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Economic Policy Uncertainty: Persistence and Cross-Country Linkages

Abstract

This paper provides new evidence on the stochastic behaviour of the EPU (Economic Policy Uncertainty (EPU) index constructed by Baker et al. (2016) in six of the biggest economies (Canada, France, Japan, US, Ireland, and Sweden) over the period from January 1985 to October 2019. In particular, it uses fractional integration methods to shed light on its degree of persistence, and also carries out appropriate break tests. Further, the possible co-movement of this index between countries is examined applying a fractional cointegration method which tests for the possible existence of a long-run equilibrium relationship linking the individual indices. EPU is found to be in most cases a non-stationary, mean-reverting series which is characterised by long memory. Several breaks are also detected in each country. Finally, there is very little evidence of cross-country linkages.

JEL-Codes: C150, C320, C510, C520, E600.

Keywords: economic policy uncertainty, persistence, long memory, fractional integration, fractional cointegration.

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1. Introduction

Economic activity and the behaviour of economic agents at the household and firm level are greatly influenced by uncertainty (Bernanke, 1983; Carroll, 1997; Bansal & Yaron, 2004; McDonald & Siegel, 1986; Dixit & Pindyck, 1994; Bloom, Bond, & Van Reenen 2001; Dixit, 1989). In particular, in recent years the role played by economic policy uncertainty (EPU thereafter) in driving macroeconomic fluctuations has been one of the most intensely discussed issues among academics, policy-makers and practitioners. In his well-known study, Bloom (2009) estimated a time-varying model using firm-level data and concluded that higher uncertainty can generate sharp recessions, and subsequent swift rebounds, in both output and employment, owing to the 'wait and see' attitude of firms making investment and hiring decisions subject to uncertainty.

Other studies provide mixed evidence on the impact of EPU on economic activity. For example, Baker et al. (2016), using a structural VAR model, showed that it causes statistically significant declines in employment, investment and industrial production both in the US economy and in an international setting. Gulen and Ion (2016) and Kang et al. (2014) (in the case of the US) and Rodrik and Fernandez (1991) (for the developing countries) found that uncertainty causes capital investment and productivity to plummet. Leduc and Liu (2016) reported that an uncertainty shock increases unemployment and at the same time lowers inflation. Pastor and Veronesi (2012) showed that higher policy uncertainty is associated with lower stock prices, higher volatility and higher correlations among stock returns. Ko and Lee (2015) found that an increase in EPU reduces stock prices. Sahinoz and Cosar (2018) concluded that EPU has an adverse effect on economic growth and investment.

Although there exists a comprehensive literature on the impact of EPU on the economy, various key issues are yet to be analysed – for instance, the stochastic properties of EPU (for example, its degree of persistence), spillovers across countries and structural breaks; in particular, examining EPU cross-country linkages could provide useful insights to both investors focusing on higher frequencies or short-term movement and hedgers and arbitragers who are mainly interested in lower frequencies or long-term co-movement. The present study addresses these issues by carrying out a comprehensive analysis of EPU over the period January 1985 to October 2019 for six countries (Canada, France, Japan, US, Ireland, and Sweden); specifically, fractional integration and cointegration techniques are applied, respectively, to investigate the stochastic properties of and the bilateral linkages between the series of interest, and break tests are also carried out.

The layout of the paper is the following. Section 2 provides a brief review of the relevant literature. Section 3 outlines the empirical methodology. Section 4 describes the data and presents the empirical results. Section 5 provides some concluding remarks.

2. Literature Review

Economic policy uncertainty (EPU) is defined as the agents' inability to predict future economic policies as well as the consequences of policies that have already been adopted by the government. Agents often face uncertainty about the timing, content and potential effect of policy decisions. Quantifying policy uncertainty is very difficult because of its unobservable nature. Baker et al. (2016) constructed an index for EPU based on newspaper coverage frequency, the underlying idea being that a higher number of news articles about EPU reflects a higher level of uncertainty faced by agents. Subsequent papers have followed a similar approach for developing EPU indices for other countries (Arbatli et al. 2017; Cerda, Silva, and Valente 2016; Zalla 2017;

Hlatshwayo and Saxegaard 2016; Kroese, Kok, and Parlevliet 2015; Bhagat, Ghosh, and Rangan 2013).

Other studies have examined the impact of the EPU index constructed as in Baker et al. (2014 and 2016) on various economic variables. Using firm-level data, Gulen and Ion (2016) found that EPU can explain up to 32% of the drop in corporate investment over the 2007-2009 time period. Pastor and Veronesi (2012, 2013) developed a model in which agents learn through a Bayesian updating process about the effects of policies endogenously chosen by governments; they also showed that higher EPU is associated with higher volatility of US equities and higher correlations between them. Gourinchas and Parker (2002) and Guiso et al. (2013**)** showed the importance of life-cycle income uncertainty on pre-cautionary savings. Brogaard and Detzel (2015) found that increases in EPU lower equity prices by raising the discount rate on future cash flows and by affecting the risk premium. Shoag and Veuger (2016) showed that the cross-sectional variation in uncertainty can explain a significant percentage of unemployment fluctuations during the Great Recession.

As for the effects of specific types of uncertainty, Baker et al. (2016) found that tax policy uncertainty is the largest source of policy uncertainty in the US. Kydland and Zarazaga (2016) showed that uncertainty about fiscal policy (and, more specifically, tax policy) accounts for the weaker than expected recovery of the US economy after the 2007-2008 crisis. Sinha (2016) reported that an increase in interest rate uncertainty leads to lower output, while Husted et al. (2018) found that higher monetary policy uncertainty in the US increases interest rates and yield spreads and lowers output and inflation. Aghion et al. (2009) provided evidence that real exchange rate volatility can affect output growth significantly, while Aguiar (2005) found that, after the Mexican Peso devaluation, the balance sheet effect outweighed the potential benefits for exports.

