine tensions. *Resources Policy*, *82*, 103515. https://doi.org/10.1016/j.resourpol.2023.103515

Bossman, A., Gubareva, M., & Teplova, T. (2023b). Economic policy uncertainty, geopolitical risk, market sentiment, and regional stocks: Asymmetric analyses of the EU sectors. *Eurasian Economic Review*, *13*(3), 321–372. https://doi.org/10.1007/s40822-023-00234-y

Boungou, W., & Yatié, A. (2022). The impact of the Ukraine–Russia war on world stock market returns. *Economics Letters*, *215*, 1–3. https://doi.org/10.1016/j.econlet.2022.110516

Bouras, C., Christou, C., Gupta, R., & Suleman, T. (2019). Geopolitical risks, returns, and volatility in emerging stock markets: Evidence from a panel GARCH model. *Emerging Markets Finance and Trade*, *55*(8), 1841–1856. https://doi.org/10.1080/1540496X.2018.1507906
Bozoklu, S., Yilanci, V., & Gorus, M. S. (2020). Persistence in per capita energy consumption: A fractional integration approach with a Fourier function. *Energy Economics*, *91*, 1–12. https://doi.org/10.1016/j.eneco.2020.104926
Caldara, D., & Iacoviello, M. (2018). Measuring geopolitical risk. *FRB International Finance Discussion Paper*, *1222*, 1–66. https://doi.org/10.17016/IFDP.2018.1222
Caldara, D., & Iacoviello, M. (2022). Measuring geopolitical risk. *American Economic Review*, *112*(4), 1194–1225. https://doi.org/10.1257/aer.20191823
Chang, T., Chen, W. Y., Gupta, R., & Nguyen, D. K. (2015). Are stock prices related to the political uncertainty index in OECD countries? Evidence from the bootstrap panel causality test. *Economic Systems*, *39*(2), 288–300. https://doi.org/10.1016/j.ecosys.2014.10.005
Chen, X., & Chiang, T. C. (2020). Empirical investigation of changes in policy uncertainty on stock returns – Evidence from China's market. *Research in International Business and Finance*, *53*, 1–19. https://doi.org/10.1016/j.ribaf.2020.101183
Chiang, T. C. (2019). Economic policy uncertainty, risk and stock returns: Evidence from G7 stock markets. *Finance Research Letters*, *29*, 41–49. https://doi.org/10.1016/j.frl.2019.03.018
Christopoulos, D. K., & León-Ledesma, M. A. (2010). Smooth breaks and non-linear mean reversion: Post-Bretton woods real exchange rates. *Journal of International Money and Finance*, *29*(6), 1076–1093. https://doi.org/10.1016/j.jimonfin.2010.02.003
Christou, C., Cunado, J., Gupta, R., & Hassapis, C. (2017). Economic policy uncertainty and stock market returns in PacificRim countries: Evidence based on a Bayesian panel VAR model. *Journal of Multinational Financial Management*, *40*, 92–102. https://doi.org/10.1016/j.mulfin.2017.03.001
Costola, M., Donadelli, M., Gerotto, L., & Gufler, I. (2022). Global risks, the macroeconomy, and asset prices. *Empirical Economics*, *63*(5), 2357–2388. https://doi.org/10.1007/s00181-022-02205-9
Darsono, S. N. A. C., Wong, W. K., Nguyen, T. T. H., & Wardani, D. T. K. (2022). The economic policy uncertainty and its effect on sustainable investment: A panel ARDL approach. *Journal of Risk and Financial Management*, *15*(6), 1–17. https://doi.org/10.3390/jrfm15060254
Das, D., Kannadhasan, M., & Bhattacharyya, M. (2019). Do the emerging stock markets react to international economic policy uncertainty, geopolitical risk and financial stress alike? *The North American Journal of Economics and Finance*, *48*, 1–19. https://doi.org/10.1016/j.najef.2019.01.008
Das, D., & Kumar, S. B. (2018). International economic policy uncertainty and stock prices revisited: Multiple and partial wavelet approach. *Economics Letters*, *164*, 100–108. https://doi.org/10.1016/j.econlet.2018.01.013
Dash, S. R., Maitra, D., Debata, B., & Mahakud, J. (2021). Economic policy uncertainty and stock market liquidity: Evidence from G7 countries. *International Review of Finance*, *21*(2), 611–626. https://doi.org/10.1111/irfi.12277
Dimson, E., Marsh, P., & Staunton, M. (2022). *Credit suisse global investment returns yearbook 2022 (Summary edition)*. Credit Suisse Research Institute.
Enders, W., & Jones, P. (2016). Grain prices, oil prices, and multiple smooth breaks in a VAR. *Studies in Nonlinear Dynamics & Econometrics*, *20*(4), 399–419. https://doi.org/10.1515/snde-2014-0101
Enders, W., & Lee, J. (2012). The flexible Fourier form and dickey–fuller type unit root tests. *Economics Letters*, *117*(1), 196–199. https://doi.org/10.1016/j.econlet.2012.04.081
Erdoğan, L., Ceylan, R., & Abdul-Rahman, M. (2022). The impact of domestic and global risk factors on Turkish stock market: Evidence from the NARDL approach. *Emerging Markets Finance and Trade*, *58*(7), 1961–1974. https://doi.org/10.1080/1540496X.2021.1949282
Gemici, E. (2020). Ekonomi politikası belirsizliği ile G7 ülke borsaları arasındaki ilişki. *Bingöl Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, *20*, 353–372. https://doi.org/10.29029/busbed.732124
Ghani, M., & Ghani, U. (2023). Economic policy uncertainty and emerging stock market volatility. *Asia-Pacific Financial Markets*, 1–17. https://doi.org/10.1007/s10690-023-09410-1

Hasan, M., Naeem, M. A., Arif, M., Shahzad, S. J. H., & Nor, S. M. (2020). Role of economic policy uncertainty in the connectedness of cross-country stock market volatilities. *Mathematics*, *8*(11), 2–17. https://doi.org/10.3390/math8111904

Hassan, M. K., Bossman, A., Choudhury, T., & Gider, Z. (2022). Sensitivity of African stock markets to geopolitical conflicts: A time-frequency evidence from the Russian-Ukrainian military conflict. https://papers.ssrn.com/sol3/papers.cfm?abstract_id = 4183193.

