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Brexit and CDS spillovers across UK and Europe

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Abstract

The purpose of the paper is twofold. First, it aims at identifying when UK and European (France, Germany, Italy and Spain) Credit Default Swaps (CDSs) exhibit explosivity with respect to their past behaviors. Second, it seeks to quantify the dynamics of CDS volatility spillover effects surrounding the UK's EU membership referendum commonly known as "Brexit". Using a recursive identification algorithm and new spillover measures suggested by Diebold and Yilmaz (2012), two interesting findings were drawn. We detect significant build-ups in CDS prices for all countries under study soon after the day relative to the announcement of Brexit. In addition, we show that the great uncertainty over Brexit generates significant risk spillovers across the underlined CDS. In particular, we find that UK, Italy and Spain are the "net volatility transmitters", while France and Germany seem the "net volatility receivers". Our findings may help in formulating appropriate regulatory policies and designing effective hedging strategies.

JEL Classification: G12, G13, C13, C22

Keywords: Brexit, credit default swaps, explosivity, volatility, spillover effects, UK, Europe

1. Introduction

In the wake of the UK vote to leave the European Union (EU), capital markets face a period of great uncertainty with unknown consequences. Notably, the cost of buying protection against a default on British sovereign debt using Credit Default Swaps (hereafter, CDS) widened to a three-year high following the week's vote to withdraw the EU. Thomson Reuters indicates that CDS cost now $48,500 a year to protect $10 million of U.K. sovereign debt for five years, compared with levels near $32,000 prior to the June 23rd referendum. In addition, the credit risk increased in a number of European countries. France experienced a rise of its five-years CDS spread by about 49% (with less extent Germany by approximately 31%). Peripheral Europe, Italy and Spain saw their five-years CDS spread widen 24% and 25%, respectively. The sharp growth in CDS means that the latter has become crucial to help investors and traders to avoid credit risks. Compared to corporate bond spread, CDS spread were often viewed as a good proxy of inherited credit risk (Forte and Levreta 2009); it provides "insurance" against a credit event that might destroy value in a corporation's or a financial institution's debt (Berndt et al. 2007). In addition, CDS markets incorporate new information more quickly than bonds (Blanco et al. 2005; Zhu 2006; Bouoiyour et al. 2016). Interestingly, the credit default swap contracts have made a big impact recently in the financial crisis. Even though they may not be the cause of the crisis, they contributed largely to spread distress across companies and financial institutions (for example, Acharya and Johnson 2007; Saygun 2014). In light of the deepest fluctuations of CDS over the last two years, a better understanding of the interconnectedness among

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UK and European (in particular, France, Germany, Italy and Spain)[1] CDS spreads may be very useful.

Our assessment contributes to existing research in several aspects. First, we do not impose any structural breakpoint and reach beyond the comparison of selected periods (for instance, prior to and post the Brexit vote) towards the examination of gradual structural change. Accurately, using CDS spreads as proxy of credit risk, this paper sets out to capture periods of explosive behavior of UK and EU CDS spreads. For empirical purpose, we carry out a generalized sup ADF (GSADF) test procedure proposed by Phillips, et al. (2013) aimed at identifying stable and bubble-episodes in the investigated time series. Second, during crises a prominent topic discussed by academics, regulators and market participants in general is that of spillovers. This research attempts to investigate volatility linkages between UK and European CDS spreads, which remain up to now not researched over Brexit looms. To provide reliable information about CDS risk spillovers and to take efficient policy actions, there is a need for effective measures. This study conducts a generalized VAR in variance decomposition developed by Diebold and Yilamz (2012) to measure the total volatility spillover effects, and to shed some light on the net directional spillovers among UK and European CDS spreads. We should mention that relatively few empirical researches have examined the dynamic volatility spillovers across CDS indexes in European countries (Alter and Beyer 2013; Heinz 2014; Alemany 2015). By combining ARMA-FIGARCH skewed Student-t distribution as measure of volatility and Diebold and Yilamz (2012)' procedure, we carry out a full-sample spillover analysis and a rolling-sample analysis allowing for time-varying spillovers.

With the increased Brexit fears, we capture explosive periods in the prices of UK and European CDS with respect their past attitudes with the onset of the Brexit vote. Besides, we show that the uncertainty over UK's EU membership withdrawal resulted in significant volatility spillover effects across UK and EU CDS. Specifically, UK, Italy and Spain are the stress volatility exporters, whereas France and Germany are the net receivers of volatility spillovers. The structure of the article is as follows: Section 2 includes a brief discussion of the theory. Section 3 presents a description of the data used along with the methodology followed, while Section 4 reports the main empirical results. Section 5 looks at their robustness. Section 6 concludes.

2. Theoretical Considerations

The past several years have witnessed noticeable research concerning how CDS risk spillovers across countries become wider during turbulent times, and much has been written on both the theoretical and empirical sides of the issue. Specifically, the credit default swap contracts have made a big impact recently in the financial crisis. Even though they may not be the cause of the crisis, they contributed largely to spread distress across companies and financial institutions (Saygun 2014).

Some works assessed the response of CDS spreads to credit events over the last decade, by concentrating on cross-border spillover effects, addressing whether the effect of rating events extends to other countries beyond the respective economy.