Finally, Kane (2000) provided evidence about the connection between capital outflows, banking insolvency and silent runs during the Asian crisis.

3. Methodology

Granger (1980) showed that many economic aggregates display estimated spectrums with a large value at the zero frequency, which suggests that first differences of these series should be taken. However, once they are first differenced, the estimated spectrum shows values close to zero at the smallest (zero) frequency, which implies over-differentiation. This observation led to the development of fractional integration or I(d) models with $0 < d < 1$.

These processes became popular in the econometrics literature in the late 1990s. Nelson and Plosser (1982) had examined fourteen macroeconomics series and found that models with unit roots or stochastic trends were more appropriate than deterministic ones; however, using an extended sample, Gil-Alana and Robinson (1997) concluded that all of them except one displayed orders of integration in the interval (0, 1) that are significantly different from 1. Since then, I(d) models have been widely employed in the literature (see, e.g., Banerjee and Urga, 2005; Mayoral, 2006; Gil-Alana and Moreno, 2012; Abbritti et al., 2016; Baillie et al., 2019; etc.).

Fractional cointegration is a natural extension of fractional integration to the multivariate case. Cointegration was first introduced in the seminal paper by Engle and Granger (1987), who argued that two or more series are cointegrated if they are non-stationary and integrated of order d, i.e., I(d), but there exists at least one linear combination of them which is integrated of order $d – b$, with $b > 0$. Although this definition held for any real values d and b, all the empirical applications based on this approach assumed integer degrees of differentiation, namely $d = b = 1$. Subsequently, Johansen (1988, 1991, 1995) introduced the LR and trace test statistics for cointegration in a multivariate framework. The extension to the fractional case was first implemented by Cheung and Lai (1993) and Gil-Alana (2003) having been introduced in a series of papers by Maarinucci and Robinson (2001), Robinson and Yajima (2002), Robinson and Hualde (2003), Hualde and Robinson (2007), etc. Later on, Johansen and Nielsen (2010, 2012) extended the CVAR model (Johansen, 1991; Johansen and Juselius, 1994) to the fractional case (fractional CVAR, FVAR model).

4. Data and Empirical Results

The data for the EPU index constructed by Baker et al. (2016) have been downloaded from the website www.policyuncertainty.com for the period of January 1985 to October 2019 for the six countries with the longest data span (Canada, France, Japan, USA, Ireland, and Sweden). This index has already been used by several researchers (for example, He and Niu 2018, and Ko and Lee 2015) because, as argued by Istiak and Serletis (2018), it has four advantages over other uncertainty measures: (i) it incorporates past movements in policy-related economic uncertainty, (ii) it is available for all the big economies (see www.policyuncertainty.com), (iii) it reflects the true nature of uncertainty for the whole economy, and (iv) it explains the cross-sectional patterns in some economic variables.

As a first step, we carry out the univariate analysis using the following model:

$$y_t \;=\; \alpha \;+\; \beta\, t \;+\; x_t\,, \qquad (1-L)^d\, x_t \;=\; u_t\,, \qquad t \;=\; 1, 2, \ldots, \tag{1}$$

where y_t stands for the observed time series (in logs); α and β are the coefficients on the intercept and the linear time trend; d is a real value and u_t is assumed to be I(0). We report the estimated values of d from three different specifications: i) when α and β are assumed to be 0, i.e. no deterministic terms are included in the regression model (1), ii) with β = 0, that is, allowing for an intercept, and iii) estimating α and β from the data and therefore allowing for both an intercept and a linear time trend. Further, the disturbance term u_t, is assumed to follow a white noise process (in Tables 1 and 2) or, alternatively, to be autocorrelated (in Tables 3 and 4) as in the non-parametric spectral approach proposed by Bloomfield (1973).

Table 1: Estimated values of d under the assumption of white noise errors

Country	No terms	An intercept	An Intercept and a Linear Time Trend
CANADA	0.81 (0.76, 0.89)	0.60 (0.53, 0.68)	**0.59 (0.53, 0.68)**
FRANCE	0.71 (0.66, 0.77)	0.49 (0.45, 0.54)	**0.47 (0.42, 0.53)**
IRELAND	0.53 (0.48, 0.58)	0.37 (0.33, 0.42)	**0.33 (0.29, 0.39)**
JAPAN	0.91 (0.85, 0.99)	**0.65 (0.58, 0.75)**	0.66 (0.58, 0.75)
SWEDEN	0.89 (0.83, 0.95)	**0.46 (0.41, 0.53)**	0.46 (0.41, 0.53)
US	0.82 (0.76, 0.88)	**0.54 (0.47, 0.64)**	0.54 (0.46, 0.63)

Notes: In bold the estimates from the specification selected on the basis of the statistical significance of the deterministic terms for each country. In parenthesis, the 95% confidence band for the values of d.

Table 2: Estimated coefficients of the parameters of the selected models in Table 1

Country	No terms	An intercept	An Intercept and a Linear Time Trend
CANADA	0.59 (0.53, 0.68)	4.2115 (18.93)	0.0035 (2.25)
FRANCE	0.47 (0.42, 0.53)	4.2007 (20.60)	0.0033 (3.20)
IRELAND	0.33 (0.29, 0.39)	4.1979 (31.81)	0.0018 (3.31)
JAPAN	0.65 (0.58, 0.75)	4.3388 (30.16)	---
SWEDEN	0.46 (0.41, 0.53)	4.6346 (65.08)	---
US	0.54 (0.47, 0.64)	4.6219 (29.54)	---

Notes: In parenthesis, in the second column, the 95% confidence band for the values of d; in column 3 and 4, the corresponding t-values.