Hoque, M. E., & Zaidi, M. A. S. (2020). Global and country-specific geopolitical risk uncertainty and stock return of fragile emerging economies. *Borsa Istanbul Review*, *20*(3), 197–213. https://doi.org/10.1016/j.bir.2020.05.001

Hua, R., Zhao, P., Yu, H., & Fang, L. (2020). Impact of US uncertainty on Chinese stock market volatility. *Emerging Markets Finance and Trade*, *56*(3), 576–592. https://doi.org/10.1080/1540496X.2018.1519413

IMF. (2022). World economic outlook, https://www.imf.org/external/datamapper/PPPSH@WEO/MAE?year = 2021.

Jung, S., Lee, J., & Lee, S. (2021). The impact of geopolitical risk on stock returns: Evidence from inter-Korea geopolitics. IMF Working Papers, 1-36.

Kang, W., & Ratti, R. A. (2013). Oil shocks, policy uncertainty and stock market return. *Journal of International Financial Markets, Institutions and Money*, *26*, 305–318. https://doi.org/10.1016/j.intfin.2013.07.001

Kannadhasan, M., & Das, D. (2020). Do Asian emerging stock markets react to international economic policy uncertainty and geopolitical risk alike? A quantile regression approach. *Finance Research Letters*, *34*, 1–7. https://doi.org/10.1016/j.frl.2019.08.024

Karacaer Ulusoy, M., & Pirgaip, B. (2019). The causal relationship between economic policy uncertainty and stock market returns. *Atatürk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, *23*(4), 2239–2251. https://dergipark.org.tr/en/pub/ataunisosbil/issue/51800/626812.

Khojah, M., Ahmed, M., Khan, M. A., Haddad, H., Al-Ramahi, N. M., & Khan, M. A. (2023). Economic policy uncertainty and stock market in G7 Countries: A panel threshold effect perspective. *PLoS One*, *18*(7), e0288883. https://doi.org/10.1371/journal.pone.0288883

Kundu, S., & Paul, A. (2022). Effect of economic policy uncertainty on stock market return and volatility under heterogeneous market characteristics. *International Review of Economics & Finance*, *80*, 597–612. https://doi.org/10.1016/j.iref.2022.02.047

Lee, K. (2023). Geopolitical risk and household stock market participation. *Finance Research Letters*, *51*, 1–7. https://doi.org/10.1016/j.frl.2022.103328

Li, X. L., Balcilar, M., Gupta, R., & Chang, T. (2016). The causal relationship between economic policy uncertainty and stock returns in China and India: Evidence from a bootstrap rolling window approach. *Emerging Markets Finance and Trade*, *52*(3), 674–689. https://doi.org/10.1080/1540496X.2014.998564

Li, T., Ma, F., Zhang, X., & Zhang, Y. (2020). Economic policy uncertainty and the Chinese stock market volatility: Novel evidence. *Economic Modelling*, *87*, 24–33. https://doi.org/10.1016/j.econmod.2019.07.002

Li, X. M., & Peng, L. (2017). US economic policy uncertainty and co-movements between Chinese and US stock markets. *Economic Modelling*, *61*, 27–39. https://doi.org/10.1016/j.econmod.2016.11.019

Liang, C. C., Troy, C., & Rouyer, E. (2020). U.S. uncertainty and Asian stock prices: Evidence from the asymmetric NARDL model. *North American Journal of Economics and Finance*, *5*, 1–26. https://doi.org/10.1016/j.najef.2019.101046

Liu, L., & Zhang, T. (2015). Economic policy uncertainty and stock market volatility. *Finance Research Letters*, *15*, 99–105. https://doi.org/10.1016/j.frl.2015.08.009

Ma, F., Wahab, M. I. M., Liu, J., & Liu, L. (2018). Is economic policy uncertainty important to forecast the realized volatility of crude oil futures? *Applied Economics*, *50*(18), 2087–2101. https://doi.org/10.1080/00036846.2017.1388909

Mei, D., Zeng, Q., Zhang, Y., & Hou, W. (2018). Does US economic policy uncertainty matter for European stock markets volatility? *Physica A: Statistical Mechanics and its Applications*, *512*, 215–221. https://doi.org/10.1016/j.physa.2018.08.019

Mensi, W., Gubareva, M., Ko, H.-U., Vo, X. V., & Kang, S. H. (2023). Tail spillover effects between cryptocurrencies and uncertainty in the gold, oil, and stock markets. *Financial Innovation*, *9*(1), 92. https://doi.org/10.1186/s40854-023-00498-y

Naeem, M. A., Farid, S., Nor, S. M., & Shahzad, S. J. H. (2021). Spillover and drivers of uncertainty among oil and commodity markets. *Mathematics*, *9*(41), 1–26. https://doi.org/10.3390/math9040441

Nazlioglu, S., Gormus, N. A., & Soytas, U. (2016). Oil prices and real estate investment trusts (REITs): Gradual-shift causality and volatility transmission analysis. *Energy Economics*, *60*, 168–175. https://doi.org/10.1016/j.eneco.2016.09.009