[1] The European countries that experienced a marked surge in the credit risk especially after the Brexit result have been considered. According to the markit's pricing service, French, German, Italian and Spanish CDS markets are the most influenced by the referendum vote. You can refer to the following link for more information: http://www.markit.com/Product/Pricing-Data-CDS

Accordingly, Caporin et al. (2012) analyzed the sovereign risk spillovers within the euro area. They concluded that the common shift in CDS spreads is the outcome of the usual interconnection and that the strength in the transmission mechanism has not changed over the global financial collapse. Besides, by analyzing sovereign CDS spreads in the US and Europe, Ang and Longstaff (2011) claimed that systemic sovereign risk seems strongly associated to financial markets than to country-specific macro-features. Additionally, Beirne and Fratzscher (2012) showed that global financial markets (in particular, CDS markets) are more affected by economic fundamentals during turbulent rather than tranquil times. Nevertheless, they demonstrated that regional spillovers are less able to explain risks. Ejsing and Lemke (2011) empirically gauged the dynamic dependencies across CDS spreads of European countries and banks with a common risk factor and find that sovereign CDS indexes are likely to be more vulnerable to the common risk factor than banks' CDS spreads. Likewise, Kalbaska and Gatwoski (2012) investigated contagion among several European CDS markets. They corroborated that countries under distress (including Greece, Ireland, Portugal, Spain and Italy) tend to trigger slight contagion across the Euro area countries. Claeys and Vašíček (2012) carried out different spillover measures following Diebold and Yilmaz (2012)'s procedure for a sample of EU sovereign bond and CDS spreads. They concluded that the return and volatility spillover among sovereign yields and CDS rose substantially since 2007 but their strength is not uniform across the investigated countries. Also, Alter and Schüler (2012) argued for contagion from banks to sovereign CDS prior to the achievement of public rescue programs for the financial sector, while sovereign CDS spreads do spill over to bank CDS series thereafter. Moreover, Gande and Parsley (2005), Ferreira and Gama (2007) and Afonso et al. (2012) evaluated the cross-border effect of sovereign credit ratings on international sovereign bond spreads and stocks and European sovereign bond and CDS spreads. All these studies deeply suggested the occurrence of asymmetric spillovers, with the impact of downgrades being the most influential. Böninghausen and Zabel (2015) sustained the previous evidences, by examining the influence of sovereign rating events on international sovereign bond market. They argued that such impact is more pronounced for countries within the same region. Furthermore, Wengner et al. (2015) explored the impact of rating events on the CDS spreads for both the event and non-event companies. They indicated that there exist significant risk spillover effects across the major competitors. More recently, Apergis et al. (2016), using Diebold and Yilmaz (2012) total spillover index as the dependent variable, showed quite interesting findings with respect the the impact of newswire messages on intensity of spillovers across CDS spreads. In particular, they showed that the news variable generates significant spillover effects among the underlined GIIPS CDS markets during the European debt crisis.

The research complements the existing literature by analyzing the role that may play the Brexit fears in exacerbating the risk spillovers among UK and European CDS spreads. We investigate not only the effect over the dayrelative to the Brexit announcement; rather investigates the spillover effects prior to and after the decision of the UK' EU referendum.

3. Methodology and data

To properly measure the risk spillovers among UK and European CDS spreads, we conduct a three-stage empirical methodology. First, we analyze the behaviors of UK and European CDS spreads over Brexit via a novel econometric technique developed by

Phillips et al. (2013), dubbed the generalized form of the SADF (GSADF). This technique is suited to capture the stable- and bubble-periods in time series. Second, we analyze the descriptive statistics of the conditional variances, and search for preliminary evidence of the volatility process of CDS spreads for each country by utilizing an ARMA-FIGARACH skewed Student-t distribution. Third, we investigate the total and directional volatility spillovers across the underlined CDS markets following the Diebold and Yilamz (2012)'s procedure (i.e., a generalized VAR variance decomposition).

3.1. The generalized SADF technique

To label periods of price explosivity, we use a new econometric method pioneered by Phillips and Yu (2011) and Phillips et al. (2011), and then extended in a generalized form of the sup Augmented Dickey Fuller (GSADF) by Phillips et al. (2013). The main consideration in defining explosive periods are controlling for structural breaks that may yield to the non-rejection of the unit-root hypothesis (Perron 1989). To resolve this problem, Gil-Alana (2003) assumed well known structural break dates in their examination, whereas Gil-Alana (2008) applied a residuals sum squared approach where a single structural break date is accounted for at an unknown time. This study recursively determines, via a flexible moving sample test procedure (GSADF test), periods where the lower bound of the fractional order exceeds unity (bubble periods), and subsequently return to levels below unity (stable periods), enabling us to adequately capture and date-stamp explosive periods. Briefly, this approach considers multiple structural breaks at unknown dates (Balcilar et al. 2015). Based on this method, bubbles are detected in a consistent manner even with smaller sample sizes (Phillips et al. 2013; Caspi et al. 2015).

The Phillips et al. (2013)'s test procedure performed throughout this research recursively implements an ADF-type regression test through a rolling window procedure.

Suppose the rolling interval starts with a fraction r_1 and ends with a fraction r_2 of the total number of observations, with the size of the window $r_w=r_2-r_1$, then let:

$$y_t = \mu + \delta y_{t-1} + \sum_{i=1}^{p} \phi_{r_w}^{i} \delta y_{t-1} + \varepsilon_t \tag{1}$$

where μ, δ and ϕ are the parameters to be estimated via OLS regression, and the usual H_0: $\delta = 1$ then tested against the right sided alternative H_1: $\delta > 1$. The number of observations under consideration is $T_w = [r_w, T]$, where [.] is the integer part. The ADF statistic corresponding to 1 is expressed by $ADF_{r_1}^{r_2}$.