It can be seen in Table 1 that in the cases of Canada, France and Ireland a time trend is required, its coefficient being positive and significant, while an intercept is sufficient in the remaining three cases, namely Japan, Sweden and US (see Table 2). All estimated values of d are between 0 and 1 (specifically, they range between 0.23 (Ireland) and 0.65 (Japan)) and their confidence intervals exclude the case of d = 1; this implies that the series, though exhibiting long memory, are mean-reverting, with shocks having transitory effects. When allowing for autocorrelation in the residuals (in Tables 3 and 4) the time trend coefficient is significant in the cases of Canada, France and US, again with a positive coefficient, and the estimates of d are once more in the interval (0, 1), ranging from 0.40 (US) to 0.56 (France), which again implies long memory and mean-reverting behaviour.

Table 3: Estimated values of d under the assumption of autocorrelated errors

Country	No terms			An intercept			An Intercept and a Linear Time Trend		
CANADA	0.84	(0.76,	0.95)	0.56	(0.47,	0.67)	**0.54**	**(0.45,**	**0.66)**
FRANCE	0.83	(0.74,	0.96)	0.57	(0.50,	0.66)	**0.56**	**(0.47,**	**0.65)**
IRELAND	0.78	(0.69,	0.89)	**0.42**	**(0.34,**	**0.50)**	0.38	(0.30,	0.49)
JAPAN	0.85	(0.77,	0.97)	**0.53**	**(0.43,**	**0.66)**	0.53	(0.43,	0.66)
SWEDEN	0.94	(0.86,	1.07)	**0.45**	**(0.38,**	**0.53)**	0.45	(0.37,	0.52)
US	0.84	(0.76,	0.94)	0.42	(0.33,	0.52)	**0.40**	**(0.31,**	**0.53)**

Notes: In bold the estimates from the specification selected on the basis of the statistical significance of the deterministic terms for each country. In parenthesis, the 95% confidence band for the values of d.

Table 4: Estimated coefficients of the parameters of the selected models in Table 3

Country	**No terms**	**An intercept**	An Intercept and a Linear Time Trend
CANADA	0.54 (0.45, 0.66)	4.2027 (20.61)	0.0034 (2.80)
FRANCE	0.56 (0.47, 0.65)	4.2241 (17.04)	0.0033 (2.11)
IRELAND	0.42 (0.34, 0.50)	4.5514 (21.91)	---
JAPAN	0.53 (0.43, 0.66)	4.4031 (39.87)	---
SWEDEN	0.45 (0.38, 0.53)	4.6328 (67.50)	---
US	0.40 (0.31, 0.53)	4.4965 (37.63)	0.0011 (2.11)

Notes: In parenthesis, in the second column, the 95% confidence band for the values of d; in column 3 and 4, the corresponding t-values.

Next, we test for structural breaks, since high levels of persistence could be the consequence of breaks which have not been taken into account (Diebold and Inoue, 2001; Granger and Hyung, 2004; etc.); specifically, we carry out the Bai and Perron (2003) and Gil-Alana (2008) tests, the latter being an extension of the former to the fractional case. The detected breaks are the same in both cases (see Table 5).

Table 5; Bai and Perron's (2003) & Gil-Alana's (2008) tests for multiple structural breaks

Country	N. of breaks	Break dates
CANADA	3	2003m7; 2008m9; 2014m11
FRANCE	4	1997m2; 2002m3; 2007m8; 2012m9
IRELAND	3	1994m10; 2001m11; 2007m10
JAPAN	5	1992m4; 1997m8; 2003m7; 2008m6; 2013m5
SWEDEN	3	1998m11; 2003m10; 2010m5
US	4	1993m9; 1998m8; 2003m10; 2008m9

Table 6 displays the estimated values of d for each subsample and each series under the assumption of autocorrelated errors (similar results, not reported for brevity's sake, were obtained in the case of white noise disturbances). In most cases they are significantly positive, which indicates the presence of long memory. Evidence of short memory, i.e., d = 0, is only found in the last subsample for Canada and the last three subsamples for Ireland.

