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Economic policy uncertainty in G7 countries: evidence of long-range dependence and cointegration

OlaOluwa S. Yaya[1] · Nurudeen Abu[2] · Tayo P. Ogundunmade[1]

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Abstract
The global financial crisis which emanated from the USA has led to the development of indices for economic policy uncertainty for some developed and developing nations. Also, the current Brexit debate in the UK is a major economic influencer. 'News of news' or 'news of no News' in the daily newspapers in the USA and UK causes global economic uncertainty which has an aftermath reaction on the global economy. This study considers economic uncertainties in G7 countries using economic policy uncertainty indices developed majorly from newspapers information. The long-range dependence technique in time series was first carried out, and the results reveal an evidence of time series persistence for each country's index. This provided justification for the adoption of cointegration in a fractional integration setup using the fractional cointegrating vector autoregressive model recently proposed. The long-run equilibrium results obtained showed that the USA and UK are dominant drivers of economic uncertainty among the G7 countries.

Keywords G7 countries · Economy · Uncertainty index · Long-range dependence · FCVAR

JEL Classification C22 · C30 · D04 · D80

✉ Nurudeen Abu
abu.nurudeen@yahoo.com

OlaOluwa S. Yaya
os.yaya@ui.edu.ng; o.s.olaoluwa@gmail.com

Tayo P. Ogundunmade
ogundunmadetayo@yahoo.com

[1] Economic and Financial Statistics Unit, Department of Statistics, University of Ibadan & Centre for Econometric and Allied Research, University of Ibadan, Ibadan, Nigeria

[2] Department of Economics, Umaru Musa Yar'adua University, Katsina, Nigeria

1 Introduction

Economic policy uncertainty (EPU) is an economic indicator which can prevent regulatory authorities or bodies from foreseeing the consequences of their actions as they regulate trade, monetary and fiscal policies, etc., in a country. Although its definition is straightforward, the EPU is intrinsically not observable and its measurement is not straightforward. The dominant components of the EPU index are newspapers report on economic-related policies. The EPU index has often been used to measure economic performance in many countries lately. The index, having existed for several decades, became more popular due to series of economic and political crises including the global financial crisis, Eurozone crisis, Brexit situation, jumps in oil price and wars, among others (Bloom 2014). Supporting the claim of the International Monetary Fund (IMF), scholars believe that economic uncertainty does not only hamper development and growth, but it is also to a large extent responsible for weak economic performance in many countries (Ahir et al. 2018).This goes along way in affecting stocks and macroeconomic drivers of the economy. Thus, the time dynamics of EPU will be of interest to policymakers and investors since it will inform them on ways of hedging against all risks.

A considerable number of studies have analysed the economic impact of EPU indices on macroeconomic and financial variables, using various methodological approaches. These studies examined the relationships between EPU indices and certain variables using the long-range dependence (LRD) and cointegration analysis Plakandaras et al. 2019; Sun 2013), EPU spillovers in the UK and the USA (Klößner and Sekkel 2014), EPU and exchange rates volatility (Krol 2014), EPU and housing market returns (Antonakakis et al. 2015), policy uncertainty and financial stress on the price dynamics of energy and metal commodity futures prices in the USA (Reboredo and Uddin 2015), EPU and stock returns in China (Li et al. 2016; Liu and Zhang 2015), as well as European and US EPU indices and gold price (Jones and Sackley 2016). Furthermore, Balcilar et al. (2016a) investigated whether EPU can predict recessions in the USA from 1947 to 2014. Other authors such as Lean and Nguyen (2014) and Wang, Chen and Huang (2014), Arouri et al. (2016), Balcilar et al. (2016b), Balcilar et al. (2017), Antonakakis and Gupta (2016), Gozgor and Ongan (2016), Gao and Zhang (2016), Christou et al. (2017), Dakhlaoui and Aloui (2017), Balli et al. (2017), Li and Peng (2017), Tsai (2017), Caggiano et al. (2018), Akinsomi et al. (2018), Gupta et al. (2019), Phan et al. (2018), Ersan et al. (2019) including Fang et al. (2019) considered the relationships between policy uncertainty with stock prices, exchange rates, Real Estate Investments Trusts (REITs), gold prices, tourism, cryptocurrency prices and other economic variables in different countries in Europe, America and Asia. These studies have shown that EPU is an important driver of economic and financial variables or indicators. On their part, Gil-Alana and Payne (2019) and have established that EPU series is persistent, and its negative impact on financial markets goes a long way in affecting national or global economy. In addition, the size of this persistence determines policy action required to bring back an economy to normalcy. Thus, it is hard to predict future values of the EPU using trend line (see Gil-Alana and Payne 2019).