Phillips et al. (2013) proposed a backward sup ADF test where the end point of the subsample is fixed at a fraction r_2 of the whole sample and the window size is extended from the fraction r_0 to the fraction r_2. Thus, the backward sup ADF statistic is denoted as:

$$SADF_{r_2}(r_0) = \sup_{r_1 \in [0, r_2 - r_1]} ADF_{r_1}^{r_2} \tag{2}$$

The key reason behind using a sup ADF statistic is the fact that CDS price bubbles may collapse temporarily, and thus the standard unit root tests may have a restricted power in capturing bubble-periods (Caspi et al. 2015). In this context, Homm and Breitung (2012) claimed that the sup ADF test procedure seems suitable in bubble-detection purpose, especially when dealing with one or two bubble episodes.

The GSADF is constructed by re-testing the SADF test procedure for each $r_2 \in [r_0, 1]$. The GSADF can therefore be expressed as following:

$$GSADF\ (r_0) = \sup_{r_2 \in [r_0, 1]} SADF_{r_{21}}(r_0) \tag{3}$$

In brief, GSADF corresponds to a sequence of ADF statistics. The supremum value of this sequence (SADF) is utilized to test the null hypotheses of unit root against its right-tailed (mildly explosive) alternative while comparing it to its corresponding critical values. Generally speaking, the testing procedure discussed above is pursued to test whether UK and European CDS spreads exhibit bubble patterns within a specific sample. When we note significant ADF statistics (i.e., $\delta_{r_1,r_2} \succ 1$), we can deduce that there exist explosive (or bubble) periods. If the null hypothesis of no bubbles is rejected, the Phillips et al. (2013)'s test allows to date-stamping the beginning and the ending points of the explosive episodes. The starting point of a bubble corresponds to the date, expressed as T_{r_e} at which the backward sup ADF sequence crosses the critical value from below. Likewise, the ending point of a bubble is also defined as the date, written as T_{r_f} at which the backward sup ADF sequence crosses the critical value but from above. Ultimately, based on GSADF, the explosive periods can be denoted as:

$$\hat{r}_e = \inf_{r_2 \in [r_0, 1]} \left\{ r_2 : BSADF_{r_2} \succ cv_{r_2}^{\beta_T} \right\} \tag{4}$$

$$\hat{r}_f = \inf_{r_2 \in [\hat{r}_e, 1]} \left\{ r_2 : BSADF_{r_2} \succ cv_{r_2}^{\beta_T} \right\} \tag{5}$$

where $cv_{r_2}^{\beta_T}$ is the 100(1$-\beta_t$)% critical value of the sup ADF statistic based on $[T_{r_2}]$ observations. We set β_t to a constant value, 5%, as opposed to letting $\beta_t \rightarrow 0$ as T $\rightarrow$ 0. Note that the *BSADF* (r_0) for $r_2 \in [r_0, 1]$ is the backward sup ADF statistic that relates to the GSADF statistic, and denoted as:

$$GSADF(r_0) = \sup_{r_2 \in [r_0, 1]} \left\{ BSADF_{r_2}(r_0) \right\} \tag{6}$$

3.2. The conditional variance process via ARMA-FIGARCH model

The long memory and fractional integration methods have received a particular attention in recent years as the power of familiar tests for unit roots are decreasing. This paper focuses on the long memory aspects of the cyclical component of CDS markets in turbulent times via ARMA-FIGARCH. This technique is jointly based on the Fractionally Integrated ARCH (FIGARCH) model (Baillie et al., 1996), and an autoregressive fractionally integrated moving average model (ARFIMA) to account for both short and long term persistence (Sowell 1992). Although the short-run behavior of the variable is modeled via the ARMA parameters, the fractional differencing parameter (*d*) accounts for the long-run dependence (Bollerslev and Mikkelsen 1996). The model is expressed as follows:

$$\varphi(L)(1-L)^d \varepsilon_t^2 = \omega + [1-\beta(L)](\varepsilon_t^2 - \sigma_t^2) \tag{7}$$

where $(1-L)^d$ is the fractional differencing operator defined as:

$$(1-L)^d = \sum_{k=0}^{\infty} \frac{\Gamma(d+1)L^k}{\Gamma(k+1)\Gamma(d-k+1)} = (1-dL) - \frac{1}{2}d(1-d)L^2 - \frac{1}{6}d(1-d)(2-d)L^3 - \ldots = 1 - \sum_{k=1}^{\infty} c_k(d)L \tag{8}$$

with $c_1 d = d, c_2 d = \frac{1}{2}d(1-d), c_3 d = \frac{1}{6}d(1-d)(2-d), \ldots$

3.3. Measuring the volatility spillover effects

A further step consists of incorporating the conditional volatility series to a generalized VAR framework (Diebold and Yilmaz 2012). This spillover investigation covers four aspects.

First, we determine the total volatility spillover index which measures what proportion of the volatility forecast error variances comes from spillovers. Let:

$$x_t = \phi x_{t-1} + \varepsilon_t \tag{9}$$

where $x_t = (x_{1,t}, x_{2,t})$ and ϕ is a 2*2 parameter matrix; x will be considered as a vector of CDS volatilities.

