Causality between Economic Policy Uncertainty across Countries : Evidence from Linear and Nonlinear Tests

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Abstract

Following the 2007-2009 global recession, economic policy uncertainty and its effect on economic recovery has become an issue of interest in academic, media as well as policy-making circles (Baker *et al.*, 2013). Given this backdrop, we investigate causality between economic policy uncertainty in some of the world's major economies using the economic policy uncertainty index developed by Baker *et al.* (2013). We implement both the traditional linear and the nonlinear variants of the Granger causality test. Based on the Diks and Panchenko (2005) non-linear Granger causality test, we find significant evidence of bidirectional causality between countries' economic policy uncertainty across the sample. The results are consistent with the fact that the global economy has become more integrated through trade, financial and confidence linkages. Also, our findings highlight that inference from traditional (linear) Granger causality test can be misleading in the presence of non-linearity in the data.

Keywords: economic policy uncertainty, causality, linear, nonlinear
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1 - Introduction

The process of globalization has led to economies around the world to be interconnected more than ever. Hence, a shock related to any specific economic policy change in one country gets carried over across the world instantly. This is more so the case, when the economies where the shock originates from are the major role players in shaping world economic activity. In other words, a specific country is not only likely to be affected by shocks to its own economic policy environment, but also due to economic policy changes in other (major) economies of the world, and vice versa. Hence, the final effect of policy uncertainty on a particular economy can not only be long lasting but increase in magnitude due to spillovers.

Uncertainty in economic policy perceived by consumers and investors can have a negative impact on economic recovery and growth. Consumers and investors are likely to hesitate in spending and investing when they sense higher uncertainty in the economic policy environment. Economic uncertainty also tends to affect the financial market negatively as valuations of assets are likely to drop. Hence, economic uncertainty, not only country-specific but for other economies as well, is followed and analyzed closely by agents in the economy, policy makers and academic scholars around the world.

Against this backdrop, our paper analyzes the causal relationship between economic policy uncertainty across major economies (Canada, China, the aggregate Euro area, France, Germany, India, Italy, Spain, United Kingdom and United States) in the world in a bivariate set-up using both linear and nonlinear Granger causality tests, with the countries chosen based on availability of data on the index measuring economic policy uncertainty, developed recently by Baker et al., (2013). For the United States, the policy-related economic uncertainty index is constructed based on quantification of three types of underlying components, namely, newspaper coverage of policy-related economic uncertainty, the number of federal tax code provisions set to expire in future years, and disagreement among economic forecasters. For Canada, the individual European countries (and hence the aggregate Eoro area), and India, the index is based on newspaper coverage of policy-related economic uncertainty, and disagreement among economic forecasters. While, for China, the index is constructed based on information of newspaper coverage of policy-related economic uncertainty only. The Appendix of the paper provides a detailed discussion of how the index is constructed for the various countries.

Note that, the decision to use nonlinear causality tests, over and above, the standard linear Granger causality test, emanates from not only the possibility (and as we show) that uncertainty variable (just like many financial and macroeconomic variables) is likely to have nonlinear data generating process, but also due to the fact that the relationship between uncertainty across two countries, is likely to (and as we show) encounter structural breaks, thus invalidating the inferences drawn based on linear tests. Specifically, we look at causal relationships using monthly data on the economic policy uncertainty index over the period of January, 2001 to February, 2013. Though data for some of the countries are available before the starting date of our analysis, we choose January, 2001, to ensure uniformity of data availability across all countries chosen. To the best of our knowledge, this is the first study to analyze causal relationships, using linear and non linear set-ups, in economic policy uncertainty between major economies of the world. The only other paper somewhat related to our work that we are aware of is by Colombo (2012). While analyzing the impact of the economic policy uncertainty of the Unites States on macroeconomic variables of the Euro area, the paper also shows that an increase in economic policy uncertainty in the United States leads to a corresponding rise in the economic policy uncertainty of the Euro area as well.[4]

The paper is structured as follows: Section 2 presents the methodology and Section 3 discusses the data as well as the empirical results. Section 4 concludes the paper.

2 - Methodology

This section discusses, in a chronological fashion, the different causality tests used in this paper, with the discussion of the tests being ordered

[4] Sum (2012) analyzed the long-run relationship between the economic policy uncertainty indexes of the United States and the Euro Area, and found a positive and statistically significant cointegrating relationship between the two variables of concern. Sum (2012) uses Augmented Dickey-Fuller (1979) unit root test (ADF test) to first show that the two indexes are non-stationary, and then also use the same test to show that the recovered errors from the regression between these two indexes are stationary, hence implying cointegration. However, we should be cautious about these results, since they are based on the ADF test, which is known to have low power. Further, as we show below, based on more powerful unit root tests, we can reject the null of unit root for both the United States and the Euro area, thus making the cointegration analysis of Sum (2012) redundant.

in a way, such that the subsequent test builds on the drawback of the preceeding one. We start of with the linear Granger non-causality test, followed by the tests of nonlinearity and structural breaks, and then two nonlinear causality tests. The linear Granger non-causality test is naturally attractive because it simply requires determining whether the regression model coefficients, associated to past and current values are significant. The linear Granger non-causality test assumes that the data generating process of the variables involved are linear and also that parameters of the regressions do not change over time. However, if the data generating process of the variables are nonlinear due to regime switching and thresholds, and structural breaks occur, the basic assumptions of the Granger non-causality tests are violated, and hence, the inferences from the linear causality test cannot be relied upon. Hence, after conducting the linear Granger non-causality tests, we test for nonlinearity in the individual uncertainty series using the Brock et al., (1996) test for detecting serial dependence in time series, and also examine stability of the parameters of the regression model based on the tests developed by Andrews (1993) and Andrews and Ploberger (1994). Nonlinearity and structural breaks, if detected, imply that not only do the variables evolve in a nonlinear fashion, but also the relationship between the variables are nonlinear, raising doubts about the results from the Granger non-causality tests. Hence, we address this drawback by making use of two nonparametric Granger causality tests, namely, Hiemstra and Jones (1994), and Diks and Panchenko (2006). It must be emphasized here that, nonparametric methods are desirable since they emphasize prediction or causality without imposing any particular functional form to the relationship between the variables. Diks and Panchenko (2005), however, points out that the relationship tested by the widely-used Hiemstra and Jones (1994) test, is generally not compatible with Granger causality, thus, leading to a bias towards rejecting the null hypothesis of noncausality. In light of this, we primarily rely on the Diks and Panchenko (2005) variant of nonlinear Granger causality test to make final decisions on the causal relationships.

2.1 Linear Granger Causality Test

According to Granger (1969), causality between two stationary series x_t and y_t can be defined using the concept of predictability. x_t is said to "Granger" cause y_t if past realizations of x_t improve the prediction of y_t compared to predictions using historical values of x_t only.

Assuming that the stationary series x_t and y_t are of length n, a formal test for Granger causality between x_t and y_t requires estimating a p -order linear vector autoregressive model $VAR(p)$ of the form:

$$\begin{pmatrix} x_t \\ y_t \end{pmatrix} = \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix} + \begin{pmatrix} \phi_{11,1} & \phi_{12,1} \\ \phi_{21,1} & \phi_{22,1} \end{pmatrix} \begin{pmatrix} y_{t-1} \\ x_{t-1} \end{pmatrix} + \begin{pmatrix} \phi_{11,p} & \phi_{12,p} \\ \phi_{21,p} & \phi_{22,p} \end{pmatrix} \begin{pmatrix} y_{t-p} \\ x_{t-p} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix} \qquad (1)$$

where $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t})'$ represents a white noise process with zero mean and covariance matrix Σ. p is the optimal lag order of the process selected using a sequential likelihood ratio (LR) test. α_1 and α_2 are constants and $\phi's$ are parameters.

Given this framework, if x_t and y_t represent the economic policy uncertainty indices for country i and country j respectively, then we can test the null hypothesis that country i's economic policy uncertainty does not Granger cause country j's economic policy uncertainty by imposing zero restrictions i.e. $\phi_{12,k} = 0$ for $k = 1,2,\ldots, p$. Imposing such restrictions means that country i's economic policy uncertainty does not contain any predictive content for country j's economic policy uncertainty if the joint zero restrictions under H_0^E is not rejected.

$$H_0^E : \phi_{12,1} = \phi_{12,2} = \ldots = \phi_{12,p} = 0 \qquad (2)$$

In a similar fashion, to test the null hypothesis that country j's economic policy uncertainty does not Granger causes country i's political uncertainty implies that zero restrictions $\phi_{21,k} = 0$ for $k = 1,2,\ldots, p$ must be imposed. This means that country j's economic policy uncertainty does not contain any predictive content for country i's economic policy uncertainty if the joint zero restrictions under H_0^E is not rejected.

$$H_0^E : \phi_{21,1} = \phi_{21,2} = \ldots = \phi_{21,p} = 0 \qquad (3)$$

2.2 Nonlinearity and Parameter Stability Test

To check whether there is a misspecication or not in the Granger non-causality test, if the data generating process for the variables is nonlinear, we look at the Brock et al., (1996) test of detecting nonlinearity. The test, popularly known as the BDS test, is a powerful tool for detecting serial dependence in time series. It tests the null hypothesis of independent and identically distributed (i.i.d) against an unspecified alternative. The BDS test can detect nonlinearity, provided that any linear dependence, for instance due to non-stationarity, has been removed from the data.