Given the relationships that exist between the EPU index and relevant global macroeconomic variables, it is important to analyse co-movements in EPU indices across leading economies of the world. Our idea in this paper is similar to Antonakakis et al. (2018) who investigated dynamic connectedness of uncertainty within some developed economies including the USA, Europe, the UK, Japan and Canada. The authors applied a time-varying parameter vector autoregressive (TVP-VAR) model proposed by Antonakakis and Gabauer (2017). The authors' results showed a significant spillover of uncertainty from Europe to the USA. It is important to state that the VAR framework used by Antonakakis et al. (2018) only considered interdependencies, but it does not take into account the long-run dynamics of the variables. This shortcoming provides the justification for using cointegration techniques such as the vector error correction mechanism (VECM) in this study.

Specifically, we investigate the time dynamics of EPU in the Group of Seven (G7) countries by means of a long-range dependence (LRD) technique and cointegration method. The LRD technique allows one to actually determine the fractional integration parameter in the mean-reverting range ($0<d<1$) which is often difficult to determine using the classical unit root test that leads to a wrong cointegration decision. These fractional unit root estimation methods are semi-parametric and parametric in nature (see Robinson 1994, 1995a, b). Fractional integration method informs fractional cointegration, i.e. it is a version that allows more than two cointegrating variables at a time in a system. This is the fractional cointegrating vector autoregressive (FCVAR) model of Johansen and Nielsen (2012, 2016). The model captures both the long-run equilibrium relationships in the multivariate time series and in the long-memory properties of their linear combination.

This paper is the first to investigate the EPU of G7 countries by means of long-range dependence and FCVAR analyses. The findings throw more light on the time series dynamics, stating that the series are still cointegrated for the selected countries. The rest of the paper is structured as follows. Section two highlights the EPU Index and its components, while section three explains the details of FCVAR framework. The fourth section is for data and empirical results, while the fifth section concludes the paper.

2 EPU index and its computation

The EPU index is constructed from three types of underlying components. These are the newspaper policy-related economic uncertainty, the number of federal tax code provisions set that expires in future years, and the last component uses the disagreement among economic forecasters as a proxy for uncertainty. In the first component, information is obtained from 10 large newspapers such as the Chicago Tribune, the Washington Post, the Los Angeles Times, the Boston Globe, the San Francisco Chronicle, the Dallas Morning News, the New York Times and The Wall Street Journal. Then, a normalized index of the policy uncertainty is then constructed. The second component relies on temporary tax code lists compiled by the Congregational

Budget Office (CBO), and annual dollar-weighted numbers of tax code provisions expected to expire over the next 10 years are then created. The third component of the uncertainty index is based on the Federal Reserve Bank of Philadelphia's Survey of Professional Forecasters. The dispersion between individual forecasters' predictions about future levels of the Consumer Price Index, Federal Expenditures, and State and Local Expenditures is utilized to construct indices of uncertainty about policy-related macroeconomic variables (http://www.policyuncertainty.com/methodology.html).

This study considers EPU indices for the G7 countries only. The US EPU index is constructed from the three types of underlying components. First, the index searches from 10 large newspapers (USA Today, the Chicago Tribune, the Los Angeles Times, the Boston Globe, the Washington Post, the San Francisco Chronicle, the Miami Herald, the Dallas Morning News, the Houston Chronicle and the WSJ) and it is constructed by taking note of key terms/words relating to economy, tax code expiration dataset and economic forecaster disagreement of the Federal Reserve's Professional Forecasters. The overall index of EPU for the USA is then obtained by weighing the three indices from the three components together with a newspapers-based policy index taking the larger weight. In Canada, the measurement of the EPU index is based on five newspaper articles namely—The Vancouver Sun, The Toronto Star, The Ottawa Citizen, The Globe and Mail, as well as the Canadian Newswire. The number of news articles containing expected economic terms/words is captured, and each paper-specific series is normalized. France, Germany, Italy and the UK EPU indices are also based on newspaper articles, that is the Le Monde and Le Figaro (France), Handelsblatt and Frankfurter Allgemeine Zeitung (Germany), Corriere Della Sera and La Repubblica (Italy), and The Times of London and Financial Times (the UK). Japan uses articles in four major Japanese newspapers, Yomiuri, Asahi, Mainichi and Nikkei which contain the required economic terms/words, classified in three categories: (E) 'economic' or 'economy', (P) 'tax', 'government spending', 'regulation', 'central bank' or certain other policy-related terms; and (U) 'uncertain' or 'uncertainty', the raw EPU counts are then scaled down by the number of articles in the same newspaper.

So far, only EPU indices for the UK and the USA are computed at daily and monthly frequencies, while for other countries, the indices are computed on a monthly basis only.