By covariance stationarity, the moving average representation of the VAR is denoted:

$$x_t = \Theta(L)\varepsilon_t \tag{10}$$

where $\Theta(L) = (I - \phi L)^{-1}$

Second, we consider 1-step-ahead forecasting. The optimal forecast is given by:

$$x_{t+1,t} = \phi x_t \tag{11}$$

with corresponding 1-step-ahead error vector:

$$e_{t+1} = x_{t+1} - x_{t+1,t} = A_0 \mu_{t+1} = \begin{bmatrix} a_{0,11} & a_{0,12} \\ a_{0,21} & a_{0,22} \end{bmatrix} \begin{bmatrix} \mu_{1,t+1} \\ \mu_{2,t+1} \end{bmatrix} \tag{12}$$

In particular, the variance of the 1-step-ahead error in forecasting $x_{1,t}$ is $a_{0,11}^2 + a_{0,12}^2$, and the variance of the 1-step-ahead error in forecasting $x_{2,t}$ is $a_{0,21}^2 + a_{0,22}^2$. There exist two possible spillovers in our example: x_{1t} shocks that exert influence on the forecast error variance of x_{2t} (with contribution $a_{0,21}^2$), and x_{2t} shocks that affect the forecast error variance of x_{1t} (with contribution $a_{0,12}^2$). Hence the total spillover effect is equal to $a_{0,12}^2 + a_{0,21}^2$.Having outlined the Spillover Index in a first-order two-variable VAR, it is easier to generalize this to a dynamic framework for a p^{th}-order N-variable case.

Third, we quantify the net directional volatility spillover indices for CDS, in order to identify which of the considered countries are net volatility importers, and which of them are stress volatility exporters. At this stage, we decompose the total spillover index for CDS volatilities into all of the forecast error variance components for variable *i* coming from shocks to variable *j*, for all *i* and *j*.

Fourth, a volatility spillover plots are constructed from the rolling-samples of the spillover indices to examine the extent and the nature of volatility spillover variation over time.

3.4. Data

This study examines the volatility transmission between UK and four European (France, Germany, Italy and Spain) CDS spreads over the period from January 01, 2014 to July 28, 2016, which includes 136 weeks[2], particularly surrounding the Brexit turmoil. Even though there is no clear consensus in the existing literature on which measure or indicator effectively represents sovereign default risk, the fact that CDS spreads reflect the expectations on the extent of the creditworthiness of sovereign economies is meaningful for our task as it will help us better understand the differences in individual countries exposures to risk spillovers under uncertain markets circumstances. Given this consideration, we use CDSs as a credit risk measure. We look at changes in CDS spreads rather than levels (Campbell 1996; Blanco et al. 2005; Ang et al. 2006) because we want to investigate the transmission of "news" or "information" about credit risks.The choice of this period is motivated by the degree of attention given to Brexit

[2] We prefer use weekly instead of daily data, given that daily or high-frequency data may be heavily influenced by drifts and noise that could mask or did not reflect appropriately the dependence between the investigated variables and thus complicate modeling of the marginal distributions via non-stationary variances, long memory processes and sudden jumps.

via Google Trends and social networking (in particular, Twitter). Before 2014, the interest to Brexit was negligible. However, millions of internet users start since January 2014 to interact with search engines, creating valuable sources of data regarding the information related to "Brexit" (see Figure A, Appendix). The data of UK, German, French, Italian and Spanish CDS were collected from Datastream database. The investigated CDS spreads were transformed by taking natural logarithms to correct for heteroskedasticity and dimensional differences. Descriptive statistics for return series (first logarithmic differences) are reported in Table 1. We note that UK CDS spreads have the most sizeable volatility. All time series display positive skewness (except Italy) and excess kurtosis (above 3). Hence, most CDS indexes have flatter tails than the normal distribution. The Jarque-Bera test statistic rejects the hypothesis of normality for all cases.

Before quantifying the risk spillovers among the focal CDSs markets, we first test for a unit root in UK and European CDS indexes series using familiar tests including the Augmented Dickey-Fuller (1979), the Phillips-Perron (1988), and the Kwiatkowski et al. (1992) unit root tests. The results displayed in Table 1 indicate that we cannot reject the null hypothesis of a unit for none of the series at the 1% significance level.

Table 1. Some statistical properties of the CDS returns

	UK	France	Germany	Italy	Spain
Mean	-0.0010	-0.0002	0.0006	-0.0001	-0.0011
Std. Dev.	0.0926	0.0488	0.0721	0.1978	0.0917
Skew	1.3358	0.4971	1.2229	-3.4612	0.5504
Kurt	27.927	5.6098	11.555	13.452	9.2572
J-B	513.42	647.95	505.07	438.29	711.23
ADF	-19.10^{+}	-20.15^{+}	-21.42^{+}	-26.45^{+}	-23.84^{+}
PP	-19.12^{+}	-20.21^{+}	-21.41^{+}	-27.86^{+}	-23.71^{+}
KPSS	0.321+	0.186+	0.166+	0.218+	0.207+