Further, the linear Granger non-causality test assumes that the *VAR*'s parameters do not change over time. However, the presence of structural breaks violates this assumption. Also, Granger (1996) argues that parameter non-constancy is a key challenge in current empirical studies. Given this backdrop, we test for stability of the *VAR*'s parameters.

Practically, various tests can be conducted to study the temporal stability of a *VAR* model (*e.g.* Hansen, 1992; Andrews, 1993; Andrews and Ploberg, 1994). Following Andrews (1993) and Andrews and Ploberger (1994), we investigate the stability of short-run parameters by using the *Sup-F*, *Ave-F* and *Exp-F* tests. The *Sup-F* statistic is appropriate when testing whether a one-time swift regime shift in parameters occurred. The *Ave-F* and *Exp-F*[5] assume that parameters follow a martingale process and test whether parameters have evolved gradually over time.

These tests are obtained from the sequence of *LR* statistics that test the null hypothesis of constant parameters against the alternative of a one-time structural change at each possible point of time in the entire sample. Critical values for the non-standard asymptotic distributions of these tests are reported in Andrews (1993) and Andrews and Ploberger (1994). However, instead of using asymptotic distributions, critical values and *p*-values are computed using a parametric bootstrap method. To this end, *p*-values are computed from a bootstrap approximation to the null distribution of the test statistics constructed using Monte Carlo simulations based on 2000 samples generated from a *VAR* model with constant parameters. Based on Andrews (1993), we trim 15 percent

[5] Andrews and Ploberger (1994) prove that the *Ave-F* and *Exp-F* are optimal tests.

from both ends of the sample and compute the *Sup-F*, *Ave-F* and *Exp-F* tests for the remaining fraction [0.15,0.85] of the sample.

2.3 Nonlinear Granger Causality Test

Although the linear Granger causality testing is desirable owing to its ease of implementation, it has some drawbacks. Given that it is a parametric test, the linear Granger causality test requires certain modeling assumptions of which the most important is the linearity of the regression structure. Nonetheless, most economic and financial series have been shown to exhibit nonlinearities emanating in certain cases from structural breaks, or the data generating process being nonlinear. In addition, Baek and Brock (1992) find that the linear Granger causality test may fail to detect nonlinear effects on the conditional distribution given that it is only sensitive to causality in the conditional mean. Diks and Pachenko (2005, 2006) also argue that a higher order structure such as conditional heteroskedasticity can often be ignored. In the same perspective, traditional linear Granger causality tests have been found to have low power for detecting some nonlinear relationships (Hiemstra and Jones, 1994).

Given this backdrop, nonparametric methods are desirable since they emphasize prediction without imposing any particular functional form. One of the most prominent nonparametric tests in the literature is a variant of Baek and Brock (1992) developed by Hiemstra and Jones (1994). On the other hand, Diks and Panchenko (2005) develop an alternative nonlinear test on the basis that the relationship tested by Hiemstra and Jones (1994) is generally not compatible with Granger causality, leading to a bias towards rejecting the null hypothesis of noncausality. Therefore, this study primarily relies on the Diks and Panchenko (2005) variant of nonlinear Granger causality tests.

2.3.1 The Hiemstra-Jones Test

Hiemstra and Jones (1994) develop a nonparametric statistical procedure to detect nonlinear causal relationships using the correlation integral. To define the concept of nonlinear Granger causality, let $\{X_t\}$ and $\{Y_t\}$ $(t = 1,2,3,\ldots,T)$ be two strictly and weakly dependent time series. Let $\mathbf{X}_t^m$ represent the m-length lead vector of X_t and let $\mathbf{X}_{t-Lx}^{Lx}$ and $\mathbf{Y}_{t-Ly}^{Ly}$ designate the Lx-length and Ly-length vectors of X_t and Y_t, respectively.

Given the values of m, Lx and $Ly \geq 1$ and $\forall \varepsilon > 0$, $\{Y_t\}$ does not Granger cause $\{X_t\}$ if:[6]

$$P(\| \mathbf{X}_t^m - \mathbf{X}_s^m \| < \varepsilon \,\|\, \| \mathbf{X}_{t-Lx}^{Lx} - \mathbf{X}_{s-Lx}^{Lx} \| < \varepsilon, \| \mathbf{Y}_{t-Ly}^{Ly} - \mathbf{Y}_{s-Ly}^{Ly} \| < \varepsilon$$
$$= P(\| \mathbf{X}_t^m - \mathbf{X}_s^m \| < \varepsilon \,\|\, \| \mathbf{X}_{t-Lx}^{Lx} - \mathbf{X}_{s-Lx}^{Lx} \| < \varepsilon), \quad (4)$$

where $P(.)$ denotes probability and $\|.\|$ represents the maximum norm. According to Eq. (4), the probability that $\mathbf{X}_t^m$ and $\mathbf{X}_s^m$, arbitrary m-length lead vectors of $\{X_t\}$ are within a distance ε from each other, conditioned on the fact that the corresponding Lx-length lag vectors of $\{X_t\}$ i.e. $\mathbf{X}_{t-Lx}^{Lx}$ and $\mathbf{X}_{s-Lx}^{Lx}$ are also separated by ε, is equal to the case when one introduces the condition that $\mathbf{Y}_{t-Ly}^{Ly}$ and $\mathbf{Y}_{s-Ly}^{Ly}$, two Ly-length lag vectors of $\{Y_t\}$ are also ε-close.

To test Eq. (4), conditional probabilities are expressed in terms of the corresponding ratios of joint probabilities as follows:

$$\frac{C1(m+Lx, Ly, \varepsilon)}{C2(Lx, Ly, \varepsilon)} = \frac{C3(m+Lx, \varepsilon)}{C4(Lx, \varepsilon)} \quad (5)$$

where $C1$, $C2$, $C3$ and $C4$ represent the correlation integral estimator of the joint probabilities (Hiemstra and Jones, 1994). Using an additional index n and assuming $\{X_t\}$ and $\{Y_t\}$ are strictly stationary, weakly dependent, Hiemstra and Jones (1994) demonstrate that if $\{Y_t\}$ does not strictly Granger cause $\{X_t\}$ then,

$$\sqrt{n}\left(\frac{C1(m+Lx, Ly, \varepsilon, n)}{C2(Lx, Ly, \varepsilon, n)}\right) - \left(\frac{C3(m+Lx, \varepsilon, n)}{C4(Lx, \varepsilon, n)}\right) \sim AN(0, \sigma^2(m, Lx, Ly, \varepsilon)) \quad (6)$$

[6] According to Hiemstra and Jones (1994), strict Granger causality implies that historical values of one time series influence the current and future values of another time series.

where $n = T + 1 - m - \max(Lx, Ly)$. The appendix of Hiemstra and Jones (1994) presents the definition and an estimator of $\sigma^2(m, Lx, Ly, \varepsilon)$. Given this asymptotic result, right-tailed critical values are used, rejecting the null hypothesis when the computed value of the test statistic in Eq. (6) is too large.

Testing for nonlinear Granger causality between $\{X_t\}$ and $\{Y_t\}$ requires applying the test in Eq. (6) to the estimated residual series from the bivariate *VAR* model. The null hypothesis is "$\{Y_t\}$ does not nonlinearly strictly Granger cause $\{X_t\}$" and Eq. (6) holds $\forall m, Lx, Ly \geq 1$ and $\varepsilon > 0$. By removing a linear predictive power from a linear *VAR* model, any remaining incremental predictive power of one residual series for another can be considered as nonlinear predictive power (Baek and Brock, 1992).

2.3.2 The Diks-Panchenko Test

Responding to the shortcoming of the Hiemstra and Jones (1994) test, Diks and Panchenko (2005) propose a test that reduces the risk of bias in rejecting the null hypothesis of non-causality. As a solution, Diks and Panchenko (2006) develop a Granger non-causality parametric test that uses an average of local conditional dependence measures rather than the global statistic.

Assuming that $X_t^{l_X} = (X_{t-l_X+1}, \ldots, X_t)$ and $Y_t^{l_Y} = (Y_{t-l_Y+1}, \ldots, Y_t)$ represent the delay vectors and $l_X, l_Y \leq 1$. The null hypothesis that $X_t^{l_X}$ contain any additional information about $Y_t^{l_Y}$ is defined as follows:

$$H_0 = Y_{t+1} \,|\, (X_t^{l_X}; Y_t^{l_Y}) : Y_{t+1} \,|\, Y_t^{l_Y} \qquad (7)$$

The null hypothesis is a statement about the invariant distribution of the $(l_X + l_Y + 1)$-dimensional vector $W_t = (X_t^{l_X}, Y_t^{l_Y}, Z_t)$, where $Z_t = Y_{t+1}$. Ignoring the time index and assuming that $l_X = l_Y = 1$, the distribution of Z

- given that $(X,Y)=(x,y)$ - is identical to that of Z given $Y=y$. That is to say, X and Z are independently conditionally on $Y=y$ for each fixed value of y, so the joint probability density function $f_{X,Y,Z}(x,y,z)$ and its marginals must satisfy the following relationship:

$$\frac{f_{X,Y,Z}(x,y,z)}{f_Y(y)}=\frac{f_{X,Y}(x,y)}{f_Y(y)}.\frac{f_{X,Z}(y,z)}{f_Y(y)} \tag{8}$$

According to Diks and Panchenko (2006), the restated null hypothesis implies that:

$$q\equiv E[f_{X,Y,Z}(X,Y,Z)f_Y(Y)-f_{X,Y}(X,Y)f_{Y,Z}(Y,Z)]=0 \tag{9}$$

where $\hat{f}_W(W_i)$ represents a local density estimator of a d_W-variate random vector W at W_i, defined by $\hat{f}_W(W_i)=(2\varepsilon_n)^{-d_W}(n-1)^{-1}\Sigma_{j,j\neq i}I_{ij}^W$, where $I_{ij}^W=I(|W_i-W_j|<\varepsilon_n)$, $I(.)$ is the indicator function and ε_n is the bandwidth and depends on n, the sample size.