Omay, T. (2015). Fractional frequency flexible Fourier form to approximate smooth breaks in unit root testing. *Economics Letters*, *134*, 123–126. https://doi.org/10.1016/j.econlet.2015.07.010

Phan, D. H. B., Sharma, S. S., & Tran, V. T. (2018). Can economic policy uncertainty predict stock returns? Global evidence. *Journal of International Financial Markets, Institutions and Money*, *55*, 134–150. https://doi.org/10.1016/j.intfin.2018.04.004

Poon, S. H., & Granger, C. W. J. (2003). Forecasting volatility in financial markets: A review. *Journal of Economic Literature*, *41*(2), 478–539. https://doi.org/10.1257/jel.41.2.478

Şahin, E. E., & Arslan, H. (2021). An analysis of the effects of geopolitical risks on stock returns and exchange rates using a nonparametric method. *Muhasebe ve Finansman Dergisi*, *89*(89), 237–250. https://doi.org/10.25095/mufad.852174

Sansa, N. A. (2020). The impact of the COVID-19 on the financial markets: Evidence from China and USA. *Electronic Research Journal of Social Sciences and Humanities*, *2*(2), 29–39. https://ssrn.com/abstract = 3562530.

Sharif, A., Aloui, C., & Yarovaya, L. (2020). COVID-19 pandemic, oil prices, stock market, geopolitical risk and policy uncertainty nexus in the US economy: Fresh evidence from the wavelet-based approach. *International Review of Financial Analysis*, *70*, 1–9. https://doi.org/10.1016/j.irfa.2020.101496

Si, D. K., Zhao, B., Li, X. L., & Ding, H. (2021). Policy uncertainty and sectoral stock market volatility in China. *Economic Analysis and Policy*, *69*, 557–573. https://doi.org/10.1016/j.eap.2021.01.006

Škrinjarić, T., & Orlović, Z. (2020). Economic policy uncertainty and stock market spillovers: Case of selected CEE markets. *Mathematics*, *8*(7), 1077. https://doi.org/10.3390/math8071077

Su, Z., Fang, T., & Yin, L. (2019). Understanding stock market volatility: What is the role of US uncertainty? *The North American Journal of Economics and Finance*, 582–590. https://doi.org/10.1016/j.najef.2018.07.014

Sum, V. (2012a). Economic policy uncertainty and stock market performance: Evidence from the European Union, Croatia, Norway, Russia, Switzerland, Turkey and Ukraine. *Journal of Money, Investment and Banking*, *25*, 99–104. https://doi.org/10.2139/ssrn.2094175

Sum, V. (2012b). The impulse response function of economic policy uncertainty and stock market returns: a look at the Eurozone. *Journal of International Finance Studies*, *12*, 100–105. https://doi.org/10.2139/ssrn.2088700

Tajaddini, R., & Gholipour, H. F. (2023). Trade dependence and stock market reaction to the Russia-Ukraine war. *International Review of Finance*, 1–12. https://doi.org/10.1111/irfi.12414

Tissot, B. (2016). Globalisation and financial stability risks: Is the residency-based approach of the national accounts old-fashioned? *BIS Working Paper*, 587. https://ssrn.com/abstract = 2857775.

Umar, Z., Polat, O., Choi, S. Y., & Teplova, T. (2022). The impact of the Russia-Ukraine conflict on the connectedness of financial markets. *Finance Research Letters*, *48*, 102976. https://doi.org/10.1016/j.frl.2022.102976

Wu, T. P., Liu, S. B., & Hsueh, S. J. (2016). The causal relationship between economic policy uncertainty and stock market: A panel data analysis. *International Economic Journal*, *30*(1), 109–122. https://doi.org/10.1080/10168737.2015.1136668

Yao, C. Z., & Sun, B. Y. (2018). The study on the tail dependence structure between the economic policy uncertainty and several financial markets. *The North American Journal of Economics and Finance*, *45*, 245–265. https://doi.org/10.1016/j.najef.2018.03.005

Yilanci, V., & Gorus, M. S. (2020). Does economic globalization have predictive power for ecological footprint in MENA counties? A panel causality test with a Fourier function. *Environmental Science and Pollution Research*, *27*(32), 40552–40562. https://doi.org/10.1007/s11356-020-10092-9

Yu, H., Fang, L., & Sun, W. (2018). Forecasting performance of global economic policy uncertainty for volatility of Chinese stock market. *Physica A: Statistical Mechanics and Its Applications*, *505*, 931–940. https://doi.org/10.1016/j.physa.2018.03.083

Zeng, Q., Lu, X., Dong, D., & Li, P. (2022). Category-specific EPU indices, macroeconomic variables and stock market return predictability. *International Review of Financial Analysis*, *84*, 102353. https://doi.org/10.1016/j.irfa.2022.102353

Zeng, Q., Tang, Y., Yang, H., & Zhang, X. (2023). Stock market volatility and economic policy uncertainty: New insight into a dynamic threshold mixed-frequency model. *Finance Research Letters*, 104714. https://doi.org/10.1016/j.frl.2023.104714

Zhang, Y., He, J., He, M., & Li, S. (2023). Geopolitical risk and stock market volatility: A global perspective. *Finance Research Letters*, *53*, 103620. https://doi.org/10.1016/j.frl.2022.103620

Zhang, D., Hu, M., & Ji, Q. (2020). Financial markets under the global pandemic of COVID-19. *Finance Research Letters*, *36*, 1–6. https://doi.org/10.1016/j.frl.2020.101528

Zhou, D., & Jiang, Y. (2020). Research on the relationship between China's economic policy uncertainty and stock market. *Journal of Financial Risk Management*, *9*(4), 462–479. https://doi.org/10.4236/jfrm.2020.94025

Appendix

Table 6. Results for Canada.