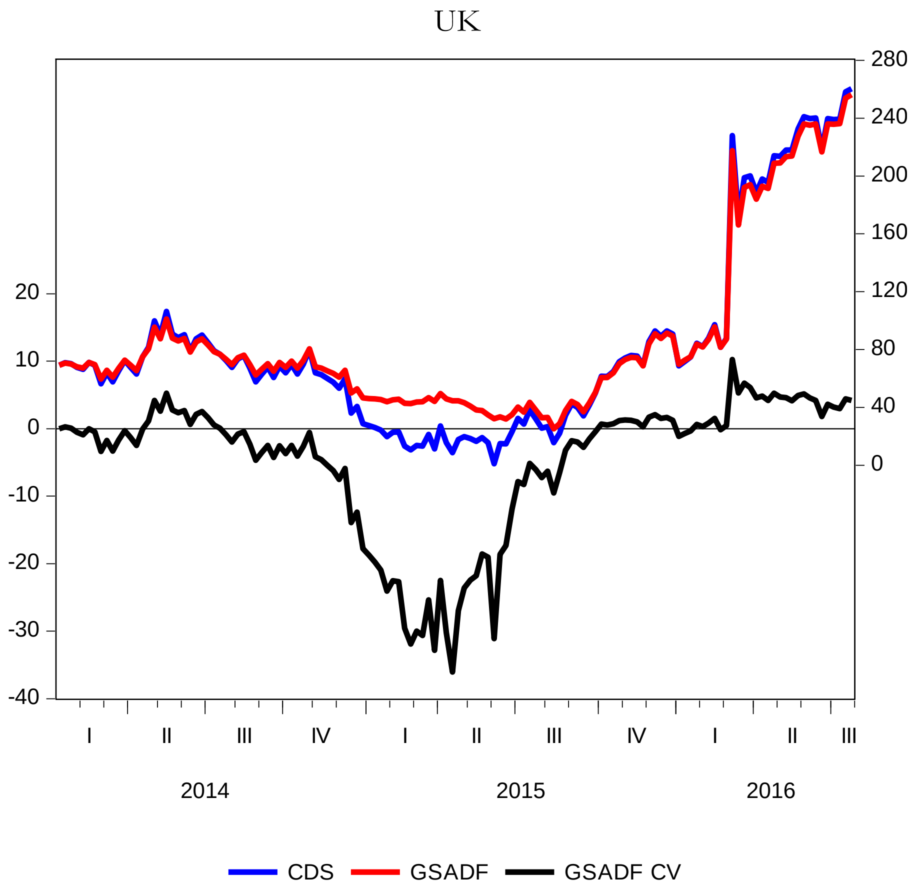
Notes: ADF, PP and KPSS are the empirical statistics of the Augmented Dickey-Fuller (1979), and the Phillips-Perron (1988) unit root tests, and the Kwiatkowski et al. (1992) stationarity test, respectively. + denotes the rejection of the null hypotheses of non-stationarity at the 1% significance.

4. Empirical results

4.1. Test of explosivity

The GSADF results are graphically dispalyed in Figure 1. Remarkably, the CDS spreads have continued to rise from January 2014 with the growing attention given to Brexit, reaching its highest level in the day relative to the announcement of Brexit (i.e., June 23rd, 2016). The Brexit event sparked the most turbulent times for bond and CDS markets, with the UK and European bonds trending widely downward (Bouoiyour and Selmi 2016). In addition, the prices of government bonds increased substantially with the deep anxiety over the UK and European economic prospects, threatening the credit rating. Indeed, the Brexit fears feed back into the financial sector by significantly impacting balance sheets of financial institutions and thereby harming banks' ratings. In fact, just a week after the Brexit, UK has been stripped of its top AAA rating. Similarly, the EU's rating was cut from AA+ to AA. Commenting on the reason for the change, the credit agency Standard & Poor's warned of the economic, fiscal and constitutional risks UK and EU' s bloc face with the Brexit vote to leave Europe. The announcement of Brexit raised the CDS spreads for all of the sampled groups of countries, especially for UK, Italy and Spain. This bubble period identified for all the markets should be interpreted with caution. The fact that the cost of purchasing protection against a default on sovereign debts jumped markedly in these markets suggest that investors and traders wary of the ability of these countries to mitigate the harmful Brexit costs and to service their debts in the face of uncertainty coupled with the global slowdown. Also remarkable is the fact that CDS spreads on the Germany and France are elevated in the day of Brexit vote but then fell, may reflect that these countries were be seen after the event as fiscally sound. However, for UK and Italy, the fact that these spreads have continued to increase or to be volatile (as is the case of Spain) does not bode well for these countries. This means that investors' concerns about dealing with the uncertainty over the Brexit costs continue to persist. In brief and based on GSADF findings, we can deduce that during times of panic where the viability of most investments are damaged, and CDS are strongly influenced, diversifying away risk across countries does not appear beneficial.