Table 6: Estimated values of d under the assumption of autocorrelated errors

Country		No terms	An intercept	An Intercept and a Linear Time Trend
	1987M1 - 2003M6	0.79 (0.71, 0.89)	**0.54 (0.45, 0.67)**	0.55 (0.45, 0.67)
LCAN	2003M7 - 2008M8	0.98 (0.81, 1.23)	**0.45 (0.27, 0.75)**	0.45 (0.26, 0.76)
	2008M9 - 2014M10	0.88 (0.72, 1.10)	**0.69 (0.53, 0.89)**	0.70 (0.56, 0.89)
	20014M11- 2019M10	0.90 (0.74, 1.12)	0.39 (0.28, 0.56)	**0.21 (0.00, 0.50)**
	1987M1 - 1997M1	0.80 (0.70, 0.93)	**0.34 (0.24, 0.48)**	0.34 (0.23, 0.48)
	1997M2 - 2002M2	0.74 (0.60, 0.94)	**0.36 (0.25, 0.51)**	0.36 (0.25, 0.51)
LFRA	2002M3 - 2007M7	0.81 (0.67, 0.99)	0.38 (0.24, 0.62)	**0.32 (0.12, 0.61)**
	2007M8 - 2012M8	0.88 (0.69, 1.17)	0.39 (0.28, 0.55)	**0.24 (0.05, 0.48)**
	2012M9 – 2019M10	0.90 (0.77, 1.09)	**0.42 (0.29, 0.61)**	0.42 (0.27, 0.61)
	1987M1 - 1994M9	0.64 (0.50, 0.81)	**0.14 (0.03, 0.30)**	0.09 (-0.05, 0.28)
LIRE	1994M10 - 2001M10	0.61 (0.46, 0.79)	**-0.07 (-0.20, 0.12)**	-0.09 (-0.23, 0.11)
	2001M11 - 2007M9	0.68 (0.54, 0.85)	0.10 (0.01, 0.23)	**-0.06 (-0.19, 0.12)**
	20007M10- 2019M10	0.69 (0.61, 0.79)	**0.08 (-0.02, 0.22)**	0.07 (-0.04, 0.21)
	1987M1 - 1992M3	0.98 (0.80, 1.23)	**0.55 (0.34, 0.93)**	0.54 (0.31, 0.94)
	1992M4 - 1997M7	0.96 (0.80, 1.24)	**0.48 (0.28, 0.74)**	0.48 (0.28, 0.74)
	1997M8 - 2003M6	0.94 (0.81, 1.13)	**0.72 (0.55, 0.98)**	0.72 (0.53, 0.98)
LJAP	2003M7 - 2008M5	0.94 (0.77, 1.19)	**0.45 (0.34, 0.62)**	0.43 (0.31, 0.61)
	2008M6 – 2013M4	0.93 (0.77, 1.16)	**0.41 (0.16, 0.78)**	0.40 (0.15, 0.78)
	2013M5 – 2019M10	0.91 (0.77, 1.12)	**0.71 (0.53, 1.00)**	0.71 (0.52, 1.00)
	1987M1 - 1998M10	0.90 (0.81, 1.02)	**0.34 (0.24, 0.49)**	0.35 (0.25, 0.49)
LSWE	1998M11 - 2003M9	0.91 (0.75, 1.14)	**0.49 (0.34, 0.80)**	0.52 (0.36, 0.80)
	2003M10 - 2010M5	0.94 (0.79, 1.13)	**0.39 (0.25, 0.60)**	0.36 (0.17, 0.59)
	2010M6 - 2019M10	0.89 (0.75, 1.09)	**0.19 (0.04, 0.41)**	0.15 (-0.05, 0.40)
	1987M1 - 1993M8	0.87 (0.74, 1.06)	**0.45 (0.24, 0.75)**	0.44 (0.23, 0.74)
	1993M9 - 1998M7	0.96 (0.79, 1.26)	**0.30 (0.09, 0.66)**	0.30 (0.06, 0.66)
LUS	1998M8 - 2003M9	0.93 (0.71, 1.22)	**0.72 (0.52, 1.02)**	0.72 (0.50, 1.02)
	2003M10 - 2008M8	0.86 (0.72, 1.07)	**0.48 (0.33, 0.69)**	0.47 (0.32, 0.69)
	2008M9 - 2019M10	0.85 (0.75, 0.99)	**0.44 (0.33, 0.62)**	0.45 (0.33, 0.64)

Notes: In bold the estimates from the specification selected on the basis of the statistical significance of the deterministic terms for each country. In parenthesis, the 95% confidence band for the values of d.

Next, we examine the possible existence of a long-run equilibrium relationship between the series of interest by carrying out fractional cointegration tests. This requires establishing in the first instance whether the individual series have the same degree of integration.

Table 7: Estimates of d on the parent series using Robinson (1994)

Series	No autocorrelation	With autocorrelation
CANADA	0.59 (0.53, 0.68)	0.54 (0.45, 0.66)
FRANCE	0.47 (0.42, 0.53)	0.56 (0.47, 0.65)
IRELAND	0.33 (0.29, 0.39)	0.42 (0.34, 0.50)
JAPAN	0.65 (0.58, 0.75)	0.53 (0.43, 0.66)
SWEDEN	0.46 (0.41, 0.53)	0.45 (0.38, 0.53)
US	0.54 (0.47, 0.64)	0.40 (0.31, 0.53)

Notes: In parenthesis, the 95% confidence band for the values of d.

Table 7 summarises the estimated values of d for each series using Robinson's (1994) parametric approach. Table 8 shows instead the estimates obtained applying a semi-parametric method which does not require any assumption about the I(0) error term; in particular, we use a "local" Whittle approach with the frequencies degenerating to zero as in Robinson (1995); this has the advantage of being simple and requiring a single bandwidth parameter, whilst more recent methods (see, e.g., Velasco, 1999, Phillips and Shimotsu, 2005, Abadir et al., 2007) require additional ones, with the estimates of d generally being very sensitive to those. It can be seen that the semi-parametric estimates are much higher than the parametric ones, in all cases exceeding 0.5, which implies non-stationary behaviour.

Table 8: Estimates of d using a semi-parametric approach

Series / m	$11 \approx T^{0.4}$	$18 \approx T^{0.5} - 1$	$19 \approx T^{0.5}$	$20 \approx T^{0.5}+1$	$36 \approx T^{0.6}$
CANADA	0.692	0.706	0.714	0.731	0.600
FRANCE	0.756	0.722	0.731	0.739	0.634
IRELAND	0.891	0.746	0.758	0.796	0.509
JAPAN	0.560	0.521	0.564	0.618	0.849
SWEDEN	0.843	0.748	0.749	0.723	0.570
US	0.535	0.640	0.693	0.735	0.470

Next we test for the homogeneity in the orders of integration across countries by employing the Robinson and Yajima's (2002) approach. The results are displayed in Table 9: the null of equal orders of integration cannot be rejected in any case. The same conclusion is reached using Hualde's (2003) approach (these results are not reported to save space).