The test statistic is defined as:

$$T_n(\varepsilon_n)=\frac{n-1}{n(n-2)}.\Sigma_i(\hat{f}_{X,Z,Y}(X_i,Z_i,Y_i)\hat{f}_Y(Y_i)-\hat{f}_{X,Y}(X_i,Y_i)\hat{f}_{Y,Z}(Y_i,Z_i)) \tag{10}$$

where T_n consists of a weighted average of local contributions $\hat{f}_{X,Z,Y}(X_i,Z_i,Y_i)\hat{f}_Y(Y_i)-\hat{f}_{X,Y}(X_i,Y_i)\hat{f}_{Y,Z}(Y_i,Z_i)$ which approach zero in probability under H_0.

Diks and Pachenko (2006) show that if $\varepsilon_n=Cn^{-\beta}(c>0,\frac{1}{4}<\beta<\frac{1}{3})$ for one lag then the test statistic in Eq. (4) satisfies:

$$\sqrt{n}\,\frac{(T_n(\varepsilon_n)-q)}{S_n}\,D \to N(0,1) \tag{11}$$

where $D \to$ denotes convergence in distribution and S_n represents an estimator of the asymptotic variance of $T_n(.)$.

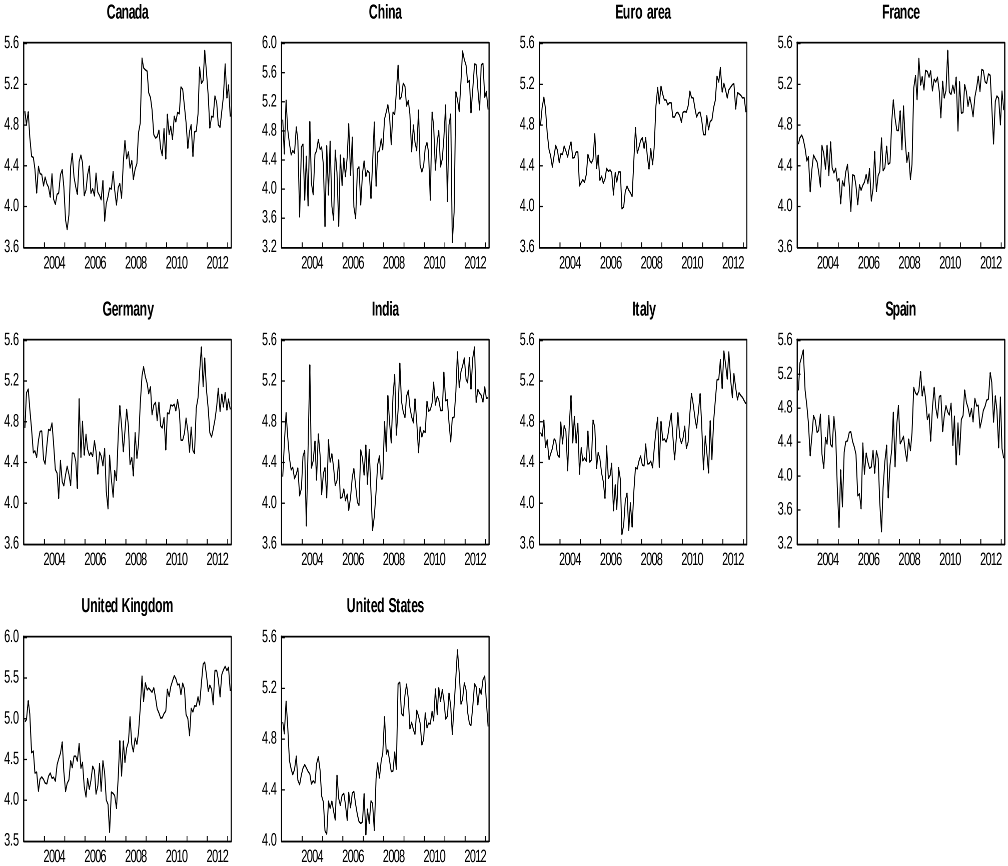
3 - Data and Empirical Results

3.1 Data and Preliminary Analysis

Baker *et al.* (2013) develop an economic policy uncertainty (EPU) index to measure policy-related economic uncertainty in the world's major economies. The index is based mainly on two underlying components: newspaper coverage of policy-related economic uncertainty and economic forecasters' disagreements about inflation and government purchases. Further details on the construction of the index for the various countries is available in the Appendix of the paper.

We use monthly data spanning from January 2003 to February 2013 for the EPU index of Canada, China, the Euro area, France, Germany, India, Italy, Spain, the UK and the US. The data series are obtainable on-line from: www.PolicyUncertainty.com. Figure 1 plots the natural logarithm of the EPU index for countries under investigation across the sample period.

Figure 1: Natural logarithm of economic policy uncertainty (*EPU*) index, Baker *et al.*, 2013.



Before testing for nonlinearity in the uncertainty series, stability of the *VAR(p)* model's parameters, as well as, the pairwise Granger causality, we investigate the order of integration of each country's *EPU* index by means of the Augmented Dickey-Fuller (*ADF*) (1979) test, Phillips (1987) and Phillips-Perron (1988)'s Z_α unit root test and Ng-Perron (2001)'s MZ_α test. Checking for stationarity of the data is important since all our tests (nonlinearity, structural breaks, linear and nonlinear causality) require that variables must be stationary. Based on the MZ_α test - which has higher power compared to the *ADF* and Z_α unit root tests - we can conclude that all the *EPU* index series are stationary.[7]

3.2 Results from the Linear Granger Causality Test

After estimating a *VAR(p)* model[8] [9], we perform the linear Granger causality test with the null hypothesis of absence of causality running from country i 's economic policy uncertainty to country j 's. Table 1 presents the results. There is evidence of causality running from country i 's economic policy uncertainty to country j 's in 51 cases out of 85. Of these, 30 cases[10] comprise country pairs that exhibit bidirectional causality of economic policy uncertainty. The remaining 21 cases[11] exhibit unidirectional causality between countries' economic policy uncertainty. For the remaining 34 cases[12], the test fails to establish a causal relationship running from country i 's economic policy uncertainty to country j 's.

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[7] For brevity purposes, we do not report these tests in the paper. However, they are available from the authors upon request.

[8] Using the Akaike Information Criterion (*AIC*), Table A.1 in the Appendix reports the lag lengths used in the specification of the *VAR(p)* model, specific to each country pair.

[9] We have excluded the ordered pairs Euro Area-France, Euro Area-Germany, Euro Area-Italy, Euro Area-Spain and Euro Area-UK given that the EU's EPU index is constructed based on underlying information gathered from its members. Against this backdrop, the number of possible cases (pairs) for our sample of 10 countries is given by:

$$\frac{n!}{(n-r)!}-5=\frac{10!}{(10-2)!}-5=85$$

[10] The following ordered pairs as well as their respective inverses: Canada-China, Canada-Euro area, Canada-Germany, Canada-UK, Canada-US, Euro area-India, Spain-France, France-UK, Germany-India, Germany-Italy, Germany-UK, India-Italy, India-UK, Spain-UK and UK-US.

[11] The ordered pairs are: Canada-France, Canada-Italy, Canada-Spain, Euro area-China, Germany-China, Germany-Euro area, Germany-France, India-Canada, India-China, India-Spain, Italy-China, Spain-Euro, UK-China, UK-Italy, US-China, US-Euro area, US-France, US-Germany, US-India, US-Italy and US-Spain

[12] The ordered pairs are as follows: Canada-India, China-Euro area, China-France, China-Germany, China-India, China-Italy, China-Spain, China-UK, China-US, Euro area-US, France-Canada, France-China, France-Euro area, France-Germany, France-India, France-Italy, France-US, Germany-Spain, Germany-US, India-France, India-US, Italy-Canada, Italy-Euro area, Italy-France, Italy-Spain, Italy-UK, Italy-US, Spain-Canada, Spain-China, Spain-Germany, Spain-India, Spain-Italy, Spain-US and UK-Euro area.