	Granger causality tests		Fourier Granger causality tests			Fourier fractional frequency Granger causality tests		
	Test stat	Optimal lag length	Test stat	Optimal lag length	Optimal freq	Test stat	Optimal lag length	Optimal freq
$CAN_{EPU} \rightarrow CAN_{SP}$	4.62*	2	1.19	1	3	0.04	1	0.8
$CAN_{SP} \rightarrow CAN_{EPU}$	14.56***	2	11.94***	1	3	4.37***	1	0.8
$GER_{EPU} \rightarrow CAN_{SP}$	5.58	4	0.81	1	1	0.72	1	0.8
$CAN_{SP} \rightarrow GER_{EPU}$	8.94*	4	14.01***	1	1	12.64***	1	0.8
$FRA_{EPU} \rightarrow CAN_{SP}$	0.02	1	1.06	2	1	0.01	1	0.8
$CAN_{SP} \rightarrow FRA_{EPU}$	7.78***	1	19.90***	2	1	0.11***	1	0.8
$ITA_{EPU} \rightarrow CAN_{SP}$	3.04	2	2.37	2	3	1.49	1	0.8
$CAN_{SP} \rightarrow ITA_{EPU}$	10.68***	2	11.87***	2	3	10.82***	1	0.8
$JAP_{EPU} \rightarrow CAN_{SP}$	0.13	1	2.72	2	3	0.00	1	0.8
$CAN_{SP} \rightarrow JAP_{EPU}$	10.67***	1	16.43***	2	3	11.64***	1	0.8
$UK_{EPU} \rightarrow CAN_{SP}$	6.23	1	2.23	1	1	0.72	1	0.8
$CAN_{SP} \rightarrow UK_{EPU}$	3.12	1	0.00	1	1	4.54**	1	0.8
$USA_{EPU} \rightarrow CAN_{SP}$	5.38	2	3.98*	2	3	1.09	1	0.8
$CAN_{SP} \rightarrow USA_{EPU}$	21.57***	2	20.64***	2	3	2.44*	1	0.8
$CAN_{GPR} \rightarrow CAN_{SP}$	0.05	1	11.64	9	1	0.02	1	0.8
$CAN_{SP} \rightarrow CAN_{GPR}$	0.13	1	2.22	9	1	1.32	1	0.8
$GER_{GPR} \rightarrow CAN_{SP}$	0.57	1	0.59	1	1	1.63	1	0.8
$CAN_{SP} \rightarrow GER_{GPR}$	0.82	1	2.28	1	1	1.06	1	0.8
$FRA_{GPR} \rightarrow CAN_{SP}$	0.97	1	0.79	1	1	1.34	1	0.8
$CAN_{SP} \rightarrow FRA_{GPR}$	0.28	1	2.82	1	1	1.39	1	0.8
$ITA_{GPR} \rightarrow CAN_{SP}$	1.29	1	1.41	1	1	1.41	1	0.8
$CAN_{SP} \rightarrow ITA_{GPR}$	0.02	1	0.67	1	1	0.59	1	0.8
$JAP_{GPR} \rightarrow CAN_{SP}$	0.27	1	0.23	1	1	0.17	1	0.8
$CAN_{SP} \rightarrow JAP_{GPR}$	0.42	1	5.26**	1	1	5.33**	1	0.8
$UK_{GPR} \rightarrow CAN_{SP}$	0.01	1	0.02	1	1	0.01	1	0.8
$CAN_{SP} \rightarrow UK_{GPR}$	0.02	1	2.49	1	1	1.19	1	0.8
$USA_{GPR} \rightarrow CAN_{SP}$	0.03	1	8.88	9	1	0.00	1	0.8
$CAN_{SP} \rightarrow USA_{GPR}$	0.15	1	7.4	9	1	3.16	1	0.8

Note: *, **, and *** denote significance at 1%, 5%, and 10% levels, respectively. For critical values of the F Stat and FADF unit root test stat, please see Enders and Lee (2012), and Bozoklu et al. (2020), respectively.

Table 7. Results for Germany.