Table 9: Robinson and Yajima's (2002) tests for homogeneity in the integration order

	FRANCE	IRELAND	JAPAN	SWEDEN	US
CANADA	-0.170	-0.440	1.499	-0.350	0.209
FRANCE	---	-0.270	1.669	-0.180	0.379
IRELAND	---	---	1.940	0.090	0.649
JAPAN	---	---	---	-1.850	-1.293
SWEDEN	---	---	---	---	0.559
US	---	---	---	---	---

To test for cointegration we use first Engle and Granger (1987)'s approach; this involves testing the order of integration of the estimated residuals from the OLS regression of one variable against another (see Gil-Alana, 2003). The estimated values of d for the three model specifications are reported in Tables 10 and 11 for the two cases of white noise and autocorrelated errors respectively, and provide very little evidence of a lower degree of integration compared to the individual series. The values in bold are those corresponding in each case to our preferred specification (which is selected on the basis of the statistical significance of the other coefficients) and are also reported in Table 12.

Table 10: Fractional cointegration using Engle and Granger (1987) (Gil-Alana, 2003) under the assumption of white noise errors

Country	No terms	An intercept	An Intercept and a Linear Time Trend
LCAN / LFRA	0.41 (0.35, 0.47)	**0.41 (0.35, 0.47)**	0.41 (0.35, 0.47)
LCAN / LIRE	0.40 (0.35, 0.46)	0.40 (0.35, 0.46)	**0.39 (0.34, 0.46)**
LCAN / LJAP	0.53 (0.48, 0.60)	0.53 (0.48, 0.60)	**0.52 (0.47, 0.60)**
LCAN / LSWE	0.52 (0.46, 0.59)	0.50 (0.45, 0.57)	**0.48 (0.41, 0.56)**
LCAN / LUS	0.40 (0.36, 0.45)	0.39 (0.35, 0.45)	**0.38 (0.34, 0.44)**
LFRA / LIRE	0.33 (0.28, 0.38)	0.32 (0.28, 0.37)	**0.28 (0.24, 0.34)**
LFRA / LJAP	0.49 (0.43, 0.54)	0.48 (0.44, 0.53)	**0.47 (0.42, 0.52)**
LFRA / LSWE	0.49 (0.45, 0.55)	0.48 (0.44, 0.53)	**0.45 (0.40, 0.52)**
LFRA / LUS	0.44 (0.40, 0.49)	0.43 (0.34, 0.49)	**0.42 (0.37, 0.48)**
LIRE / LJAP	0.26 (0.22, 0.30)	0.26 (0.22, 0.30)	**0.23 (0.19, 0.28)**
LIRE / LSWE	0.26 (0.22, 0.31)	0.26 (0.22, 0.31)	**0.21 (0.17, 0.26)**
LIRE / LUS	0.18 (0.14, 0.23)	0.18 (0.14, 0.23)	**0.15 (0.08, 0.21)**
LJAP / LSWE	0.65 (0.58, 0.74)	**0.65 (0.57, 0.74)**	0.65 (0.57, 0.74)
LJAP / LUS	0.54 (0.47, 0.61)	**0.53 (0.47, 0.61)**	0.53 (0.47, 0.61)
LSWE / LUS	0.44 (0.39, 0.51)	**0.44 (0.39, 0.50)**	0.43 (0.38, 0.49)

Notes: In bold the estimates from the specification selected on the basis of the statistical significance of the deterministic terms for each pair of countries. In parenthesis, the 95% confidence band for the values of d.

Table 11: Fractional cointegration using Engle and Granger (1987) (Gil-Alana, 2003) under the assumption of autocorrelated errors

Country	No terms	An intercept	An Intercept and a Linear Time Trend
LCAN / LFRA	0.44 (0.38, 0.63)	**0.49 (0.38, 0.63)**	0.50 (0.40, 0.63)
LCAN / LIRE	0.46 (0.37, 0.56)	0.44 (0.36, 0.56)	**0.45 (0.35, 0.57)**
LCAN / LJAP	0.55 (0.46, 0.65)	0.45 (0.47, 0.65)	**0.54 (0.45, 0.66)**
LCAN / LSWE	0.50 (0.42, 0.59)	0.48 (0.41, 0.57)	**0.41 (0.32, 0.54)**
LCAN / LUS	0.47 (0.40, 0.56)	0.46 (0.40, 0.54)	**0.45 (0.39, 0.54)**
LFRA / LIRE	0.43 (0.36, 0.50)	0.41 (0.35, 0.48)	**0.38 (0.30, 0.48)**
LFRA / LJAP	0.62 (0.55, 0.72)	**0.62 (0.53, 0.70)**	0.60 (0.53, 0.70)
LFRA / LSWE	0.56 (0.50, 0.65)	0.54 (0.48, 0.62)	**0.51 (0.43, 0.61)**
LFRA / LUS	0.52 (0.46, 0.60)	0.51 (0.44, 0.60)	**0.49 (0.43, 0.59)**
LIRE / LJAP	0.39 (0.33, 0.49)	**0.40 (0.34, 0.48)**	0.37 (0.30, 0.47)
LIRE / LSWE	0.39 (0.33, 0.48)	0.39 (0.33, 0.49)	**0.35 (0.26, 0.46)**
LIRE / LUS	0.25 (0.19, 0.33)	0.25 (0.19, 0.34)	**0.21 (0.13, 0.32)**
LJAP / LSWE	0.57 (0.47, 0.70)	**0.55 (0.45, 0.68)**	0.55 (0.45, 0.68)
LJAP / LUS	0.55 (0.45, 0.70)	**0.54 (0.44, 0.68)**	0.55 (0.44, 0.68)
LSWE / LUS	0.47 (0.40, 0.56)	**0.46 (0.40, 0.54)**	0.45 (0.38, 0.53)

Notes: In bold the estimates from the specification selected on the basis of the statistical significance of the deterministic terms for each pair of countries. In parenthesis, the 95% confidence band for the values of d.