Table 1: Results from linear Granger causality test

Country *j* / Country *i*	Canada	China	Euro Area	France	Germany	India	Italy	Spain	UK	US
Canada	-	0.0055 [a]	0.0679 [c]	0.0868 [c]	0.0002 [a]	0.2489	0.0413 [b]	0.0067 [a]	0.0220 [b]	0.0227 [b]
China	0.0115 [b]	-	0.5877	0.1548	0.1891	0.2210	0.2203	0.1729	0.6209	0.1261
Euro Area	0.0040 [a]	0.0813 [c]	-	-	-	0.0010 [a]	-	-	-	0.7146
France	0.1397	0.7017	0.2107	-	0.1476	0.1819	0.2943	0.0091 [a]	0.0291 [b]	0.3943
Germany	0.0088 [a]	0.0968 [c]	0.0637 [c]	0.0828 [c]	-	0.0024 [a]	0.0352 [b]	0.1530	0.0926 [c]	0. 1833
India	0.0000 [a]	0.0092 [a]	0.0028 [a]	0.1370	0.0003 [a]	-	0.0054 [a]	0.0107 [b]	0.0110 [b]	0.1297
Italy	0.2556	0.0357 [b]	0.8629	0.3493	0.0727 [c]	0.0139 [b]	-	0.4946	0.3324	0.8147
Spain	0.1596	0.7650	0.0372 [b]	0.0029 [a]	0.2046	0.5435	0.4054	-	0.0693 [c]	0.6459
UK	0.0041 [a]	0.0010 [a]	0.4595	0.0062 [a]	0.0037 [a]	0.0155 [b]	0.0316 [b]	0.0103 [b]	-	0.0013 [a]
US	0.0006 [a]	0.0981 [c]	0.0076 [a]	0.0876 [c]	0.0000 [a]	0.0234 [b]	0.0499 [b]	0.0145 [b]	0.0024 [a]	-

Notes: This table reports the p-values of the Granger causality tests. [a], [b] and [c] indicate the rejection of the null hypothesis of absence of causality running from country i to country j at the 1%, 5% and 10% levels, respectively.

In the cases where the linear test confirms evidence of bidirectional causality, the causal relationship predominantly involves advanced economies such as Canada, France, Spain, Italy, the UK and the US. Such outcomes are intuitive, given the interconnectedness of these economies. However, some results raise suspicion. For instance, contrary to observation made during the Eurozone debt crisis, results from the linear Granger causality test tend to suggest that there is no causal relationship between economic policy uncertainty involving a number of Eurozone countries. To illustrate, while there is evidence of causality between Italy's and Germany's economic policy uncertainty, the linear test finds no evidence of causality between Italy's economic policy uncertainty on the one hand and that in France, Spain, the UK as well as the Euro area (as a whole) on the other hand. Recent experience has shown that concerns over fiscal policy paralysis and sovereign debt in countries such as Italy and Spain as well as countries on the periphery such as Greece and Cyprus have had considerable ramifications throughout the whole zone. Therefore, we question the fact that linear tests establish causality in some cases but fail to do so in other similar and related instances.

3.3 Results from Nonlinearity and Parameter Stability Tests

First, results from the BDS test, reported in Table 2, indicates that the null hypothesis that the series are i.i.d. is rejected for all countries. Consequently, the results from the test suggest that there may be nonlinear structure in the data. Second, following Andrews (1993) and Andrews and Ploberger (1994), we perform the *Sup-F*, *Ave-F* and *Exp-F* tests to investigate the parameter stability of the *VAR(p)* model. All tests, *i.e Sup-F*, *Ave-F* and *Exp-F* must fail to reject the null hypothesis for us to conclude that the *VAR(p)*'s parameters are stable. Table 3 presents the conclusions of the parameter stability tests, where the null hypothesis is that of parameter stability. We identify 25 cases where all tests show evidence of parameter stability at the 10% level of significance. However, at least one of the three tests rejects the null hypothesis of parameter stability for the majority of ordered country pairs - *i.e.* the remaining 60 cases.

Table 2: *BDS* test results

Dim	Canada	China	Euro Area	France	Germany	India	Italy	Spain	UK	US
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Notes: Dim stands for dimension. Table reports the p-values of the *BDS* test.

Table 3: Parameter stability tests

Country j / Country i	Canada	China	Euro Area	France	Germany	India	Italy	Spain	UK	US
Canada	-	n(3)	n(3)	n(3)	n(3)	y(3)	n(2)	n(3)	n(1)	n(3)
China	n(1)	-	n(3)	n(3)	n(3)	n(3)	n(3)	n(3)	n(1)	n(3)
Euro Area	n(3)	n(3)	-	-	-	n(3)	-	-	-	y(3)
France	n(1)	n(3)	n(1)	-	n(3)	n(1)	n(1)	n(1)	n(1)	n(1)
Germany	n(3)	n(3)	n(1)	n(1)	-	n(3)	n(3)	n(2)	n(3)	y(3)
India	y(3)	n(2)	y(3)	y(3)	y(3)	-	n(2)	y(3)	y(3)	y(3)
Italy	y(3)	y(3)	y(3)	y(3)	n(1)	n(1)	-	y(3)	y(3)	n(1)
Spain	n(3)	y(3)	n(2)	y(3)	n(1)	y(3)	n(2)	-	y(3)	y(3)
UK	n(3)	n(3)	n(2)	n(1)	n(2)	y(3)	n(3)	n(3)	-	y(3)
US	n(3)	n(2)	y(3)	n(2)	n(3)	n(3)	y(3)	n(1)	n(1)	-

Notes: H_0 : parameter stability; "y" stands for "yes" and means fail to reject H_0 at 10% level of significance; numbers in between ( ) refer to number of tests failing to reject H_0. "n" (i.e. "no") means reject H_0 at 0.1 level of significance. Country i (j) in row (column) header.

3.4 Results from the Diks-Panchenko Nonlinear Granger Causality Test

Because the linear Granger causality test is sensitive to nonlinearity in the data generating process and structural breaks in the relationship between the uncertainty variables across two specific pairs of economies, inferences based on such a test are misleading, especially given the evidence of nonlinearity in all the 10 countries and parameter non-constancy in 60 out of 85 cases identified. Therefore, we perform pairwise nonlinear Granger causality tests following Diks and Panchenko (2005).[13] Table 4 reports the results. We reject the null hypothesis of the absence of causality running from country i 's economic policy uncertainty to country j 's in 83 cases. The results also support bidirectional causality in all these cases. Barring the cases involving the ordered pairs of Italy-Euro area and Spain-Italy, we have causality running in both directions in all other remaining cases. These results could be explained by the increase in linkages among the major global economies due to globalization. In fact, economic and financial conditions in the world's largest economies are interlinked. The recent financial crisis and the ensuing global recession have exposed the fact that there are close trade, financial as well as confidence linkages among the world's major economies. As such an increase in economic policy uncertainty in a given country and the resulting imbalances in trade, financial and confidence trends would have spillover effects onto other countries' economic policy uncertainty. Overall, our results highlight that not accounting for nonlinearity in the data generating process of a series, as well as nonlinearity in the relationship between two series, would lead to incomplete and misleading results derived from relying simply on linear tests. Given this technical glitch, then leads to inappropriate policy decisions and economic outcomes.

Table 4: Dicks-Panchenko nonlinear causality test

		Country j								
Country i	Lags	China	Euro Area	France	Germany	India	Italy	Spain	UK	US
Canada	1	0.0134 ^{b}	0.0010 ^{a}	0.0019 ^{a}	0.0071 ^{a}	0.0069 ^{a}	0.0116 ^{b}	0.1245	0.0141 ^{b}	0.0141 ^{b}
	2	0.0493 ^{b}	0.0546 ^{b}	0.0728 ^{c}	0.0651 ^{c}	0.0506 ^{c}	0.0208 ^{b}	0.3250	0.0968 ^{c}	0.0410 ^{b}
	3	0.5953	0.2171	0.1109	0.0726 ^{c}	0.0930 ^{c}	0.0588 ^{c}	0.2456	0.3373	0.1481
	4	0.4962	0.1181	0.1577	0.0771 ^{c}	0.2001	0.0681 ^{c}	0.0963 ^{c}	0.4890	0.0761 ^{c}

[13] Results from the Hiemstra and Jones (1994) test are reported in the Appendix.