3 Fractional cointegrating VAR framework

Fractional integration (i.e. fractional unit root) in time series has led to the development of fractional cointegration, even though Engle and Granger (1987)'s definition of cointegration is not restrictive to integer values of integration parameters. Thus, the decision based on the Augmented Dickey–Fuller (ADF) unit root test may mislead readers and policymakers. The scope of cointegration has therefore been widened due to the introduction of fractional integration (see Cheung and Lai 1993).

Time series integration is expressed as:

$$(1-L)^d y_t = x_t \tag{1}$$

where y_t is the EPU index under investigation and x_t is the resulting differenced series expected to be covariance stationary. The parameter d is the difference parameter which takes any real value, L is the lag operator such that $Ly_t = y_{t-1.}$ For $d=0$ in (1), $y_t = x_t$ which is the case of stationary time series, thus the EPU index is a stationary series in this sense. For $d=1$, $y_t - y_{t-1} = x_t$, this is the case of non-stationary series as in the autoregressive integrated moving average (ARIMA) model. Fixing $d=0$ or 1 is restrictive since this can be computed as a decimal value as in fractional integration of Granger and Joyeux (1980). The time series differencing in Eq. (1) can easily be expanded using the binomial expansion.

Another appealing characteristic of fractional integration over the classical ADF testing approach is the interpretation of the estimates. The value determines the degree of association between time series y_t and its lagged values $y_{t-1}, \ldots, y_{t-k}$ ($k=1, \ldots, N+1$). For example, $0<d<1$ implies long-range dependence with persistent autocorrelations. At this point, the series is mean-reverting meaning that the effect of the shocks is temporal. For $d \geq 1$, the time series is non-stationary and non-mean reverting, implying that the effect of the shocks could last for a longer period.

For the estimation of fractional integration parameter, we applied both semi-parametric and parametric approaches to fractional integration.[1]The parametric method of fractional integration developed in Robinson (1994) is based on the Lagrange multiplier (LM) principle with Whittle function in the frequency domain. The set-up follows three regression types: no deterministic term, intercept only and the linear trend case (see Gil-Alana and Robinson 1997). The semi-parametric approaches are the log-periodogram regression method of Geweke and Porter-Hudak (GPH) (Geweke and Porter-Hudak 1983; Robinson 1995a) and Gaussian Semi-Parametric with Local Whittle estimates of Robinson (1995b).These methods are developed in the frequency domain with varying periodogram ordinate values.

The determination of integration order often serves as a pre-test to cointegration. After this stage, we determine next the cointegration by employing the FCVAR model (see Johansen and Nielsen 2010, 2012, 2016). The FCVAR model is built on the CVAR model of Johansen (1995) which is based on unit integration results from the ADF test, only that CVAR model gives unreliable results due to its weakness in the presence of fractional unit root alternatives, i.e. stationary and non-stationary mean reversions cases. The FCVAR system allows for more than two time series to be cointegrated in a VAR framework with unconditional fractional d value.

We define a $(k+1)$-dimensional time series vector y_t, $t = 1, 2, \ldots, N$, each of fractional integration order d_{y}. Then, by setting $\Pi = \alpha\beta'$, and using the differencing lag operator $Ly_t = y_{t-1}$,

[1] Nonparametric approach to estimating d is too restrictive as it gives reliable values in the range $0<d<0.5$ only.

$$\Delta y_t = \alpha\beta' L y_t + \sum_{i=1}^{k} \Gamma_i \Delta L^i y_t + \varepsilon_t, \tag{2}$$

where α and β are matrices of constant and regressors in the long-run equation. Then, by substituting the difference and lag operator Δ and $L = 1 - \Delta$ in (2) as in unit root with their fractional unit root counterparts, Δ^b and $L_b = 1 - \Delta_b$, respectively. Thus,

$$\Delta^b y_t = \alpha\beta' L_b y_t + \sum_{i=1}^{k} \Gamma_i \Delta^b L_b^i y_t + \varepsilon_t \tag{3}$$

and

$$\Delta^d x_t = \alpha\beta' \Delta^{d-b} L_b x_t + \sum_{i=1}^{k} \Gamma_i \Delta^d L_b^i x_t + \varepsilon_t, \tag{4}$$