Figure 1. A detection of bubble-periods in UK and European CDS prices



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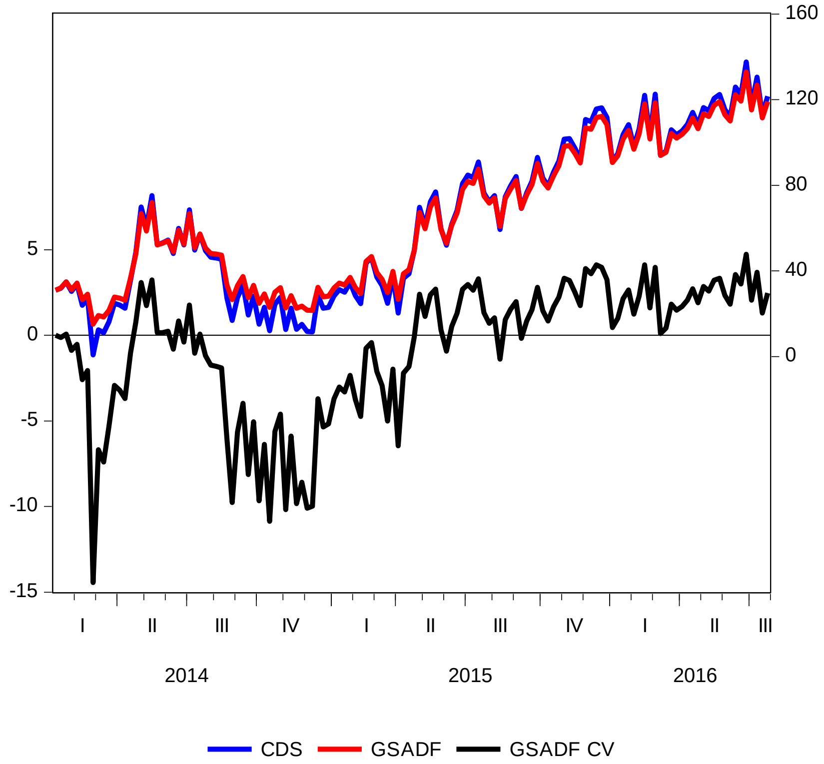
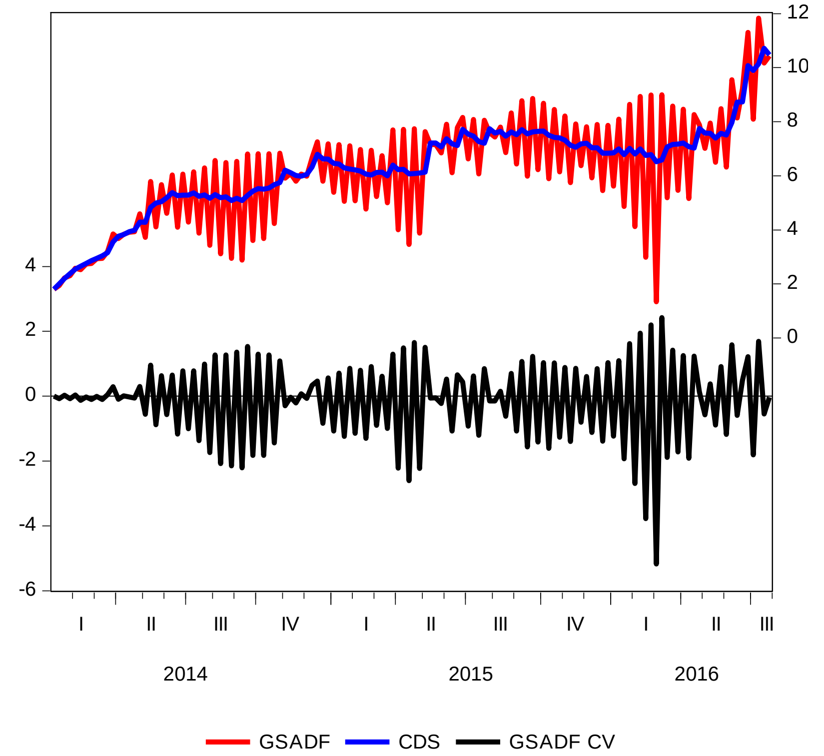
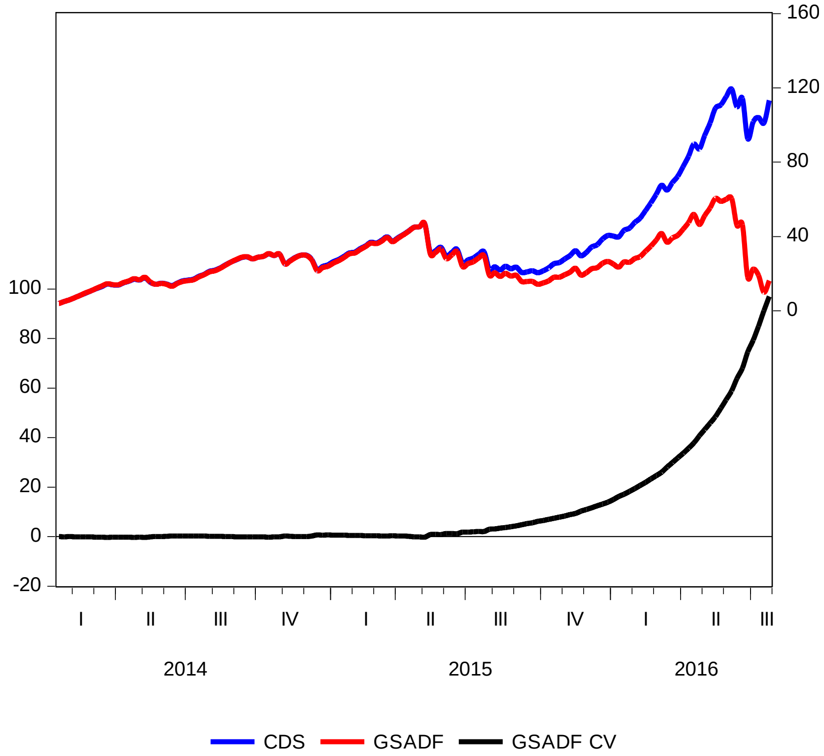