	5	0.4758	0.1388	0.1849	0.1304	0.2530	0.1390	0.0768[c]	0.4555	0.1935
	6	0.2812	0.1740	0.1548	0.1793	0.1510	0.1723	0.0747[c]	0.4842	0.2274
	7	0.3788	0.1461	0.2791	0.0654	0.1414	0.2759	0.0935[c]	0.3376	0.2101
	8	0.1670	0.1388	0.5067	0.1164	0.1489	0.2937	0.1675	0.2654	0.1852

					Country *j*					
Country *i*	lag	Canada	Euro Area	France	Germany	India	Italy	Spain	UK	US
China	1	0.0276[b]	0.0350[b]	0.0941[c]	0.0484[b]	0.0090[a]	0.0071[a]	0.0240[b]	0.1914	0.0967[c]
	2	0.0161[b]	0.1059	0.0194[b]	0.0252[b]	0.0403[b]	0.0870[c]	0.0361[b]	0.1787	0.0495[b]
	3	0.0248[b]	0.1079	0.0369[b]	0.0187[b]	0.0706[c]	0.1017	0.0660[c]	0.1031	0.0766[c]
	4	0.0371[b]	0.0976[c]	0.0532[c]	0.0251[b]	0.3139	0.1700	0.0499[b]	0.0709[c]	0.1294
	5	0.0600[c]	0.0679[c]	0.0700[c]	0.0136[b]	0.1793	0.2243	0.0397[b]	0.0727[c]	0.1550
	6	0.0492[b]	0.0708[c]	0.1147	0.0163[b]	0.0970[c]	0.3051	0.0325[b]	0.0541[c]	0.1431
	7	0.0453[b]	0.0641[c]	0.1300	0.0193[b]	0.0458[b]	0.2749	0.0485[b]	0.0679[c]	0.1253
	8	0.0527[c]	0.0739[c]	0.1614	0.0359[b]	0.0842[c]	0.2196	0.0670[c]	0.1040	0.0973[c]

					Country *j*					
Country *i*	lag	Canada	China	France	Germany	India	Italy	Spain	UK	US
Euro Area	1	0.0008[a]	0.0139[b]	-	-	0.0003[a]	-	-	-	0.0002[a]
	2	0.0012[a]	0.1738	-	-	0.0099[a]	-	-	-	0.0048[a]
	3	0.0013[a]	0.3579	-	-	0.0545[c]	-	-	-	0.0288[b]
	4	0.0028[a]	0.2771	-	-	0.0815[c]	-	-	-	0.0442[b]
	5	0.0077[a]	0.2651	-	-	0.1264	-	-	-	0.1430
	6	0.0103[b]	0.2521	-	-	0.1266	-	-	-	0.1698
	7	0.0131[b]	0.2320	-	-	0.2045	-	-	-	0.1371
	8	0.0177[b]	0.1517	-	-	0.2150	-	-	-	0.1124

					Country *j*					
Country *i*	Lags	Canada	China	Euro Area	Germany	India	Italy	Spain	UK	US
France	1	0.0254[b]	0.0742[c]	0.0125[b]	0.0177[b]	0.0153[b]	0.0433[b]	0.0091[a]	0.0082[a]	0.0010[a]
	2	0.0154[b]	0.3247	0.0203[b]	0.0193[b]	0.0094[a]	0.0452[b]	0.0282[b]	0.0364[b]	0.0169[b]
	3	0.0029[a]	0.2745	0.0143[b]	0.0215[b]	0.0193[b]	0.0607[c]	0.0379[b]	0.0120[b]	0.0261[b]
	4	0.0064[a]	0.1932	0.0223[b]	0.0121[b]	0.0358[b]	0.1411	0.0853[c]	0.0211[b]	0.0352[b]
	5	0.0080[a]	0.0868[c]	0.0384[b]	0.0253[b]	0.0563[c]	0.2371	0.0665[c]	0.0353[b]	0.1301
	6	0.0100[b]	0.0466[b]	0.0183[b]	0.0252[b]	0.0443[b]	0.2705	0.0315[b]	0.1353	0.0549[c]
	7	0.0146[b]	0.0168[b]	0.0334[b]	0.0282[b]	0.0762[c]	0.3709	0.0279[b]	0.0340[b]	0.0680[c]
	8	0.0207[b]	0.0179[b]	0.0551[c]	0.0385[b]	0.0955[c]	0.4131	0.0375[b]	0.0786[c]	0.0878[c]

		Country j								
Country i	lag	Canada	China	Euro Area	France	India	Italy	Spain	UK	US
Germany	1	0.0087 [a]	0.0151 [b]	0.0594 [c]	0.0425 [b]	0.0078 [a]	0.0984 [c]	0.0494 [b]	0.0274 [b]	0.0387 [b]
	2	0.0047 [a]	0.0485 [b]	0.0311 [b]	0.1232	0.0471 [b]	0.1284	0.1736	0.0656 [c]	0.0831 [c]
	3	0.0092 [a]	0.1503	0.0645 [c]	0.2708	0.1167	0.1113	0.2060	0.1535	0.3305
	4	0.0174 [b]	0.2591	0.0975 [c]	0.4908	0.2300	0.1530	0.3672	0.2647	0.2147
	5	0.0111 [b]	0.2093	0.1215	0.7943	0.2610	0.3600	0.4922	0.0729 [c]	0.2363
	6	0.0167 [b]	0.1552	0.1082	0.7776	0.1241	0.3579	0.7143	0.0448 [b]	0.2531
	7	0.0277 [b]	0.1283	0.1621	0.7832	0.1824	0.5275	0.6369	0.0342 [b]	0.2081
	8	0.0356 [b]	0.1677	0.0909 [c]	0.5518	0.2981	0.6096	0.2534	0.0530 [c]	0.0952 [c]

Notes: This table reports the p-values of the Dicks-Panchenko causality tests. [a], [b] and [c] indicate the rejection of the null hypothesis of absence of causality running from country i to country j at the 1%, 5% and 10% levels, respectively.

Table 4 (continued): Dicks-Panchenko nonlinear causality test

		Country j								
Country i	lag	Canada	China	Euro Area	France	Germany	Italy	Spain	UK	US
India	1	0.0077 [a]	0.0015 [a]	0.0250 [b]	0.0170 [b]	0.0487 [b]	0.0064 [a]	0.0237 [b]	0.0245 [b]	0.0089 [a]
	2	0.0161 [b]	0.0104 [b]	0.0323 [b]	0.0071 [a]	0.1005	0.0132 [b]	0.0130 [b]	0.2097	0.0190 [b]
	3	0.0069 [a]	0.0248 [b]	0.0110 [b]	0.0553 [c]	0.0517 [c]	0.0059 [a]	0.0143 [b]	0.0774 [c]	0.0269 [b]
	4	0.0295 [b]	0.0414 [b]	0.0237 [b]	0.0975 [c]	0.0363 [b]	0.0093 [a]	0.0502 [c]	0.082 [c]	0.0524 [c]
	5	0.0186 [b]	0.0184 [b]	0.0379 [b]	0.1808	0.0316 [b]	0.0184 [b]	0.0618 [c]	0.0702 [c]	0.1321
	6	0.0142 [b]	0.0330 [b]	0.0508 [c]	0.1672	0.0295 [c]	0.0302 [b]	0.0429 [b]	0.0178 [b]	0.1243
	7	0.0154 [b]	0.0790 [c]	0.0593 [c]	0.2696	0.0501 [c]	0.0372 [b]	0.0539 [c]	0.0313 [b]	0.1658
	8	0.0185 [b]	0.0687 [c]	0.0673 [c]	0.2395	0.0684 [c]	0.0577 [c]	0.0581 [c]	0.0506 [c]	0.2323

		Country j								
Country i	Lags	Canada	China	Euro Area	France	Germany	India	Spain	UK	US
Italy	1	0.0192 [b]	0.0541 [c]	0.1642	0.0442 [b]	0.0430 [b]	0.0051 [a]	0.0846 [c]	0.0538 [c]	0.0655 [c]
	2	0.0306 [b]	0.1594	0.7969	0.0884 [c]	0.0617 [c]	0.0900 [c]	0.2083	0.1448	0.2670
	3	0.0302 [b]	0.5235	0.8709	0.1034	0.0411 [b]	0.3729	0.2046	0.1235	0.2153
	4	0.0829 [c]	0.7250	0.9122	0.1354	0.0562 [c]	0.4144	0.1266	0.2909	0.3225

	5	0.1634	0.7248	0.9580	0.2284	0.0863[c]	0.6341	0.2034	0.3099	0.5101
	6	0.2411	0.7200	0.9773	0.1063	0.1389	0.6499	0.1747	0.4159	0.4590
	7	0.2695	0.6370	0.9659	0.2122	0.1233	0.6642	0.2479	0.5496	0.4966
	8	0.2486	0.3603	0.9300	0.1690	0.1360	0.3517	0.3378	0.4298	0.2079

					Country j					
Country i	lag	Canada	China	Euro Area	France	Germany	India	Italy	UK	US
Spain	1	0.0305[b]	0.0652[c]	0.0445[b]	0.0375[b]	0.0249[b]	0.2011	0.1152	0.0097[a]	0.0143[b]
	2	0.0207[b]	0.4145	0.0572[c]	0.0331[b]	0.0197[b]	0.3857	0.2130	0.0099[a]	0.0232[b]
	3	0.0293[b]	0.7463	0.1337	0.1919	0.0266[b]	0.1744	0.3313	0.0287[b]	0.1106
	4	0.0359[b]	0.5989	0.0477	0.2255	0.0163[b]	0.1063	0.4117	0.0406[b]	0.1226
	5	0.0229[b]	0.6933	0.1063	0.5774	0.0355[b]	0.1871	0.4469	0.0720[c]	0.4588
	6	0.0367[b]	0.6487	0.1799	0.6682	0.0389[b]	0.1211	0.2687	0.0510[c]	0.4343
	7	0.0396[b]	0.4854	0.3098	0.7159	0.0374[b]	0.1116	0.2303	0.0716[c]	0.4787
	8	0.0438[b]	0.3273	0.4561	0.6419	0.0505[c]	0.0700[c]	0.2450	0.1436	0.3384