with $y_t = \Delta^{d-b} x_t$ where Δ^d is the fractional operator, b is the cointegrating factor and L_b is the fractional lag operator. The degree of fractional cointegration of the long-run equation is $d-b$ (with $b>0$), that is, the fractional integration order of $\beta' x_t$, which assumes value lower than y_t itself. Therefore, it is said that fractional cointegration exists in the VAR framework. The elements of $\beta' x_t$ give the cointegrating relationships in the system, where k determines the number of long-run equilibrium relationships, i.e. the cointegration or co-fractional rank, and $\Gamma = \Gamma_i, \ldots, \Gamma_k$ governs the short-run dynamics. The coefficients in the matrix α represent the speed of adjustment towards equilibrium for each of the variables in response to shocks. The details on the estimation and settings of FCVAR methodology can be found in Matlab programming code of Nielsen and Popiel (2016).[2] However, the estimation may suffer from convergence problems which may result in inconsistent estimates. Nielsen and Popiel (2016) documented that weak convergence for cointegration is obtained when $0<b<0.5$, while strong cointegration is obtained when $0.5<b<d$.

4 Data and empirical results

The data employed in this study are monthly time series of EPU indices for Canada, France, Germany, Italy, Japan, the UK and the USA. Each series spans from January 1997 to May 2019 covering 269 data points. The data were sourced from private website http://www.policyuncertainty.com, data compilation directed by Baker, Bloom and Davis.[3] Figure 1 presents plots of the indices for the seven countries. We observe possible co-movement, with longer spikes on many occasions implying

[2] Thanks to Morten Orregaard Nielsen and Michal Ksawery Popiel of Queen's University for providing freely the FCVAR Matlab code, and also to Jurgen A. Doornik and Marius Ooms for the free OxMetrics-ARFIMA code.

[3] Details on computation of EPU index for the USA are given in Baker, Bloom and Davis (2016).

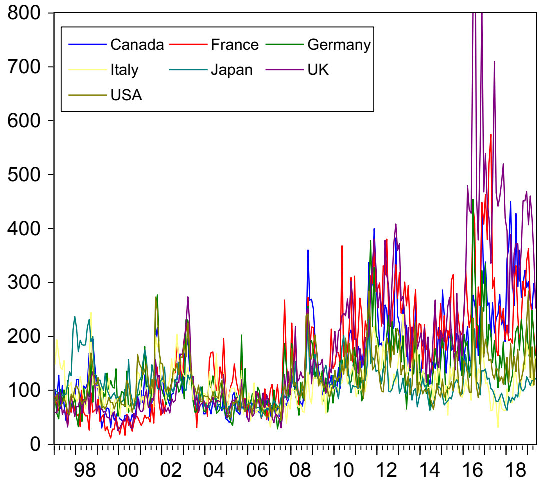

Fig. 1 Plots of EPU indices for G7 countries

Table 1 Data summary

Country	Starting EPU index (January 1997)	Ending EPU index (May 2019)	Min (date)	Max (date)
Canada	101.64	275.82	30.10 (March 1999)	449.62 (March 2018)
France	88.76	159.85	11.29 (August 1999)	574.63 (April 2017)
Germany	86.68	145.93	28.43 (May 2007)	454.01 (June 2016)
Italy	147.87	163.97	31.70 (August 2017)	243.89 (September 1998)
Japan	99.30	122.54	48.57 (August 2006)	237.05 (December 1997)
UK	59.41	251.71	25.34 (December 1999)	1141.80 (July 2016)
USA	75.45	159.85	44.78 (July 2007)	284.14 (January 2019)

points of high economic uncertainty. These countries have experienced occasional high EPU. For example, Germany and Italy EPU move together between 1997 and 2001, while Canada and France EPU move together from 2008/09 till present. The UK started experiencing high EPU around 2016 and till present, and it recorded very high uncertainty compared to other G7 countries as of May 2019 (see Table 1). During 2010–2013 and 2016–2019, the plots also indicated that due to political overturn, oil price falls, USA shutdowns, etc., Canada, France and the USA experienced high EPU during 2016–2019.

Table 1 summarizes the entire dataset. The UK has the lowest EPU value of 59.41 among the G7 countries in January 1997, ending with a 251.71 index value in May 2019. This country experienced its lowest index value of 25.34 in December 1999. Its highest value was recorded in July 2016 at 1141.80. This was as a result of the reaction of the leave European Union referendum by the British (Brexit) in that month. The decision to leave the European Union appeared to have affected Germany. For example, Germany had her highest EPU of 454.01 around that period

Table 2 Unit root tests results

	No intercept	Intercept	Intercept and the trend
Canada	– 1.3886[1]	**– 3.3893[1]**	**– 5.3659[1]**
France	– 0.7794[4]	– 2.1474[4]	**– 6.4841[1]**
Germany	– 1.1207[4]	**– 5.6437[1]**	**– 9.5159[0]**
Italy	– 1.1264[3]	**– 5.907[1]**	**– 6.1191[1]**
Japan	– 0.9021[3]	**– 5.8189[0]**	**– 5.8303[0]**
UK	– 1.0678[4]	– 2.2497[4]	**– 3.8656[4]**
USA	– 1.0285[3]	**– 7.3262[0]**	**– 7.9396[0]**