Germany



Italy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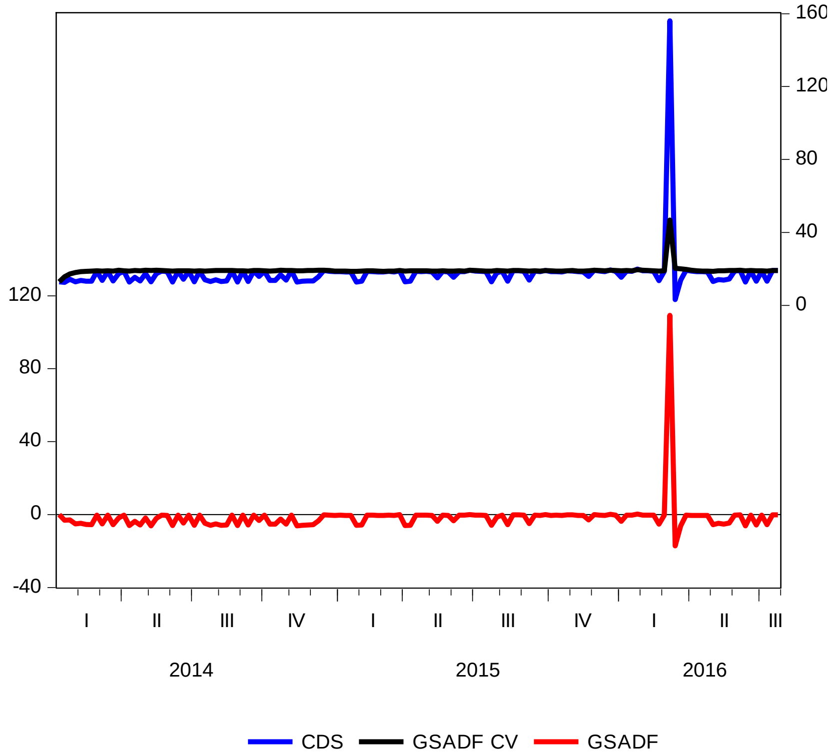
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4.2. The volatility spillovers across UK and European CDS spreads

The results derived from ARMA-FIGARCH model are reported in Table 2. A long memory process in the cyclical components is found for all the CDSs studied. In particular, the estimated fractional integrated parameters *d* are found to be positive and statistically significant. Furthermore, we clearly show that the estimated ARCH and GARCH coefficients are significant and their sums (i.e., the duration of persistence) are close or superior to one for the five considered countries. This means that the volatility of CDS for UK and the European countries over Brexit period tend towards a long memory process. Moreover, the Student parameters Cst(V) are statistically significant for all cases, implying the existence of fat tails.

Table 2. The ARMA-FIGARCH with skew t estimates

	UK	France	Germany	Italy	Spain
Cst(M) estimate	0.0034***	0.0612***	-0.0453***	-0.0289*	-0.0001
p-values	0.0000	0.0003	0.0000	0.0678	0.3415
AR(1) estimate	0.9067***	0.9743***	0.3474*	0.052**	0.1567**
p-values	0.0000	0.0000	0.0512	0.0013	0.0029
MA(1)	-0.894***	-1.000***	-0.2721	0.0513	-0.2870
p-values	0.0000	0.0000	0.5717	0.9055	0.2478
Cst(V)	1.9452***	1.4052	1.7913	1.8303	1.7923
p-values	0.0000	0.3425	0.1916	0.7023	0.5595
d-FIGARCH	0.5123***	0.4310***	0.4672**	0.4069	0.2984**
p-values	0.0000	0.0000	0.0046	0.3150	0.0037
ARCH(α)	0.1205***	0.1182***	0.2038	0.0391	0.1352
p-values	0.0000	0.0000	0.1628	0.8347	0.7470
GARCH(β)	0.8729***	0.6509*	0.6921***	0.6072	0.6990*
p-values	0.0000	0.0544	0.0000	0.5816	0.0109
Asymmetry	-0.0310	0.0098	0.0835	-0.0339	0.0869
p-values	0.2493	0.8706	0.1462	0.4693	0.1500
Tail	4.5612***	1.9863**	3.7075***	2.8375***	2.3277***
p-values	0.0000	0.0012	0.0000	0.0000	0.0000

*Note: ***, ** and * imply significance at the 1%, 5% and 10%, respectively.*

Table 3 provides an approximate "input-output" decomposition of the total volatility spillover index. In particular, based on the study of Diebold and Yilmaz (2012), we decompose the spillover index into all of the forecast error variance components for variable *i* coming from shocks to variable *j*, for all *i* and *j*. The ij^{th} entry is the estimated contribution to the forecast variance of market *i*, resulting from innovations to market *j*. The sum of variances in a row (column), excluding the contribution to its own volatilities (diagonal variances), indicates the impact on the volatilities of other CDS markets. The last row in the table is the contribution to the volatilities of all markets from this particular market. We show that for total volatility spillovers to others (128.7%) is stronger than total volatility spillovers from others (121.1%). Remarkably, UK, Italy and Spain (in this order) are the net volatility transmitters (i.e., risk spillovers to others). Specifically, these CDS markets contribute by around 46.9%, 39.8% and 27.2% of the forecast error variances, respectively, to the French and German CDSs.

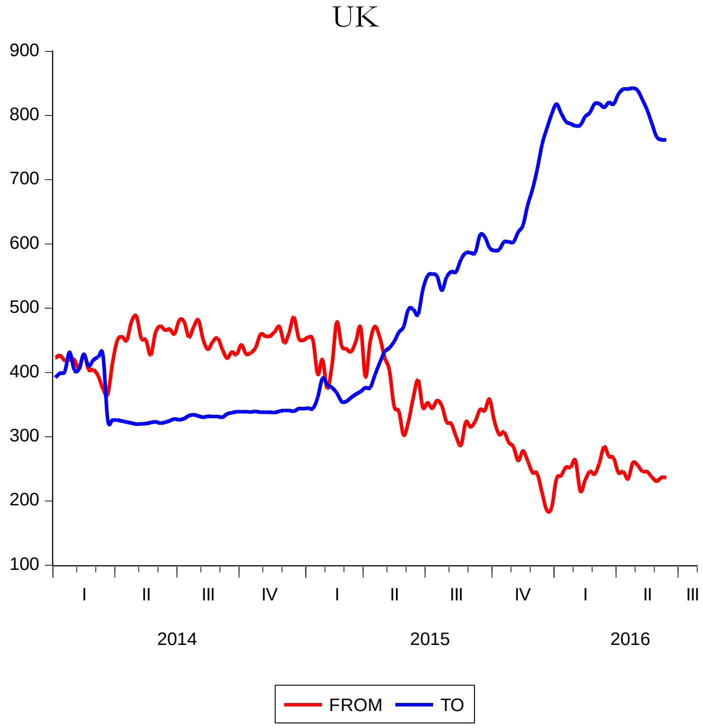
Nevertheless the volatility spillovers from others appear stronger for Germany, (51.4%) and France (45.6%).