					Country j					
Country i	lag	Canada	China	Euro Area	France	Germany	India	Italy	Spain	US
UK	1	0.0023[a]	0.0357[b]	0.0005[a]	0.0006[a]	0.0052[a]	0.0003[a]	0.0012[a]	0.0341[b]	0.0003[a]
	2	0.0035[a]	0.1266	0.0165[b]	0.0108[b]	0.0109[b]	0.0063[a]	0.0081[a]	0.0868[c]	0.0067[a]
	3	0.0034[a]	0.1826	0.0287[b]	0.0464[b]	0.0092[a]	0.0141[b]	0.0184[b]	0.0899[c]	0.0202[b]
	4	0.0088[a]	0.1683	0.0173[b]	0.0635[c]	0.0132[b]	0.0395[b]	0.0338[b]	0.0557[c]	0.0277[b]
	5	0.0128[b]	0.1288	0.0181[b]	0.1379	0.0230[b]	0.0871[c]	0.0685[c]	0.0823[c]	0.1100
	6	0.0096[a]	0.1142	0.0278[b]	0.1353	0.0305[b]	0.1018	0.1012	0.1291	0.1151
	7	0.0095[a]	0.0835[c]	0.0360[b]	0.3992	0.0266[b]	0.1020	0.1410	0.1311	0.1030
	8	0.0141[b]	0.0667[c]	0.0761[c]	0.5252	0.0590[c]	0.0912[c]	0.1771	0.1515	0.1099

					Country j					
Country i	Lags	Canada	China	Euro Area	France	Germany	India	Italy	Spain	UK
US	1	0.0018[a]	0.0064[a]	0.0003[a]	0.0015[a]	0.0030[a]	0.0006[a]	0.0013[a]	0.0094[a]	0.0021[a]
	2	0.0025[a]	0.0270[b]	0.0082[a]	0.0057[a]	0.0101[b]	0.0017[a]	0.0076[a]	0.0479[b]	0.0152[b]
	3	0.0022[a]	0.0416[b]	0.0186[b]	0.0425[b]	0.0127[b]	0.0247[b]	0.0168[b]	0.0641[c]	0.0089[a]
	4	0.0109[b]	0.0411[b]	0.0225[b]	0.0670[c]	0.0181[b]	0.0499[b]	0.0433[b]	0.1008	0.0126[b]
	5	0.0117[b]	0.0283[b]	0.0322[b]	0.1363	0.0230[b]	0.0482[b]	0.1063	0.1444	0.0125[b]
	6	0.0145[b]	0.0390[b]	0.0548[c]	0.2675	0.0289[b]	0.0579[c]	0.1287	0.1764	0.0182[b]
	7	0.0171[b]	0.0447[b]	0.0772[c]	0.6288	0.0481[b]	0.0616[c]	0.2059	0.1886	0.0282[b]

8	0.0197 ^{b}	0.0456 ^{b}	0.0547 ^{c}	0.5450	0.0518 ^{c}	0.0484 ^{b}	0.1918	0.0744	0.0890 ^{c}	

Notes: This table reports the p-values of the Dicks-Panchenko causality tests. ^{a} , ^{b} and ^{c} indicate the rejection of the null hypothesis of absence of causality running from country i to country j at the 1%, 5% and 10% levels, respectively.

4 - Conclusion

According to the IMF (2012), uncertainty is countercyclical. It tends to rise during the downward phase of the business cycle and fall during an upward phase. This assertion is in line with Baker *et al.*(2012)'s findings that economic policy uncertainty has increased in the wake of the recent global recession. Given that globalization has created extensive trade and financial linkages across the world, we investigate whether a causal relationship exists between economic policy uncertainty for pairs of major global economies. Due to shortcomings of the linear Granger causality test, especially in the presence of nonlinearity and structural breaks (existence of which has been indicated above), our study relies on the nonlinear variant of the Granger causality test as developed by Diks and Panchenko (2005). We find extensive and significant evidence of cross-country economic policy uncertainty causal relationships.

Table 5: Summary of results from the linear and nonlinear Granger causality tests

Country *j* / Country *i*	Canada	China	Euro Area	France	Germany	India	Italy	Spain	UK	US
Canada	-	l , nl	l , nl	l , nl	l , nl	nl	l , nl	l , nl	l , nl	l , nl
China	l , nl	-	nl	nl	nl	nl	nl	nl	nl	nl
Euro Area	l , nl	l , nl	-	-	-	l , nl	-	-	-	nl
France	nl	nl	nl	-	nl	nl	nl	l , nl	l , nl	nl
Germany	l , nl	l , nl	l , nl	l , nl	-	l , nl	nl	nl	l , nl	nl
India	l , nl	l , nl	l , nl	nl	l , nl	-	l , nl	l , nl	l , nl	nl
Italy	nl	l , nl	-	nl	l , nl	l , nl	-	nl	nl	nl
Spain	nl	nl	l , nl	l , nl	nl	nl	-	-	l , nl	nl
UK	l , nl	l , nl	nl	l , nl	l , nl	l , nl	l , nl	l , nl	-	l , nl
US	l , nl	l , nl	l , nl	l , nl	l , nl	l , nl	l , nl	l , nl	l , nl	-

Note: "l" ("nl") means that the linear (nonlinear) Granger causality test shows evidence of causality running from country i's economic policy uncertainty to country j's based on at least any of the conventional levels of significance.

As shown in Table 5, the Diks-Panchenko (2005) test outperforms the traditional Granger causality test in unveiling causal relationships. The Diks-Panchenko (2005) test matches all instances where the linear test establishes causality. In addition, the non-linear test uncovers causality in cases where the linear test failed. Overall, our results have two important implications: First, from a technical point of view, one needs to explicitly test for nonlinearity of individual series and structural breaks in the relationship while analyzing causal relationships. Since, failure to account for nonlinearity and structural changes, and reliance on only linear Granger causality tests, would fail to pick up all possible causal relationships and lead to incomplete and misleading conclusions, and; second, from a policy perspective, it is important for the policy-makers of a specific country to realize that the economic environment of their country is likely to be affected by policy decisions in another country (countries) as well, over and above their own policy decisions. Similarly, in a globalized world, the formulation of this particular country's domestic economic policies are simultaneously going to have potential repercussions on other countries' economies through trade and financial linkages, implying that a one-time policy change in a specific country or another country is likely to have more persistent effect over time.

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Appendix

The *VAR(p)* lag lengths

Table A.1: Optimal lag length tests of the VAR

Country *i* \ Country *j*	Canada	China	Euro Area	France	Germany	India	Italy	Spain	UK	US
Canada	-									
China	4	-								
Euro Area	3	3	-							
France	3	3	3	-						
Germany	3	3	3	3	-					
India	3	3	3	3	3	-				
Italy	3	3	3	3	3	3	-			
Spain	1	3	2	3	2	3	3	-		
UK	3	3	2	6	4	3	3	3	-	
US	4	4	4	4	4	4	4	6	1	-

Note: This table reports the VAR(p)'s lag length based on the Akaike Information Criterion (AIC).

The Hiemstra-Jones tests results

Table A.2: Hiemstra-Jones nonlinear causality test

Country *i*	Lags	China	Euro Area	France	Germany	India	Italy	Spain	UK	US
		Country *j*								
Canada	1	-5.0537	-7.8463	-5.5865	-10.5774	-7.6556	-7.7443	-7.3045	-8.5955	-3.0680
	2	-3.1973	-23.825	0.5022	-12.1441	35.1171 [a]	-25.1249	-26.5284	1.2959	0.7776
	3	-4.7426	52.3822 [a]	9.4922 [a]	46.1176 [a]	-3.0694	-15.3192	-14.7771	-2.0597	-0.1166
	4	-9.5765	186.821 [a]	1.1592	2.2370 [b]	0.8075	-0.7818	126.4541 [a]	4.4718 [a]	0.4089
	5	-7.7954	-1.1251	0.0174	5.1965 [a]	-2.5587	-0.2650	16.4720 [a]	-2.4866	-5.2470
	6	2.1845 [b]	0.2303	0.4546	5.1217 [a]	-1.3637	-0.3978	11.5909 [a]	-3.4527	-0.4506
	7	-2.8989	-0.3493	1.0745	3.0511 [a]	-1.4274	-2.6095	4.2434 [a]	-3.1693	-6.6124
	8	-4.8745	-0.6253	0.2514	1.6991 [c]	-1.6511	-2.7084	-0.7991	-4.6084	20.0176 [a]

Country *i*	lag	Canada	Euro Area	France	Germany	India	Italy	Spain	UK	US
		Country *j*								
China	1	-6.6271	-8.1529	-13.3777	-5.6832	-11.1919	-41.5507	-10.3965	-6.1249	-3.0449

	2	-14.8393	-10.5136	-7.8713	-7.1180	-7.4639	0.0147	-1.9616	74.2775 [a]	2.0271 [b]
	3	-5.1631	-1.1315	12.6341 [a]	-14.8219	35.5854 [a]	-2.7767	1.7357	-14.3773	0.9847
	4	-0.1088	-1.6479	17.3014 [a]	1.3553	-0.2670	-2.8089	-0.2344	-7.6170	-2.0763
	5	-1.6725	-1.1912	3.3786 [a]	0.2730	-7.4107	-6.7691	0.0000	0.1109	-2.0698
	6	3.3602 [a]	-3.5077	4.7906 [a]	0.0000	-18.9372	-26.0959	0.0000	-2.2617	-2.8791
	7	-1.4918	-5.2678	4.6585 [a]	0.0000	0.0000	41.1229 [a]	0.0000	-3.8565	-3.6403
	8	0.4196	-10.5356	0.0000	0.0000	0.0000	-8.4652	0.0000	-10.5356	-5.3325