Table 12: Summary results of Tables 10 and 11

Country	No autocorrelation	With autocorrelation
LCAN / LFRA	0.41 (0.35, 0.47)	0.49 (0.38, 0.63)
LCAN / LIRE	0.39 (0.34, 0.46)	0.45 (0.35, 0.57)
LCAN / LJAP	0.52 (0.47, 0.60)	0.54 (0.45, 0.66)
LCAN / LSWE	0.48 (0.41, 0.56)	0.41 (0.32, 0.54)
LCAN / LUS	0.38 (0.34, 0.44)	0.45 (0.39, 0.54)
LFRA / LIRE	0.28 (0.24, 0.34)	0.38 (0.30, 0.48)
LFRA / LJAP	0.47 (0.42, 0.52)	0.62 (0.53, 0.70)
LFRA / LSWE	0.45 (0.40, 0.52)	0.51 (0.43, 0.61)
LFRA / LUS	0.42 (0.37, 0.48)	0.49 (0.43, 0.59)
LIRE / LJAP	0.23 (0.19, 0.28)	0.40 (0.34, 0.48)
LIRE / LSWE	0.21 (0.17, 0.26)	0.35 (0.26, 0.46)
LIRE / LUS	0.15 (0.08, 0.21)	0.21 (0.13, 0.32)
LJAP / LSWE	0.65 (0.57, 0.74)	0.55 (0.45, 0.68)
LJAP / LUS	0.53 (0.47, 0.61)	0.54 (0.44, 0.68)
LSWE / LUS	0.44 (0.39, 0.50)	0.46 (0.40, 0.54)

Notes: In parenthesis, the 95% confidence band for the values of d.

Next, we test the null hypothesis of no cointegration versus the alternative of fractional cointegration by carrying out the Hausman test proposed by Marinucci and Robinson (2001), who tested that

$$\mathrm{H}_{\mathrm{is}} \;=\; 8\,s\,(\hat{d}_* - \hat{d}_i)^2 \;\to_d\; \chi^2_1 \qquad as \qquad \frac{1}{s} + \frac{s}{T} \to\; 0 \qquad (5)$$

where i = x, y; s < [T/2] is another bandwidth parameter similar to m above, and $\hat{d}_*$ is a restricted estimate of d obtained from the bivariate representation of the two series under the assumption that $d_x = d_y$. More precisely:

$$\hat{\mathrm{d}}_* \;=\; -\frac{\sum_{\mathrm{j}=1}^{\mathrm{s}} 1_2^{\mathrm{T}}\,\hat{\Omega}^{-1} Y_j v_j}{2\,1_2^{\mathrm{T}}\,\hat{\Omega}^{-1} \sum_{j=1}^{s} v_j^2},$$

where $Y_j = [\log I_{xx}(\lambda_j), \log I_{yy}(\lambda_j)]^T$ and $v_j = \log j - \frac{1}{s}\sum_{j=1}^{s} \log j$, and $\hat{\Omega}$ is a consistent estimate of the limiting variance matrix of $2s^{1/2}(\hat{d} - d)$.

The estimates of d_* from the joint representation of the two series for a range of bandwidth parameters from 10 to 15 are reported in Table 13; they are required for the Hausman test in a semi-parametric context.

Table 13 Estimates of d_* in the bivariate representation of the series

Series / m	$11 \approx T^{0.4}$	$18 \approx T^{0.5} - 1$	$19 \approx T^{0.5}$	$20 \approx T^{0.5}+1$	$36 \approx T^{0.6}$
LCAN / LFRA	0.811	0.595	0.586	0.599	0.498
LCAN / LIRE	0.800	0.698	0.715	0.728	0.659
LCAN / LJAP	0.693	0.673	0.686	0.710	0.578
LCAN / LSWE	0.586	0.513	0.587	0.634	0.498
LCAN / LUS	0.694	0.763	0.760	0.719	0.637
LFRA / LIRE	0.660	0.539	0.567	0.584	0.553
LFRA / LJAP	0.706	0.713	0.724	0.732	0.649
LFRA / LSWE	0.742	0.671	0.690	0.680	0.608
LFRA / LUS	0.766	0.766	0.781	0.777	0.638
LIRE / LJAP	0.741	0.731	0.739	0.771	0.463
LIRE / LSWE	0.744	0.738	0.755	0.787	0.414
LIRE / LUS	0.687	0.595	0.614	0.488	0.348
LJAP / LSWE	0.307	0.390	0.353	0.486	0.862
LJAP / LUS	0.319	0.392	0.427	0.450	0.471
LSWE / LUS	0.633	0.759	0.762	0.717	0.594

Tables 14 and 15 display the Hausman test results for testing the null of no cointegration against the alternative of cointegration. Specifically, Table 14 presents the results based on Robinson's (1994) parametric approach, and Table 15 those obtained using the “local” Whittle semi-parametric approach. In the former case the only evidence of cointegration is obtained for Canada versus US for two of the bandwidth parameters, and for Ireland versus US for all bandwidths. In the latter case there is some evidence of cointegration only for the cases of France/Ireland, Ireland/US, Japan/Sweden and Japan/US.

Table 14: Testing fractional cointegration with Robinson and Marinucci (2001) using the parametric approach of Robinson (1994)