In bold, 5% significance level of *t*-statistics for the ADF test. In squared brackets are the optimal lags based on minimum information criteria necessary to white the noise process during the estimation

Table 3 Johansen cointegration test

No. of cointegrating equations/rank	Eigenvalue	Trace statistic	*p* value	Max. eigenvalue statistic	*p* value
0	0.1917	218.79	0.0000	56.20	0.0119
1	0.1720	162.59	0.0000	49.82	0.0120
2	0.1281	112.77	0.0003	36.18	0.0865
3	0.0949	76.59	0.0030	26.32	0.2163
4	0.0866	50.27	0.0078	23.90	0.0879
5	0.0553	26.37	0.0433	15.01	0.1931
6	0.0421	11.36	0.0774	11.36	0.0774

p value indicates a 5% rejection probability for the null hypothesis of the existence of that number of cointegrating equations. The test was conducted for intercept and trend in the cointegrating equation with intercept in VAR. The results obtained here are similar to those obtained based on other deterministic trend assumptions in the cointegration test

of the Brexit referendum (June 2016). The dynamics of the time series of the EPU indices therefore provided the ground for cointegration analysis.

Prior to conducting the cointegration analysis, there was a need to establish the integration order of the series. The results of the unit root for the G7 EPU indices using the ADF test are presented in Table 2. We found a non-rejection of a unit root in all the series based on no intercept in the ADF regression model, while for intercept and trend model, the null hypothesis of the unit root was rejected in all the series. These mixed results suggest that fractional integration might exist. Coupled with this is the fact that unit root tests have low power under fractional unit root alternatives (Hassler and Wolters 1994; Lee and Schmidt 1996). Although unit root decision warrants conducting Johansen cointegration test and due to mixed unit root decision, we still conducted this test to check if cointegration exists. The results of the Johansen's cointegration test are reported in Table 3. Based on the Trace test, the null hypotheses of up to six cointegrating equations are rejected at the 5% level of significance for probabilities 0.0000, 0.0000, 0003, 0030, 0.0078 and 0.0433, while

Table 4 Estimating d in the I (d) setting using Gaussian semi-parametric approach

Country	$m=T^{0.4}$	$m=T^{0.5}$	$m=T^{0.6}$
Canada	**0.6824** (**0.3557**, **1.0091**)	**0.6785** (**0.4335**, **0.9235**)	**0.6842** (**0.4990**, **0.8694**)
France	**1.1336** (**0.8069**, **1.4603**)	**0.7195** (**0.4745**, **0.9645**)	**0.7255** (**0.5403**, **0.9107**)
Germany	**0.5137** (**0.1870**, **0.8404**)	**0.5023** (**0.2573**, **0.7473**)	**0.4934** (**0.3082**, **0.6786**)
Italy	**0.4530** (**0.1263**, **0.7797**)	**0.4668** (**0.2218. 0.7118**)	**0.5066** (**0.3214**, **0.6918**)
Japan	0.3037 (−0.0230, 0.6304)	**0.5283** (**0.2833**, **0.7733**)	**0.6114** (**0.4262**, **0.7966**)
UK	**1.0868** (**0.7601**, **1.4135**)	**0.8204** (**0.5754**, **1.0654**)	**0.8026** (**0.6174**, **0.9878**)
USA	**0.4522** (**0.1255**, **0.7789**)	**0.4861** (**0.2411**, **0.7311**)	**0.4549** (**0.2697**, **0.6401**)

Significant estimates of d at 5% level are in bold, and 95% confidence intervals for d are in parentheses

this is not rejected for the seventh rank. Thus, cointegration exists among the variables. By looking at the results based on the Max. eigenvalue statistic, the null was rejected for the first rank at 5% significance level with probability 0.0120 and this was unrejected at rank 2 based on 0.0865 probability at 5% significance level. Burke and Hunter (2005) and Enders (2014) suggested that Trace and Maximum eigenvalue tests do not test exactly the same hypothesis and could give different results. But if this happens, one should go by the decision of the Trace test.