		Country *j*								
Country *i*	lag	Canada	China	France	Germany	India	Italy	Spain	UK	US
Euro Area	1	-6.0152	-5.8905	-	-	-6.0908	-	-	-	-5.8558
	2	-6.1630	-5.3221	-	-	-9.8626	-	-	-	14.0768 [a]
	3	-4.4404	-4.9592	-	-	-72.3717	-	-	-	-5.7887
	4	174.015 [a]	-0.4372	-	-	8.2225 [a]	-	-	-	-8.5224
	5	1.5631	-0.5702	-	-	-0.0849	-	-	-	-11.0325
	6	-2.1656	-0.9092	-	-	0.6278	-	-	-	16.4050 [a]
	7	-2.3327	0.0000	-	-	3.8809 [a]	-	-	-	5.0120 [a]
	8	-3.0752	0.0000	-	-	1.5313	-	-	-	2.9319 [a]

		Country *j*								
Country *i*	Lags	Canada	China	Euro Area	Germany	India	Italy	Spain	UK	US
France	1	-7.5055	-7.1945	-5.6897	-12.6425	-6.5905	-5.8102	-7.3812	-4.4683	-7.2764
	2	-16.3505	-5.5266	-3.7818	-23.2776	-2.3657	-0.5742	1.5869	-8.4475	-14.8407
	3	8.7229 [a]	-13.8156	-11.0478	-13.8215	-3.6805	-4.6813	0.4874	-1.2868	10.9059 [a]
	4	-2.3303	8.9245 [a]	50.7952 [a]	-7.3033	-0.1694	-0.0146	-0.8563	-4.4805	2.3755 [b]
	5	-0.4152	-3.9111	18.5112 [a]	-4.5438	-2.7067	-3.0588	-3.7728	-12.3649	-2.0855
	6	0.6147	-3.8933	-20.1586	-2.3892	-6.5541	-0.0068	-6.4627	60.3039 [a]	-4.4044
	7	0.5961	-3.5878	53.5656 [a]	-0.8496	-6.1271	0.0000	-16.3516	4.7917 [a]	-7.4591
	8	0.4168	-3.4211	-0.0958	-0.8383	-10.2432	0.0000	-2.1166	1.1809	181.033 [a]

		Country *j*								
Country *i*	lag	Canada	China	Euro Area	France	India	Italy	Spain	UK	US
Germany	1	-5.0592	-3.4592	-6.3883	-4.5908	-5.3274	-7.7056	-3.2006	-1.6543	-5.3790
	2	-5.9561	-4.6223	-6.3978	20.5556 [a]	-0.5346	-62.1142	-1.8414	-56.9882	5.8782 [a]
	3	58.4895 [a]	-12.6730	-2.7605	10.9575 [a]	-1.3511	-12.0829	-6.9624	-19.1967	-9.7475
	4	3.6146 [a]	-7.0252	-5.1520	7.9427 [a]	-2.9040	0.0000	-22.6521	-1.6478	-4.6571
	5	2.0736 [b]	-19.1714	-6.2176	3.8809 [a]	-0.2195	-15.4828	-1.6880	-1.3103	-9.9628

	6	0.8785	21.1815[a]	-4.6297	1.4182	-0.2850	0.0000	-3.5276	-1.9592	43.9766[a]
	7	1.4267	-7.0716	-6.2966	2.5934[b]	-0.4496	0.0000	-5.2915	-1.2029	4.3074[a]
	8	0.5913	-10.5356	-9.0209	2.2251[b]	-0.7519	54.5583[a]	-10.5830	-2.4955	0.0000

Notes: This table reports the standardized test statistic of Hiemetra-Jones (1994). "lags" denotes the number of lags in the residual series used in the test. [a], [b] and [c] indicate the rejection of the null hypothesis of absence of causality running from country i to country j at the 1%, 5% and 10% levels, respectively.

Table A.2 (continued): Hiemstra-Jones nonlinear causality test

		Country *j*								
Country *i*	lag	Canada	China	Euro Area	France	Germany	Italy	Spain	UK	US
India	1	-8.4382	-8.1396	-6.8449	-7.1537	-4.2589	-6.9120	-6.3756	-4.3133	-7.0439
	2	35.3800[a]	9.4973[a]	-9.3313	-1.3959	-2.8303	-6.1859	-3.5799	-10.3283	-12.6655
	3	-4.5117	54.4399[a]	12.4892[a]	-0.3464	-4.0718	-5.8435	1.5131	9.43129[a]	-0.4283
	4	28.5746[a]	-1.6365	-8.4605	-1.5216	-3.7422	-9.8554	-14.4818	-14.3273	10.3603[a]
	5	0.8346	-9.0392	-8.8124	-1.2738	-0.4142	-19.9590	4.6135[a]	-13.6556	1.62515
	6	1.1131	2.3192	-30.6696	0.0951	-3.8560	0.0000	0.3113	-430.1016	-0.7777
	7	0.2293	-2.6339	8.8523[a]	1.8935[c]	-4.2358	0.0000	0.0000	8.2741[a]	-1.0907
	8	0.2652	-3.5118	-5.0969	3.1655[a]	-7.0825	0.0000	0.0000	-0.6409	-0.1209
		Country *j*								
Country *i*	Lags	Canada	China	Euro Area	France	Germany	India	Spain	UK	US
Italy	1	-6.0392	-31.1556	-5.3616	-7.0801	-11.0229	-6.5077	-13.5913	-9.1378	-11.0451
	2	-6.6489	0.4844	-14.5540	-4.1092	-19.5423	0.6861	-6.3108	28.2247[a]	-31.9277
	3	-6.4066	4.8379[a]	-17.9485	-0.3991	-6.4771	3.5425[a]	-7.5738	2.4006[b]	71.9213[a]
	4	3.8295[a]	2.4758[b]	-233.1854	-0.6758	-9.9622	-0.7929	-18.5903	24.1193[a]	-139.2930
	5	8.4800[a]	-3.8769	-0.9711	-3.7088	0.0000	2.0587[b]	-1539.7663	-21.2085	126.1181[a]
	6	3.1605[a]	10.5800[a]	-1.6509	-10.3703	0.0000	-6.8138	-2.7597	1.0559	0.0000
	7	2.2246[b]	-8.4843	1.5093	0.0000	0.0000	-19.2887	-10.5356	0.000	0.000
	8	2.1242[b]	-2.0704	0.0000	0.0000	46.5251[a]	0.0000	0.0000	0.000	0.000
		Country *j*								
Country *i*	lag	Canada	China	Euro Area	France	Germany	India	Italy	UK	US

Spain	1	-8.6570	-8.1756	-5.8813	-10.8394	-2.3259	-6.4139	-24.5346	-10.5614	-9.4391
	2	3.7799 [a]	-4.1639	-3.6029	-38.5367	-3.0726	-5.8575	4.7029 [a]	5.5234 [a]	-35.3762
	3	2.3882 [b]	2.8190 [a]	-2.3956	15.6078 [a]	-2.6913	-8.4976	0.0697	3.1259 [a]	80.0821 [a]
	4	20.6288 [a]	-0.7041	-1.1452	5.9605 [a]	4.3003 [a]	-11.6202	5.0572 [a]	0.4407	-0.9669
	5	-2.1954	-2.6246	4.4239	1.9991 [b]	-7.2456	-5.1333	-925.8663	0.0000	59.0187 [a]
	6	1.5805	-1.4633	0.0000	0.0000	0.0000	-5.6390	-11.4759	0.0000	9.6623 [a]
	7	-0.4636	-5.0182	0.0000	0.0000	0.0000	-0.5566	0.0000	0.0000	29.2986 [a]
	8	-0.2826	-7.3266	0.0000	0.0000	0.0000	-5.2678	0.0000	0.0000	17.7775 [a]

		Country *j*								
Country *i*	lag	Canada	China	Euro Area	France	Germany	India	Italy	Spain	US
UK	1	-4.8763	-15.577	-5.5911	-5.4157	-11.3933	-5.8595	-8.8199	-8.6057	-3.5728
	2	-5.3528	79.9269 [a]	-7.0519	-7.8717	53.3561 [a]	-5.3701	27.6843 [a]	-0.7129	-2.8071
	3	-5.5502	17.3401 [a]	-11.4705	15.3854 [a]	47.8266 [a]	-0.6254	-12.0000	-6.4092	-1.7296
	4	4.4103 [a]	-8.7673	111.6625 [a]	-0.0122	8.2290 [a]	7.0783 [a]	-30.2687	-4.4617	0.03971
	5	-0.3530	3.1985 [a]	1.8751 [c]	-7.8203	3.4429 [a]	3.5790 [a]	-13.0317	-5.3209	-0.2967
	6	0.0000	4.6401 [a]	10.7815 [a]	0.0000	1.4465	53.4836 [a]	-1.6518	-10.0995	-2.3084
	7	0.0000	3.5406 [a]	5.4647 [a]	0.0000	1.3685	-1.5392	-5.2678	0.0000	-3.3383
	8	0.0000	0.0000	3.4513 [a]	0.0000	-0.1214	-0.9389	-10.5356	0.0000	-4.3329