	Granger causality tests		Fourier Granger causality tests			Fourier fractional frequency Granger causality tests		
	Test stat	Optimal lag length	Test stat	Optimal lag length	Optimal freq	Test stat	Optimal lag length	Optimal freq
$CAN_{EPU} \rightarrow GER_{SP}$	7.74*	3	11.18**	3	3	3.53**	1	0.8
$GER_{SP} \rightarrow CAN_{EPU}$	48.15***	3	60.24***	3	3	6.17**	1	0.8
$GER_{EPU} \rightarrow GER_{SP}$	5.39*	2	6.74***	1	2	6.84***	1	0.8
$GER_{SP} \rightarrow GER_{EPU}$	27.09***	2	15.18***	1	2	2.68*	1	0.8
$FRA_{EPU} \rightarrow GER_{SP}$	4.75*	2	4.69*	2	1	2.79	1	0.8
$GER_{SP} \rightarrow FRA_{EPU}$	28.01***	2	18.29***	2	1	1.91	1	0.8
$ITA_{EPU} \rightarrow GER_{SP}$	7.63**	2	8.32**	2	3	1.92	1	0.8
$GER_{SP} \rightarrow ITA_{EPU}$	15.88***	2	29.17***	2	3	22.18***	1	0.8
$JAP_{EPU} \rightarrow GER_{SP}$	1.98	2	0.92	1	3	0.01	1	0.8
$GER_{SP} \rightarrow JAP_{EPU}$	10.6**	2	0.04	1	3	2.78*	1	0.8
$UK_{EPU} \rightarrow GER_{SP}$	10.08**	4	8.14***	1	1	3.87**	1	0.8
$GER_{SP} \rightarrow UK_{EPU}$	9.44**	4	0.28	1	1	8.41***	1	0.8
$USA_{EPU} \rightarrow GER_{SP}$	8.42**	2	10.42***	2	3	5.44**	1	0.8
$GER_{SP} \rightarrow USA_{EPU}$	22.21***	2	27.29***	2	3	6.71***	1	0.8
$CAN_{GPR} \rightarrow GER_{SP}$	0.21	1	5.42	9	1	0.33	1	0.8
$GER_{SP} \rightarrow CAN_{GPR}$	0.01	1	5.23	9	1	0.76	1	0.8
$GER_{GPR} \rightarrow GER_{SP}$	0.09	1	0.05	1	1	0.16	1	0.8
$GER_{SP} \rightarrow GER_{GPR}$	7.17***	1	1.32	1	1	0.43	1	0.8
$FRA_{GPR} \rightarrow GER_{SP}$	0.84	1	1.09	1	2	1.39	1	0.8
$GER_{SP} \rightarrow FRA_{GPR}$	0.72	1	3.43*	1	2	1.12	1	0.8
$ITA_{GPR} \rightarrow GER_{SP}$	0.01	1	0.00	1	1	0.03	1	0.8
$GER_{SP} \rightarrow ITA_{GPR}$	2.08	1	0.04	1	1	0.02	1	0.8
$JAP_{GPR} \rightarrow GER_{SP}$	0.79	2	1.28	1	1	0.68	1	0.8
$GER_{SP} \rightarrow JAP_{GPR}$	3.52	2	6.13**	1	1	5.74*	1	0.8
$UK_{GPR} \rightarrow GER_{SP}$	0.12	1	0.29	1	1	0.17	1	0.8
$GER_{SP} \rightarrow UK_{GPR}$	0.66	1	2.51	1	1	1.09	1	0.8
$USA_{GPR} \rightarrow GER_{SP}$	0.27	1	7.83*	9	1	0.83	1	0.8
$GER_{SP} \rightarrow USA_{GPR}$	0.26	1	6.11	9	1	2.99*	1	0.8

Note: *, **, and *** denote significance at 1%, 5%, and 10% levels, respectively. For critical values of the F Stat and FADF unit root test stat, please see Enders and Lee (2012), and Bozoklu et al. (2020), respectively.

Table 8. Results for France.

	Granger causality tests		Fourier Granger causality tests			Fourier fractional frequency Granger causality tests		
	Test stat	Optimal lag length	Test stat	Optimal lag length	Optimal freq	Test stat	Optimal lag length	Optimal freq
$CAN_{EPU} \rightarrow FRA_{SP}$	4.93*	2	3.28	2	1	0.86	1	0.8
$FRA_{SP} \rightarrow CAN_{EPU}$	10.48***	2	8.82**	2	1	5.95**	1	0.8
$GER_{EPU} \rightarrow FRA_{SP}$	8.59***	1	12.19***	2	2	4.41**	1	0.8
$FRA_{SP} \rightarrow GER_{EPU}$	9.21***	1	22.44***	2	2	7.82*	1	0.8
$FRA_{EPU} \rightarrow FRA_{SP}$	4.01	2	3.17	2	1	1.38	1	0.8
$FRA_{SP} \rightarrow FRA_{EPU}$	12.87***	2	11.96***	2	1	3.59**	1	0.8
$ITA_{EPU} \rightarrow FRA_{SP}$	3.54	2	1.74**	2	1	0.21	1	0.8
$FRA_{SP} \rightarrow ITA_{EPU}$	16.26***	2	21.87***	2	1	25.62***	1	0.8
$JAP_{EPU} \rightarrow FRA_{SP}$	0.04	1	0.14	2	1	1.39	1	0.8
$FRA_{SP} \rightarrow JAP_{EPU}$	17.16***	1	18.93***	2	1	19.83***	1	0.8
$UK_{EPU} \rightarrow FRA_{SP}$	8.99*	4	4.6**	1	1	3.91*	1	0.8
$FRA_{SP} \rightarrow UK_{EPU}$	7.97*	4	8.48*	1	1	4.49**	1	0.8
$USA_{EPU} \rightarrow FRA_{SP}$	4.27*	2	4.86*	2	3	3.31*	1	0.8
$FRA_{SP} \rightarrow USA_{EPU}$	16.05**	2	20.42***	2	3	6.18**	1	0.8
$CAN_{GPR} \rightarrow FRA_{SP}$	2.19	1	17.69	9	1	2.03	1	0.8
$FRA_{SP} \rightarrow CAN_{GPR}$	1.82	1	3.73	9	1	0.42	1	0.8
$GER_{GPR} \rightarrow FRA_{SP}$	1.09	1	0.48	1	1	0.17	1	0.8
$FRA_{SP} \rightarrow GER_{GPR}$	7.73***	1	1.09	1	1	0.29	1	0.8
$FRA_{GPR} \rightarrow FRA_{SP}$	0.03	1	0.03	1	3	0.11	1	0.8
$FRA_{SP} \rightarrow FRA_{GPR}$	0.56	1	3.21*	1	3	1.21	1	0.8
$ITA_{GPR} \rightarrow FRA_{SP}$	0.15	1	0.02	1	1	0.00	1	0.8
$FRA_{SP} \rightarrow ITA_{GPR}$	4.31**	1	0.16	1	1	0.02	1	0.8
$JAP_{GPR} \rightarrow FRA_{SP}$	3.95**	1	3.23*	1	1	3.02*	1	0.8
$FRA_{SP} \rightarrow JAP_{GPR}$	0.19	1	5.52**	1	1	4.88**	1	0.8
$UK_{GPR} \rightarrow FRA_{SP}$	1.43	1	1.44	1	1	1.85	1	0.8
$FRA_{SP} \rightarrow UK_{GPR}$	0.15	1	1.62	1	1	1.09	1	0.8
$USA_{GPR} \rightarrow FRA_{SP}$	1.73	1	15.56*	9	1	1.83	1	0.8
$FRA_{SP} \rightarrow USA_{GPR}$	0.23	1	8.59	9	1	1.74	1	0.8