series / m	**No autocorrelation**			**With autocorrelation**		
	$18 \approx T^{0.5} - 1$	$19 \approx T^{0.5}$	$20 \approx T^{0.5}+1$	$18 \approx T^{0.5} - 1$	$19 \approx T^{0.5}$	$20 \approx T^{0.5}+1$
LCAN /	H_{10}: 4.66	H_{10}: 4.92	H_{10}: 5.18	H_{10}: 0.36	H_{10}: 0.38	H_{10}: 0.40
LFRA	H_{20}: 0.51	H_{20}: 0.54	H_{20}: 0.57	H_{20}: 0.70	H_{20}: 0.74	H_{20}: 0.78
LCAN /	H_{10}: 5.75	H_{10}: 6.07	H_{10}: 6.39	H_{10}: 1.16	H_{10}: 1.23	H_{10}: 1.29
LIRE	H_{20}:0.51	H_{20}:0.54	H_{20}:0.57	H_{20}: 0.12	H_{20}: 0.13	H_{20}: 0.14
LCAN /	H_{10}:0.70	H_{10}:0.74	H_{10}:0.78	H_{10}: 0.00	H_{10}: 0.01	H_{10}: 0.00
LJAP	H_{20}: 2.43	H_{20}: 2.56	H_{20}: 2.70	H_{20}: 0.01	H_{20}: 0.01	H_{20}: 0.01
LCAN /	H_{10}: 1.74	H_{10}: 1.83	H_{10}: 1.93	H_{10}: 2.43	H_{10}: 2.56	H_{10}: 2.70
LSWE	H_{20}: 0.05	H_{20}: 0.06	H_{20}: 0.06	H_{20}: 0.24	H_{20}: 0.24	H_{20}: 0.26
LCAN /	H_{10}: 6.35	**H_{10}: 6.70**	**H_{10}: 7.05**	H_{10}: 1.16	H_{10}: 1.23	H_{10}: 1.29
LUS	H_{20}: 3.68	**H_{20}: 3.89**	**H_{20}: 4.09**	H_{20}: 0.36	H_{20}: 0.37	H_{20}: 0.40
LFRA /	H_{10}: 5.19	H_{10}: 5.48	H_{10}: 5.77	H_{10}: 4.66	H_{10}: 4.92	H_{10}: 5.18
LIRE	H_{20}: 0.36	H_{20}: 0.38	H_{20}: 0.40	H_{20}: 0.23	H_{20}: 0.24	H_{20}: 0.26
LFRA /	H_{10}: 0.00	H_{10}: 0.00	H_{10}: 0.00	H_{10}: 0.51	H_{10}: 0.54	H_{10}: 0.57
LJAP	H_{20}: 4.66	H_{20}: 4.92	H_{20}: 5.18	H_{20}: 1.16	H_{20}: 1.23	H_{20}: 1.29
LFRA /	H_{10}: 0.05	H_{10}: 0.06	H_{10}: 0.06	H_{10}: 0.36	H_{10}: 0.38	H_{10}: 0.40
LSWE	H_{20}: 0.01	H_{20}: 0.01	H_{20}: 0.01	H_{20}: 0.51	H_{20}: 0.54	H_{20}: 0.57
LFRA /	H_{10}: 0.36	H_{10}: 0.38	H_{10}: 0.40	H_{10}: 0.70	H_{10}: 0.74	H_{10}: 0.78
LUS	H_{20}: 2.07	H_{20}: 2.18	H_{20}: 2.30	H_{20}: 1.16	H_{20}: 1.23	H_{20}: 1.29
LIRE /	H_{10}: 1.44	H_{10}: 1.52	H_{10}: 1.60	H_{10}: 0.05	H_{10}: 0.06	H_{10}: 0.06
LJAP	H_{20}: 25.9	H_{20}: 26.8	H_{20}: 28.2	H_{20}: 2.43	H_{20}: 2.56	H_{20}: 2.70
LIRE /	H_{10}: 2.07	H_{10}: 2.18	H_{10}: 2.30	H_{10}: 0.70	H_{10}: 0.74	H_{10}: 0.78
LSWE	H_{20}: 9.00	H_{20}: 9.50	H_{20}: 10.0	H_{20}: 1.44	H_{20}: 1.51	H_{20}: 1.60
LIRE /	**H_{10}: 4.66**	**H_{10}: 4.92**	**H_{10}: 5.18**	**H_{10}: 6.35**	**H_{10}: 6.70**	**H_{10}: 7.05**
LUS	**H_{20}: 21.9**	**H_{20}: 23.1**	**H_{20}: 24.3**	**H_{20}: 5.19**	**H_{20}: 5.48**	**H_{20}: 5.77**
LJAP /	H_{10}: 0.00	H_{10}: 0.00	H_{10}: 0.00	H_{10}: 0.05	H_{10}: 0.06	H_{10}: 0.06
LSWE	H_{20}: 5.19	H_{20}: 5.48	H_{20}: 5.77	H_{20}: 1.44	H_{20}: 1.52	H_{20}: 1.60
LJAP /	H_{10}: 2.07	H_{10}: 2.18	H_{10}: 2.30	H_{10}: 0.01	H_{10}: 0.01	H_{10}: 0.01
LUS	H_{20}: 0.01	H_{20}: 0.01	H_{20}: 0.01	H_{20}: 2.82	H_{20}: 2.97	H_{20}: 3.13
LSWE /	H_{10}: 0.05	H_{10}: 0.06	H_{10}: 0.06	H_{10}: 0.01	H_{10}: 0.01	H_{10}: 0.01
LUS	H_{20}: 1.44	H_{20}: 1.52	H_{20}: 1.60	H_{20}: 0.51	H_{20}: 0.54	H_{20}: 0.57

$\chi_1^2(5\%)$ = 3.84. * indicates rejection of the null hypothesis of no cointegration at the 5% level.