		Country *j*								
Country *i*	Lags	Canada	China	Euro Area	France	Germany	India	Italy	Spain	UK
US	1	-5.6984	-11.4529	-5.2997	-8.745	-11.8237	-5.5725	-6.0269	-7.6496	-5.1163
	2	-3.4791	-3.4676	-36.3977	-25.313	159.8872 [a]	-4.8443	-12.7261	-19.0522	-3.0071
	3	-4.8099	-2.9704	6.9625 [a]	2.4641 [b]	9.3087 [a]	-13.5530	39.6503 [a]	9.7960 [a]	-1.2647
	4	-2.6665	-3.3245	-2.7629	-0.5583	-2.7082	-5.8517	-186.9618	-1.6274	-1.3529
	5	-1.7071	-0.8371	2.1575 [b]	-1.9046	-1.1653	-0.0589	-178.2635	-9.5911	0.2414
	6	-4.4336	-3.0316	-9.6083	-1.8614	-35.4688	-0.2140	0.00000	-15.3757	-0.9212
	7	-2.6127	-3.9734	-3.7914	-3.2672	10.1965 [a]	0.0000	-8.2941	-22.8393	-1.0821
	8	-35.4951	-5.1556	-3.0089	224.963 [a]	9.6128 [a]	-2.2231	-139.6881	-14.0849	-2.5633

Notes: This table reports the standardized test statistic of Hiemetra-Jones (1994)."lags" denotes the number of lags in the residual series used in the test. [a] , [b] and [c] indicate the rejection of the null hypothesis of absence of causality running from country i to country j at the 1%, 5% and 10% levels, respectively.

Economic Policy Uncertainty (EPU) index construction

Baker *et al.* (2013) construct the monthly EPU index mainly by using two underlying components: (1) the news coverage about policy-related economic uncertainty and (2) economic forecasters disagreement. However, in the case of the US, the authors use the federal tax code provisions set to expire in coming years as an additional component. For China, Baker *et al.* (2013) only rely on a scaled frequency count of newspaper articles in the South China Morning Post which is Hong Kong's top English language newspaper. In the following lines, we summarize Baker *et al.* (2013)'s approach to constructing each underlying component as well as the overall EPU index for the US, Canada, Europe, India and China.

News coverage about policy-related economic uncertainty (all countries)

The news coverage component is an index of search results of a given country's top newspapers (done using the native language of the paper in question) for terms related to economic and policy uncertainty. Table A.3 illustrates the structuring of the first component in the case of the US, Canada, Europe and India (China's case is an exception and therefore presented separately).

Table A.3: Structure of the news coverage component

Country	Newspapers	Terms searched
US	USA Today, the Miami Herald, 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	uncertainty, uncertain, economic, economy, congress, legislation, white house, regulation, federal reserve, deficit
Canada	The Gazette, The Vancouver Sun, The Toronto Star, The Ottawa Citizen, The Globe and Mail	policy, tax, spending, regulation, central bank, budget, deficit
Europe	2 papers from Germany, the UK, France, Italy and Spain: El Pais, El Mundo, Corriere della Sera, La Repubblica, Le Monde, Le Figaro, the Financial Times, The Times of London, Handelsblatt, Faz	policy, tax, spending, regulation, central bank, budget, deficit
India	the Economic Times, the Times of India, the Hindustan Times, the Hindu, the Statesman, the Indian Express, the Financial Express	at least one term from each of the following sets: {uncertain, uncertainties, uncertainty}; {economic, economy}; {regulation, central bank, monetary policy, policymakers, deficit, legislation, fiscal policy}

Baker *et al.* (2013) deal with fluctuating volumes of news articles for a given newspaper by dividing the raw counts of policy uncertainty articles by the total number of news articles in the paper. The authors normalize each newspaper's series to standard deviation 1 for periods prior to 2011 (2010 for the US) and aggregate each paper's series and normalize the series to an average value of 100 prior to 2011 (2010 for the US).

As pointed earlier, the news coverage index is the only underlying component for China's monthly overall EPU index. In essence, Baker *et al.* (2013) identify the South China Morning Post's articles on economic uncertainty in China. To be eligible, an article must contain at least one term from each of the China EU term sets: {China, Chinese} and {economy, economic} and {uncertain, uncertainty}. Next, Baker *et al.* (2013) use a compound text filter to single out the policy-related subset China EU articles. For an article to be selected, the following filter conditions must be met: {policy OR spending OR budget OR political OR "interest rates" OR reform} AND {government OR Beijing OR authorities}} OR tax OR regulation OR regulatory OR "central bank" OR "People's Bank of China" OR PBOC OR deficit OR WTO. Thereafter, Baker *et al.* (2013) apply these conditions in an automated search over all South China Morning Post news articles published since 1995. The search generates a monthly frequency count of policy-related economic uncertainty South China Morning Post articles. Then, the authors divide the monthly frequency count by the number of all South China Morning Post articles in the same month. By means of a multiplicative factor, Baker *et al.* (2013) normalize the ensuing series to a mean of 100 from January 1995 to December 2011.

Economic forecaster disagreement (all countries except for China)

The economic forecaster disagreement component of the EPU index represents as a proxy for uncertainty. Essentially, the authors use professional forecasters' projections of inflation (as measured by the consumer price index) as well as government spending or budget balance (see Table A.4). Given the fact that monetary and fiscal policies affect these variables, the period-specific spread (measured by the interquartile range) in the forecasts of each variable captures the uncertainty in monetary and fiscal policies (Baker *et al.*, 2013).

Table A.4: Structure of the economic forecaster disagreement component

Country	Variables	Source	Time horizon
US	Quarterly forecasts of Inflation (CPI-based), purchase of goods and services by State, Local as well as Federal Government	Federal Reserve Bank of Philadelphia	Four quarters-ahead
Canada	Monthly forecasts of consumer prices and federal government budget balance	Consensus Economics	Twelve months-ahead
Europe	Monthly forecasts of consumer prices and federal government budget balance	Consensus Economics	Twelve months-ahead
India	Monthly forecasts of consumer prices and federal government budget balance	Consensus Economics	Twelve months-ahead

In the US case, Baker *et al.* (2013) divide the interquartile range of four-quarter-ahead projections of the federal and state/local government purchases by the median four-quarter-ahead forecast and multiply the resulting numbers by a 5-year backward-looking moving average for the ratio of nominal (federal or state) purchases to nominal gross domestic product (GDP). Next, the authors keep constant the values of the forecast disagreement measures within each quarter. Lastly, Baker *et al.* (2013) aggregate the two indices - weighted by their normal sizes - to obtain one federal or state index. Given the lag in the release of data, Baker *et al.* (2013) set each quarter's data forward one month. For Canada, Europe and India, Baker *et al.* (2013) consider the monthly raw interquartile range of the budget balance's forecasts for twelve months ahead and divide it by the respective country's current annual GDP. Given the mechanically decreasing variance in projections of both inflation and government balance as the following calendar year nears, Baker *et al.* (2013) rid the data from monthly fixed effects.

Tax code expiration data (only in the US case)

Baker *et al.* (2013) obtain the tax code expiration data from the Congressional Budget Office (CBO) reports which have information on planned termination of federal tax code provisions in the corresponding calendar year and each of the upcoming ten years. According to the authors, the fact that Congress usually postpones temporary tax measure at the last minute makes them a source of uncertainty for businesses and households. Baker *et al.* (2013) compute the total yearly dollar amount of expirations up to years in the future. The authors also weight the data for January of each year using a formula that corresponds to a yearly discount rate of 100 per cent. Thereafter, Baker *et al.* (2013) aggregate the discounted number of tax code expirations to arrive at an index value for each January which they keep constant throughout the calendar year.

Constructing the overall policy-related economic uncertainty index (all countries except for China)

Baker *et al.* (2013) normalize each component by its standard deviation prior to January 2011 (January 2012 for the US case). Next, the authors determine the weighted average value of component indices as follows:

• For the US: Using weights of $1/2$ on the news coverage component index and $1/6$ on each of the tax expirations index, CPI forecast disagreement measure and the federal/state purchase disagreement measure.

• For Canada: Using weights of $1/2$ on the news coverage component index and $1/4$ on each (inflation and government balance) forecast disagreement measure. Baker *et al.* (2013) use an equal weight of $1/2$ for all components for periods with no budget balance forecasts. The authors then standardize the mean to 100 before 2011.

• For Europe: Using weights of $1/2$ on the news coverage component index and $1/4$ on each (inflation and government balance) forecast disagreement measure. However, for Spain, given the absence of budget balance data, equal weights of $1/2$ are assigned to the new coverage index and the CPI dispersion measure. After normalizing each country's index by its standard deviation, Baker *et al.* (2013) then combine each individual country index to obtain the final index whose mean is standardized to 100 before 2011.

• For India: Using weights of $2/3$ on the news coverage index and $1/6$ on each forecast disagreement measure. Next, Baker *et al.* (2013) normalize the obtained weighted average to 100 before 2011. The authors justify the use of a bigger weight for the news coverage index since they use a relatively larger number of newspapers for India compared to Europe. Also, there are relatively fewer forecasters of Indian consumer price index and budget balance.