Note: *, **, and *** denote significance at 1%, 5%, and 10% levels, respectively. For critical values of the F Stat and FADF unit root test stat, please see Enders and Lee (2012), and Bozoklu et al. (2020), respectively.

Table 9. Results for Italy.

	Granger causality tests		Fourier Granger causality tests			Fourier fractional frequency Granger causality tests		
	Test stat	Optimal lag length	Test stat	Optimal lag length	Optimal freq	Test stat	Optimal lag length	Optimal freq
$CAN_{EPU} \rightarrow ITA_{SP}$	2.32	2	8.56	9	1	1.85	1	0.8
$ITA_{SP} \rightarrow CAN_{EPU}$	17.02***	2	15.58**	9	1	1.79	1	0.8
$GER_{EPU} \rightarrow ITA_{SP}$	3.93**	1	2.99	2	3	1.15	1	0.8
$ITA_{SP} \rightarrow GER_{EPU}$	4.45**	1	10.09***	2	3	7.65***	1	0.8
$FRA_{EPU} \rightarrow ITA_{SP}$	2.29	2	0.24	2	1	0.14	1	0.8
$ITA_{SP} \rightarrow FRA_{EPU}$	11.52***	2	14.63***	2	1	9.73***	1	0.8
$ITA_{EPU} \rightarrow ITA_{SP}$	3.86	2	0.56	2	3	0.03	1	0.8
$ITA_{SP} \rightarrow ITA_{EPU}$	10.68***	2	20.82***	2	3	26.41***	1	0.8
$JAP_{EPU} \rightarrow ITA_{SP}$	0.00	1	2.12	2	1	3.57	1	0.8
$ITA_{SP} \rightarrow JAP_{EPU}$	11.86***	1	25.06***	2	1	15.88***	1	0.8
$UK_{EPU} \rightarrow ITA_{SP}$	5.81	4	2.83	1	1	1.28	1	0.8
$ITA_{SP} \rightarrow UK_{EPU}$	10.12**	4	2.95*	1	1	3.45*	1	0.8
$USA_{EPU} \rightarrow ITA_{SP}$	3.15*	1	18.88**	2	1	2.14*	1	0.8
$ITA_{SP} \rightarrow USA_{EPU}$	3.49*	1	13.01***	2	1	4.79**	1	0.8
$CAN_{GPR} \rightarrow ITA_{SP}$	2.89*	1	11.79	9	1	2.37	1	0.8
$ITA_{SP} \rightarrow CAN_{GPR}$	2.04	1	4.22	9	1	0.17	1	0.8
$GER_{GPR} \rightarrow ITA_{SP}$	1.77	1	0.96	1	1	0.85	1	0.8
$ITA_{SP} \rightarrow GER_{GPR}$	0.02	1	0.04	1	1	0.04	1	0.8
$FRA_{GPR} \rightarrow ITA_{SP}$	0.24	1	0.01	1	1	0.08	1	0.8
$ITA_{SP} \rightarrow FRA_{GPR}$	0.00	1	0.19	1	1	0.00	1	0.8
$ITA_{GPR} \rightarrow ITA_{SP}$	0.18	1	0.01	1	1	0.001	1	0.8
$ITA_{SP} \rightarrow ITA_{GPR}$	1.77	1	0.04	1	1	0.08	1	0.8
$JAP_{GPR} \rightarrow ITA_{SP}$	5.79**	1	3.98**	1	1	4.53**	1	0.8
$ITA_{SP} \rightarrow JAP_{GPR}$	1.71	1	1.67	1	1	2.73	1	0.8
$UK_{GPR} \rightarrow ITA_{SP}$	3.06*	1	2.07	1	1	2.94*	1	0.8
$ITA_{SP} \rightarrow UK_{GPR}$	1.65	1	0.19	1	1	0.87	1	0.8
$USA_{GPR} \rightarrow ITA_{SP}$	3.69**	1	11.65	9	1	3.42**	1	0.8
$ITA_{SP} \rightarrow USA_{GPR}$	2.09	1	9.23	9	1	1.01	1	0.8

Note: *, **, and *** denote significance at 1%, 5%, and 10% levels, respectively. For critical values of the F Stat and FADF unit root test stat, please see Enders and Lee (2012), and Bozoklu et al. (2020), respectively.

Table 10. Results for Japan.