The next step is the estimation of the results of fractional integration d based on semi-parametric and parametric approaches. In the results based on the Gaussian semi-parametric approach (Table 4), evidence of long-range dependence, in the mean reversion range is found in most cases of the three periodogram lengths, $m=T^{0.4}$, $T^{0.5}$ and $T^{0.6}$, except for periodogram length $T^{0.4}$ for Canada, France and the UK. Table 5 shows the results based on a parametric approach using three model specifications of no deterministic terms, only intercept and linear trend as given in Robinson (1994). The selected results for each country are based on the significance of intercept and time trend in the models. In the case of Canada, France, Germany and the UK, parameters of the fitted linear trend models are significant, while none of these parameters is significant in the case of Italy, Japan and USA. The estimates of d from these selected models are fairly around 0.4 to 0.6, and none of the upper bound of the confidence intervals approaches unity, thus, implying long-range dependence in EPU indices of the selected countries.

Since fractional integration and structural breaks are closely related, and structural break could lead to spurious detection of long memory in the series, we then conducted the Bai–Perron multiple structural break test on the series (see Bai and Perron 2003).The results of the detected breaks are given in Table 6, with two breaks detected in EPU indices of Canada, Germany and the UK. Three break dates are detected in France, Italy and USA, while four breaks are found in Japan EPU

Table 5 Estimates of d based on the parametric approach

Country	No det. terms	An intercept	A linear time trend
Canada	0.6051 (0.5123, 0.6978)	0.6051 (0.5113, 0.6988)	**0.5518** (**0.4483**, **0.6554**)
France	0.5258 (0.4408, 0.6108)	0.5258 (0.4385, 0.6131)	**0.4323** (**0.3302**, **0.5345**)
Germany	0.4469 (0.3497, 0.5442)	0.4469 (0.3493, 0.5446)	**0.3958** (**0.2875**, **0.5042**)
Italy	**0.4539** (**0.3570**, **0.5509**)	0.4539 (0.3569, 0.5510)	0.4525 (0.3548, 0.5502)
Japan	**0.6532** (**0.5447**, **0.7616**)	0.6532 (0.5437, 0.7627)	0.6513 (0.5426, 0.7601)
UK	0.6086 (0.5170, 0.7002)	0.6086 (0.5153, 0.7018)	**0.5527** (**0.4491**, **0.6563**)
USA	**0.5129** (**0.4066**, **0.6193**)	0.5129 (0.4061, 0.6198)	0.4951 (0.3851, 0.6050)

Selected model estimates for fractional integration parameter d are in bold. Models are selected based on the significance of the intercept and slope in the linear model (see Robinson 1994). In the parentheses are the corresponding 95% confidence intervals for the estimates

Table 6 Bai–Perron multiple structural break test

Country	TB1	TB2	TB3	TB4
Canada	2008M09	2016M02		
France	2001M09	2010M05	2016M02	
Germany	2007M08	2011M06		
Italy	2005M10	2010M05	2013M12	
Japan	2000M07	2003M11	2008M01	2012M07
UK	2009M12	2016M02		
USA	2000M05	2003M10	2008M09	

Critical values of Bai–Perron test are 8.58, 10.13, 11.14 and 11.83 for break dates TB1, TB2, TB3 and TB4, respectively. These break dates were obtained based on sequential method

index. In Table 7, the results based on fractional integration parametric approach is presented using break dummies obtained in Table 6. The results of fractional integration obtained agreed with those presented in Table 5. Therefore, breaks in the series do not significantly affect our results.

The detection of long-range dependence in the series based on the result in Tables 4, 5 and 7 necessitated the estimation of cointegration in fractional d set-up. A more general type of fractional cointegration framework is the FCVAR which allows for more than two variables in the system at a time. The modelling framework gives the rank tests, the estimated FCVAR model, the adjustment matrix and the equilibrium relations in Table 8, in panels A, B, C and D, respectively. The lag order for the model was first obtained using general-to-specific testing procedure

Table 7 Estimate of d with break dummies

Country	*d.*	TB1	TB2	TB3	TB4
Canada	0.5324 (0.4358, 0.6290)	109.31 (3.68)**	54.49 (1.74)*		
France	0.4826 (0.3862, 0.5790)	32.26 (0.976)	98.91 (2.90)**	56.25 (1.58)	
Germany	0.4066 (0.3025, 0.5107)	33.14 (1.35)	57.08 (2.27)**		
Italy	0.6707 (0.5621, 0.7793)	−7.87 (−0.404)	53.67 (2.65)**	3.43 (0.17)	
Japan	0.6609 (0.5398, 0.7820)	−31.93 (−1.59)	−16.80 (−0.88)	42.03 (2.18)**	−52.11 (−2.61)**
UK	0.4685 (0.3707, 0.5663)	74.86 (1.82)*	218.28 (4.82)**		
USA	0.4770 (0.3533, 0.6007)	24.77 (1.23)	−53.96 (−2.57)**	83.09 (3.74)**	