Table 15: Testing fractional cointegration with Robinson and Marinucci (2001) using the semiparametric Whittle approach

Series / m	$11 \approx T^{0.4}$	$18 \approx T^{0.5}$- 1	$19 \approx T^{0.5}$	$20 \approx T^{0.5}$+1	$36 \approx T^{0.6}$
LCAN /	H_{10}: 1.24	H_{10}: 1.08	H_{10}: 2.49	H_{10}: 2.78	H_{10}: 2.99
LFRA	H_{20}: 0.26	H_{20}: 1.41	H_{20}: 3.19	H_{20}: 3.13	H_{20}: 5.32
LCAN /	H_{10}: 1.02	H_{10}: 0.05	H_{10}: 0.01	H_{10}: 0.01	H_{10}: 1.00
LIRE	H_{20}: 0.72	H_{20}: 0.20	H_{20}: 0.28	H_{20}: 0.73	H_{20}: 6.47
LCAN /	H_{10}: 0.08	H_{10}: 0.09	H_{10}: 0.11	H_{10}: 0.07	H_{10}: 0.14
LJAP	H_{20}: 1.55	H_{20}: 2.03	H_{20}: 2.26	H_{20}: 1.35	H_{20}: 21.15
LCAN /	H_{10}: 0.98	H_{10}: 3.27	H_{10}: 2.45	H_{10}: 1.50	H_{10}: 2.99
LSWE	H_{20}: 5.81	H_{20}: 4.85	H_{20}: 3.98	H_{20}: 1.26	H_{20}: 1.49
LCAN /	H_{10}: 0.03	H_{10}: 0.31	H_{10}: 0.32	H_{10}: 0.02	H_{10}: 0.39
LUS	H_{20}: 2.22	H_{20}: 1.45	H_{20}: 0.68	H_{20}: 0.04	H_{20}: 8.03
LFRA /	H_{10}: 0.81	H_{10}: 3.21	**H_{10}: 4.08**	**H_{10}: 3.89**	H_{10}: 1.88
LIRE	H_{20}: 4.69	H_{20}: 4.11	**H_{20}: 5.54**	**H_{20}: 7.19**	H_{20}: 0.55
LFRA /	H_{10}: 0.22	H_{10}: 0.07	H_{10}: 0.07	H_{10}: 0.07	H_{10}: 0.06
LJAP	H_{20}: 1.87	H_{20}: 3.53	H_{20}: 4.81	H_{20}: 2.07	H_{20}: 11.51
LFRA /	H_{10}: 0.01	H_{10}: 0.24	H_{10}: 0.25	H_{10}: 0.55	H_{10}: 0.19
LSWE	H_{20}: 0.89	H_{20}: 0.56	H_{20}: 0.52	H_{20}: 0.29	H_{20}: 0.41
LFRA /	H_{10}: 0.08	H_{10}: 0.18	H_{10}: 0.38	H_{10}: 0.23	H_{10}: 0.04
LUS	H_{20}: 4.69	H_{20}: 0.03	H_{20}: 1.17	H_{20}: 0.28	H_{20}: 8.12
LIRE /	H_{10}: 1.97	H_{10}: 0.02	H_{10}: 0.05	H_{10}: 0.09	H_{10}: 0.60
LJAP	H_{20}: 2.60	H_{20}: 4.23	H_{20}: 4.65	H_{20}: 3.74	H_{20}: 42.91
LIRE /	H_{10}: 1.90	H_{10}: 0.06	H_{10}: 0.01	H_{10}: 0.01	H_{10}: 2.59
LSWE	H_{20}: 0.86	H_{20}: 0.09	H_{20}: 0.05	H_{20}: 0.65	H_{20}: 7.00
LIRE /	H_{10}: 3.66	H_{10}: 0.03	H_{10}: 3.15	**H_{10}: 15.17**	**H_{10}: 7.46**
LUS	H_{20}: 2.03	H_{20}: 1.52	H_{20}: 0.94	**H_{20}: 9.76**	**H_{20}: 4.28**
LJAP /	**H_{10}: 5.63**	H_{10}: 1.64	**H_{10}: 6.76**	H_{10}: 2.78	H_{10}: 0.04
LSWE	**H_{20}: 25.2**	H_{20}: 12.30	**H_{20}: 23.8**	H_{20}: 8.98	H_{20}: 24.55
LJAP /	**H_{10}: 5.11**	H_{10}: 1.59	H_{10}: 2.85	**H_{10}: 4.51**	H_{10}: 41.15
LUS	**H_{20}: 4.10**	H_{20}: 5.90	H_{20}: 10.7	**H_{20}: 12.99**	H_{20}: 0.02
LSWE /	H_{10}: 3.88	H_{10}: 0.01	H_{10}: 0.02	H_{10}: 0.05	H_{10}: 0.06
LUS	H_{20}: 0.84	H_{20}: 1.35	H_{20}: 0.72	H_{20}: 0.05	H_{20}: 4.42

$\chi_1^2(5\%)$ = 3.84. * indicates rejection of the null hypothesis of no cointegration at the 5% level.

5. Conclusions

It is well known that uncertainty in its various forms affects the behaviour of economic agents (consumers and/or firms). One specific type of uncertainty whose role has been analysed extensively in recent years is EPU. Most studies have used the index constructed by Baker et al. (2016), whose advantages are apparent, and investigated its impact on the economy as a whole and the financial sector in particular. However, its statistical properties and possible cross-country linkages have not been considered.

The present paper aims to fill this gap by providing new evidence on the stochastic behaviour of EPU in six of the biggest economies for which long runs of data are available (Canada, France, Japan, US, Ireland, and Sweden); in particular, it uses fractional integration methods to shed light on its degree of persistence, and also carries out appropriate break tests. Further, the possible co-movement of this index between countries is examined by applying a fractional cointegration method which tests for the possible existence of a long-run equilibrium relationship linking the individual indices.

The main results can be summarised as follows. EPU is found to be in most cases a non-stationary, mean-reverting series which is characterised by long memory. Several breaks are also detected in each country. Further, there is very little evidence of cross-country linkages. These findings should be taken into account by academics, policy makers and practitioners when building models aimed at evaluating the impact of EPU on the economy, designing policy measures and developing investment strategies. Future work will address other issues such as the presence of cyclical patterns in EPU and also apply alternative methods such as Johansen’s (2012) FCVAR approach to investigate further dynamic linkages across countries.

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