	Granger causality tests		Fourier Granger causality tests			Fourier fractional frequency Granger causality tests		
	Test stat	Optimal lag length	Test stat	Optimal lag length	Optimal freq	Test stat	Optimal lag length	Optimal freq
$CAN_{EPU} \rightarrow JAP_{SP}$	7.54**	2	6.43**	2	1	3.81*	1	0.8
$JAP_{SP} \rightarrow CAN_{EPU}$	14.21***	2	6.91***	2	1	5.92**	1	0.8
$GER_{EPU} \rightarrow JAP_{SP}$	6.77***	1	4.81**	1	2	3.64**	1	0.8
$JAP_{SP} \rightarrow GER_{EPU}$	0.4	1	20.71***	1	2	2.45*	1	0.8
$FRA_{EPU} \rightarrow JAP_{SP}$	4.82*	2	3.82*	1	1	2.4*	1	0.8
$JAP_{SP} \rightarrow FRA_{EPU}$	7.19**	2	2.51*	1	1	2.87**	1	0.8
$ITA_{EPU} \rightarrow JAPS_{SP}$	3.78	2	7.31**	2	1	20.97***	1	0.8
$JAP_{SP} \rightarrow ITA_{EPU}$	2.91	2	4.03	2	1	2.46	1	0.8
$JAP_{EPU} \rightarrow JAP_{SP}$	0.02	1	0.05	1	2	0.33	1	0.8
$JAP_{SP} \rightarrow JAP_{EPU}$	6.58**	1	1.51	1	2	5.58**	1	0.8
$UK_{EPU} \rightarrow JAP_{SP}$	4.84**	1	5.72**	1	1	3.41*	1	0.8
$JAP_{SP} \rightarrow UK_{EPU}$	3.39*	1	9.49**	1	1	7.99***	1	0.8
$USA_{EPU} \rightarrow JAP_{SP}$	7.46***	1	8.03***	1	2	4.13**	1	0.8
$JAP_{SP} \rightarrow USA_{EPU}$	3.28*	1	10.95**	1	2	8.14***	1	0.8
$CAN_{GPR} \rightarrow JAP_{SP}$	0.35	1	8.03	9	1	0.11	1	0.8
$JAP_{SP} \rightarrow CAN_{GPR}$	2.71*	1	12.72	9	1	1.64	1	0.8
$GER_{GPR} \rightarrow JAP_{SP}$	0.52	1	0.02	1	2	0.00	1	0.8
$JAP_{SP} \rightarrow GER_{GPR}$	2.12	1	10.03***	1	2	3.75*	1	0.8
$FRA_{GPR} \rightarrow JAP_{SP}$	0.86	1	2.55*	1	2	1.69	1	0.8
$JAP_{SP} \rightarrow FRA_{GPR}$	0.37	1	4.23**	1	2	1.34	1	0.8
$ITA_{GPR} \rightarrow JAP_{SP}$	0.05	1	0.15	1	2	0.09	1	0.8
$JAP_{SP} \rightarrow ITA_{GPR}$	2.83*	1	4.13**	1	2	3.49*	1	0.8
$JAP_{GPR} \rightarrow JAP_{SP}$	0.49	1	0.39	1	1	0.17	1	0.8
$JAP_{SP} \rightarrow JAP_{GPR}$	1.44	1	7.01***	1	1	6.17**	1	0.8
$UK_{GPR} \rightarrow JAP_{SP}$	0.19	1	0.34	1	1	0.24	1	0.8
$JAP_{SP} \rightarrow UK_{GPR}$	2.09	1	3.36*	1	1	2.21*	1	0.8
$USA_{GPR} \rightarrow JAP_{SP}$	0.11	1	6.53	9	2	0.08	1	0.8
$JAP_{SP} \rightarrow USA_{GPR}$	2.83*	1	16.44**	9	2	3.61**	1	0.8

Note: *, **, and *** denote significance at 1%, 5%, and 10% levels, respectively. For critical values of the F Stat and FADF unit root test stat, please see Enders and Lee (2012), and Bozoklu et al. (2020), respectively.

Table 11. Results for UK.

	Granger causality tests		Fourier Granger causality tests			Fourier fractional frequency Granger causality tests		
	Test stat	Optimal lag length	Test stat	Optimal lag length	Optimal freq	Test stat	Optimal lag length	Optimal freq
$CAN_{EPU} \rightarrow UK_{SP}$	1.86	2	2.74	2	1	0.38	1	0.8
$UK_{SP} \rightarrow CAN_{EPU}$	221.26***	2	7.77***	2	1	13.18***	1	0.8
$GER_{EPU} \rightarrow UK_{SP}$	1.26	1	5.72**	1	2	3.71**	1	0.8
$UK_{SP} \rightarrow GER_{EPU}$	10.22**	1	4.11**	1	2	2.05*	1	0.8
$FRA_{EPU} \rightarrow UK_{SP}$	1.48	2	2.61	1	1	0.62	1	0.8
$UKSP \rightarrow FRA_{EPU}$	11.25***	2	9.02***	1	1	4.7**	1	0.8
$ITA_{EPU} \rightarrow UK_{SP}$	1.26	1	1.36	1	1	0.28	1	0.8
$UKSP \rightarrow ITA_{EPU}$	10.22***	1	17.45***	1	1	26.14***	1	0.8
$JAP_{EPU} \rightarrow UK_{SP}$	3.14	2	0.11	1	1	0.09	1	0.8
$UK_{SP} \rightarrow JAP_{EPU}$	14.37***	2	6.77***	1	1	11.96***	1	0.8
$UK_{EPU} \rightarrow UK_{SP}$	0.64	1	1.25	1	1	0.14	1	0.8
$UK_{SP} \rightarrow UK_{EPU}$	5.33**	1	17.5***	1	1	3.45**	1	0.8
$USA_{EPU} \rightarrow UK_{SP}$	0.72	2	13.21**	1	1	0.24	1	0.8
$UK_{SP} \rightarrow USA_{EPU}$	39.05***	2	8.67***	1	1	24.25***	1	0.8
$CAN_{GPR} \rightarrow UK_{SP}$	0.09	1	9.56	9	1	0.02	1	0.8
$UK_{SP} \rightarrow CAN_{GPR}$	4.19**	1	8.98	9	1	0.41	1	0.8
$GER_{GPR} \rightarrow UK_{SP}$	0.01	1	0.09	1	1	0.02	1	0.8
$UK_{SP} \rightarrow GER_{GPR}$	1.27	1	0.37	1	1	0.03	1	0.8
$FRA_{GPR} \rightarrow UK_{SP}$	0.08	1	0.15	1	1	0.26	1	0.8
$UK_{SP} \rightarrow FRA_{GPR}$	0.14	1	2.14	1	1	1.78	1	0.8
$ITA_{GPR} \rightarrow UK_{SP}$	0.31	1	0.12	1	1	0.17	1	0.8
$UK_{SP} \rightarrow ITA_{GPR}$	6.79***	1	8.14***	1	1	6.35***	1	0.8
$JAP_{GPR} \rightarrow UK_{SP}$	0.01	1	0.12	1	1	0.01	1	0.8
$UK_{SP} \rightarrow JAP_{GPR}$	0.8	1	2.97	1	1	1.58	1	0.8
$UK_{GPR} \rightarrow UK_{SP}$	0.37	1	0.36	1	1	0.61	1	0.8
$UK_{SP} \rightarrow UK_{GPR}$	3.18*	1	2.67*	1	1	3.19*	1	0.8
$USA_{GPR} \rightarrow UK_{SP}$	0.01	1	14.25*	9	1	0.00	1	0.8
$UK_{SP} \rightarrow USA_{GPR}$	2.51*	1	7.4	9	1	2.93*	1	0.8