Significant parameters for break dummies are denoted as ** and * at 5 and 10% significant level, respectively. Confidence interval of d is in parenthesis

having checked the residuals for serial correlation, and maximum lag 5 was found as the optimal lag for *k* in the short-run dynamics. This is the rank test results, in Panel A. Since we have seven (7) variables in the VAR system, the null hypothesis of rank 0 was tested against the alternative of rank 7, and the null was rejected by 0.000 probability. The null hypothesis of rank 1 was tested again against the alternative of rank 7 and the null was rejected again by 0.000 probability. This continued on and on, until the null hypothesis of rank 5 was tested against the alternative of rank 7 and the null was accepted by probability 0.232. This result suggested five possible FCVAR models with long-run equilibria. This agreed with the results of the Johansen cointegration test in Table 3 that detected up to six cointegrating relations among the series. In Panel B and C, the integration parameter for the long-run equilibria is 0.010 which is highly significant even at the 5% level. This confirms the fractional cointegration of the series since the value (0.010) is less than the fractional d value of each of the individual series obtained in Tables 4, 5 and 7.[4]The adjustment matrix $\hat{\alpha}$ measures the speed of adjustment of the variables in response to disequilibrium errors. If the *j*th row of the matrix is zero, then, the variable x_{jt} is long-run exogenous meaning that it is unresponsive to disequilibrium errors. In Panel C results, the entries in the matrix are of high magnitude of positive and negative signs indicating that the long-run exogenous variables x_{jt} are responsive to disequilibrium errors. The equilibrium relations in Panel D contain five stationary simultaneous equations, detected in the rank tests. Note, own countries are entries

[4] Recall, Granger's definition of fractional cointegration is that the fractional d_u, that is the fractional integration of the joint cointegrating system, is less than d_i ($i = 1,\ldots,k$) where d_i is the fractional integration of the individual series with k variables to be cointegrated.

Table 8 Results of FCVAR analysis

Rank	d	b	Log-likelihood	LR statistic	p value
A. Rank tests					
0	0.238	0.238	−9397.497	123.139	0.000
1	0.271	0.271	−9377.119	82.383	0.000
2	0.137	0.137	−9362.105	52.355	0.001
3	0.085	0.085	−9354.324	36.792	0.002
4	0.054	0.054	−9347.035	22.216	0.008
5	0.010	0.010	−9338.723	5.590	0.232
6	0.010	0.010	−9336.449	1.042	0.307
7	0.010	0.010	−9335.928	–	–

B. The estimated FCVAR model

$$\Delta^{0.010}_{(0.000)}\left(\begin{bmatrix} Canada_t \\ France_t \\ Germany_t \\ Italy_t \\ Japan_t \\ UK_t \\ USA_t \end{bmatrix} - \begin{bmatrix} 131.83 \\ 176.50 \\ 149.25 \\ 101.56 \\ 130.47 \\ 115.79 \\ 111.30 \end{bmatrix}\right) = L_{0.010}\alpha\beta' x_t + \sum_{i=1}^{5} \hat{\Gamma}_i \Delta^{0.010}_{(0.010)} L^i_{0.010} x_t + \hat{\varepsilon}_t$$

C Adjustment matrix

$$\hat{\alpha} = \begin{bmatrix} -689.081 & -23.967 & -154.970 & 215.950 & -926.130 \\ -98.878 & -285.269 & -121.761 & -7.042 & 191.228 \\ 338.204 & -416.373 & -511.793 & -194.029 & -748.322 \\ 662.864 & -642.198 & 9.798 & -225.129 & -696.249 \\ 201.738 & -151.602 & 35.269 & -55.235 & -930.902 \\ -9.291 & 55.489 & -18.654 & -22.955 & -248.644 \\ -301.600 & -145.931 & 455.467 & 128.418 & -567.015 \end{bmatrix}$$

D Equilibrium relations, $\hat{\beta}' x_t = v_t$

$$\begin{bmatrix} 1.000 & 0.000 & -0.000 & 0.000 & 0.000 & 9.378 & -1.786 \\ -0.000 & 1.000 & -0.000 & 0.000 & 0.000 & -1.615 & 0.927 \\ 0.000 & -0.000 & 1.000 & -0.000 & 0.000 & -2.960 & -1.070 \\ 0.000 & 0.000 & -0.000 & 1.000 & 0.000 & 30.037 & -5.824 \\ 0.000 & 0.000 & 0.000 & -0.000 & 1.000 & 0.416 & -0.107 \end{bmatrix} \begin{bmatrix} Canada_t \\ France_t \\ Germany_t \\ Italy_t \\ Japan_t \\ UK_t \\ USA_t \end{bmatrix} = \begin{bmatrix} v_{1t} \\ v_{2t} \\ v_{3t} \\ v_{4t} \\ v_{5t} \\ v_{6t} \\ v_{7t} \end{bmatrix}$$

1.000 s, for Canada, France, Germany, Italy and Japan, while the coefficients, in the same equilibrium equation for other countries are around zero except for the UK and USA. For example, assuming $v_{1t} = v_{2t} = \cdots = v_{7t} = 0$, and using the first equation for Canada, suggesting that Canadian EPU is being driven majorly by economic activities in the UK and USA by coefficients 9.378 and −1.786. Similarly to the remaining four equations for France, Germany, Italy and Japan, the long-run equilibria contain nonzero contributions of coefficients from the UK and US EPU indices.