Note: *, **, and *** denote significance at 1%, 5%, and 10% levels, respectively. For critical values of the F Stat and FADF unit root test stat, please see Enders and Lee (2012), and Bozoklu et al. (2020), respectively.

Table 12. Results for USA.

	Granger causality tests		Fourier Granger causality tests			Fourier fractional frequency Granger causality tests		
	Test stat	Optimal lag length	Test stat	Optimal lag length	Optimal freq	Test stat	Optimal lag length	Optimal freq
$CAN_{EPU} \rightarrow USA_{SP}$	7.79**	2	7.86**	2	1	0.81	1	0.8
$USA_{SP} \rightarrow CAN_{EPU}$	10.89***	2	6.05***	2	1	0.54	1	0.8
$GER_{EPU} \rightarrow USA_{SP}$	0.00	1	1.17	1	2	0.04	1	0.8
$USA_{SP} \rightarrow GER_{EPU}$	23.48***	1	27.76***	1	2	9.58***	1	0.8
$FRA_{EPU} \rightarrow USA_{SP}$	1.13	2	0.95	2	1	0.95	1	0.8
$USA_{SP} \rightarrow FRA_{EPU}$	26.4***	2	26.74***	2	1	0.01	1	0.8
$ITA_{EPU} \rightarrow USA_{SP}$	5.31*	2	4.12*	2	3	3.64*	1	0.8
$USA_{SP} \rightarrow ITA_{EPU}$	8.67**	2	11.07***	2	3	7.22**	1	0.8
$JAP_{EPU} \rightarrow USA_{SP}$	0.39	1	0.58	1	2	0.02	1	0.8
$USA_{SP} \rightarrow JAP_{EPU}$	0.02	1	1.01	1	2	2.67	1	0.8
$UK_{EPU} \rightarrow USA_{SP}$	2.67	1	2.68	1	1	1.18	1	0.8
$USA_{SP} \rightarrow UK_{EPU}$	2.65	1	0.15	1	1	9.14**	1	0.8
$USA_{EPU} \rightarrow USA_{SP}$	5.81*	2	4.93*	2	3	3.76**	1	0.8
$USA_{SP} \rightarrow USA_{EPU}$	20.95***	2	26.59***	2	3	3.59**	1	0.8
$CAN_{GPR} \rightarrow USA_{SP}$	0.02	1	7.98	9	1	0.05	1	0.8
$USA_{SP} \rightarrow CAN_{GPR}$	0.71	1	2.95	9	1	1.41	1	0.8
$GER_{GPR} \rightarrow USA_{SP}$	2.61*	1	3.04*	1	2	2.93*	1	0.8
$USA_{SP} \rightarrow GER_{GPR}$	11.63***	1	14.48***	1	2	2.95*	1	0.8
$FRA_{GPR} \rightarrow USA_{SP}$	0.97	1	1.38	1	2	1.45	1	0.8
$USA_{SP} \rightarrow FRA_{GPR}$	1.59	1	5.16	1	2	0.76	1	0.8
$ITA_{GPR} \rightarrow USA_{SP}$	0.51	1	0.49	1	1	0.58	1	0.8
$USA_{SP} \rightarrow ITA_{GPR}$	4.79**	1	0.31	1	1	0.13	1	0.8
$JAP_{GPR} \rightarrow USA_{SP}$	0.01	1	0.01	1	1	0.01	1	0.8
$USA_{SP} \rightarrow JAP_{GPR}$	0.38	1	6.15**	1	1	6.66***	1	0.8
$UK_{GPR} \rightarrow USA_{SP}$	0.12	1	0.09	1	1	0.1	1	0.8
$USA_{SP} \rightarrow UK_{GPR}$	0.00	1	1.78	1	1	0.74	1	0.8
$USA_{GPR} \rightarrow USA_{SP}$	0.07	1	0.14	9	1	0.14	1	0.8
$USA_{SP} \rightarrow USA_{GPR}$	0.02	1	7.99*	9	1	2.93**	1	0.8

Note: *, **, and *** denote significance at 1%, 5%, and 10% levels, respectively. For critical values of the F Stat and FADF unit root test stat, please see Enders and Lee (2012), and Bozoklu et al. (2020), respectively.