We conducted Granger causality tests for up to lag 2, with causality running from the USA to other G7 countries in the first case (see Table 9), and causality running from the UK to the rest of G7 countries in the second case (see

Table 9 Results of causality from the USA to other G6 countries

Null hypothesis	Obs	*F*-statistic	Prob.
Canada does not Granger-cause USA	267	5.73426	0.0037
USA does not Granger-cause Canada		4.54000	0.0115
France does not Granger-cause USA	267	2.74387	0.0662
USA does not Granger-cause France		2.31991	0.1003
Germany does not Granger-cause USA	267	1.17473	0.3105
USA does not Granger-cause Germany		3.92619	0.0209
Italy does not Granger-cause USA	267	0.76328	0.4672
USA does not Granger-cause Italy		4.80349	0.0089
Japan does not Granger-cause USA	267	2.98821	0.0521
USA does not Granger-cause Japan		3.57295	0.0294
UK does not Granger-cause USA	267	3.13492	0.0451
USA does not Granger-cause UK		1.26511	0.2839

Table 10 Results of causality from the UK to other G6 countries

Null hypothesis	Obs	*F*-statistic	Prob.
Canada does not Granger-cause UK	267	1.97274	0.1411
UK does not Granger-cause Canada		5.51431	0.0045
France does not Granger-cause UK	267	5.47186	0.0047
UK does not Granger-cause France		3.83120	0.0229
Germany does not Granger-cause UK	267	2.11331	0.1229
UK does not Granger-cause Germany		8.28873	0.0003
Italy does not Granger-cause UK	267	2.37418	0.0951
UK does not Granger-cause ITALY		1.10227	0.3337
JAPAN does not Granger-cause UK	267	3.51295	0.0312
UK does not Granger-cause JAPAN		0.47203	0.6243
USA does not Granger-cause UK	267	1.26511	0.2839
UK does not Granger-cause USA		3.13492	0.0451

Table 10). In Table 9, we observe rejections of null hypotheses of no causality from the USA to Canada, Germany, Italy and Japan at 5% level of significance and causality is only bidirectional in the case of USA–Canada relationship. In Table 10, the UK Granger-causes Canada, France, Germany and USA, while there is bidirectional causality in only the UK–France relationship.

Clearly, uncertainty spikes are more synchronized within advanced economies since there is the tendency of spillovers. The 9/11 attacks, Gulf War II, euro debt crisis and the UK Brexit referendum are among economic uncertainties that have driven the EPU indices over time, particularly in the USA and the

UK. These uncertainty reactions vary across country and the effect is smaller in advanced economies than in the rest of the world.

5 Conclusion

The development of economic policy uncertainty (EPU) index was gingered by the 2008/09 global financial crisis and it has created an opportunity to have an index of global comparison for countries' economic and financial uncertainty. Each country's index is constructed mainly based on newspapers' news originating from 'news of news' or 'news of no news' in the USA and in the UK. Given the relevance of uncertainty indices in driving major macroeconomic and financial variables, there is the need to explore the interdependencies among uncertainty indices for some developed countries. The time dynamics of EPU in the G7 countries are investigated by means of long-range dependence and cointegration methods. Each of the statistical methods is conducted in a robust manner, scarcely applied in the literature. The FCVAR framework which allows for more than two variables in the system of equations is an advanced approach of estimating the fractional cointegration of Robinson and Marinucci (2003) and Robinson (2008). Our empirical findings show that EPU indices in the G7 countries are cointegrated, with the possibility of up to five cointegrating ranks. The FCVAR analysis indicates that the USA and UK EPUs majorly drive EPU dynamics in the other five countries of the G7.

The findings of this study suggest that policy uncertainties in G7 countries have a long-run relationship, and uncertainties in one (foreign) country affect the aggregate economy in the other (domestic country) over the long term. In addition, policy uncertainties in the USA and the UK to a large extent are responsible for uncertainties in the domestic economy of the remaining members of the G7. Thus, policymakers in respective G7 countries can be guided on how economy reacts to movements in uncertainties in foreign countries particularly the UK and USA.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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