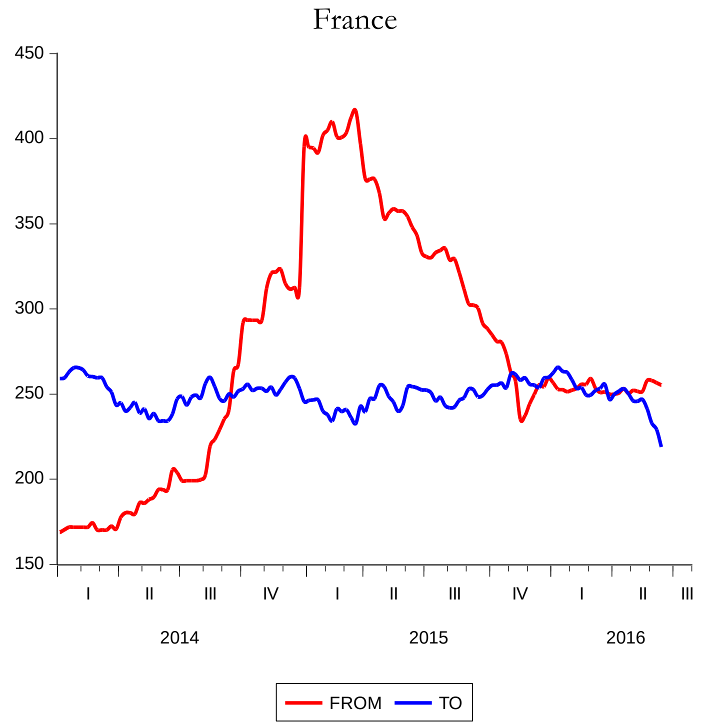
Table 3. Volatility spillover among UK and European CDS markets (in %)

	UK	**France**	**Germany**	**Italy**	**Spain**	**Contribution from others**
UK	76.3	13.1	9.6	1.9	1.3	8.2
France	0.8	59.5	1.0	0.6	0.9	45.6
Germany	0.5	1.4	69.6	0.9	1.7	51.4
Italy	4.8	10.2	3.4	72.1	2.7	6.8
Spain	2.7	9.8	5.2	2.5	76.8	9.1
Contribution to others	46.9	6.7	8.1	39.8	27.2	121.1
Contribution including own	113.2	66.2	77.7	101.9	104.0	12.1

Figure 2 outlines the directional spillovers for CDS volatility among UK, France, Germany, Italy and Spain. We note that the reactions of each CDS to shocks from other countries and the contribution of each country-specific CDS to the rest of countries seem not likely to be uniform. With spillover index fluctuating between 40% in January 2014 and 90% in June 2016 of its variance explained by the remaining CDS markets, UK seems the biggest "net volatility exporter" (with less extent Italy and Spain where the spillover indices exceed for both CDSs 25% during the period from January 2014 to mid-2015). Besides, with volatility spillovers from others ranging between 15% and 45%, Germany and France can be perceived as the main "volatility receivers".

Figure 2. The directional CDS volatility spillovers by country




France
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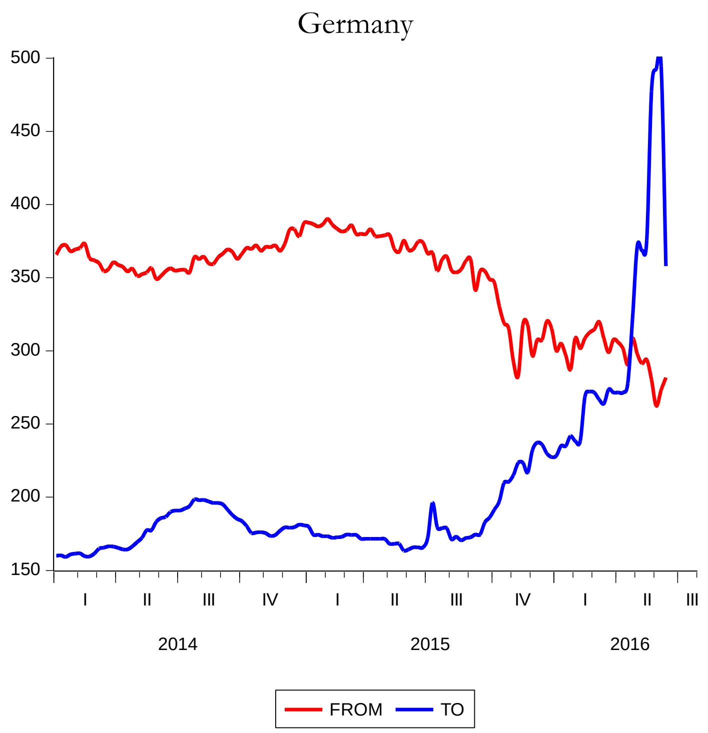
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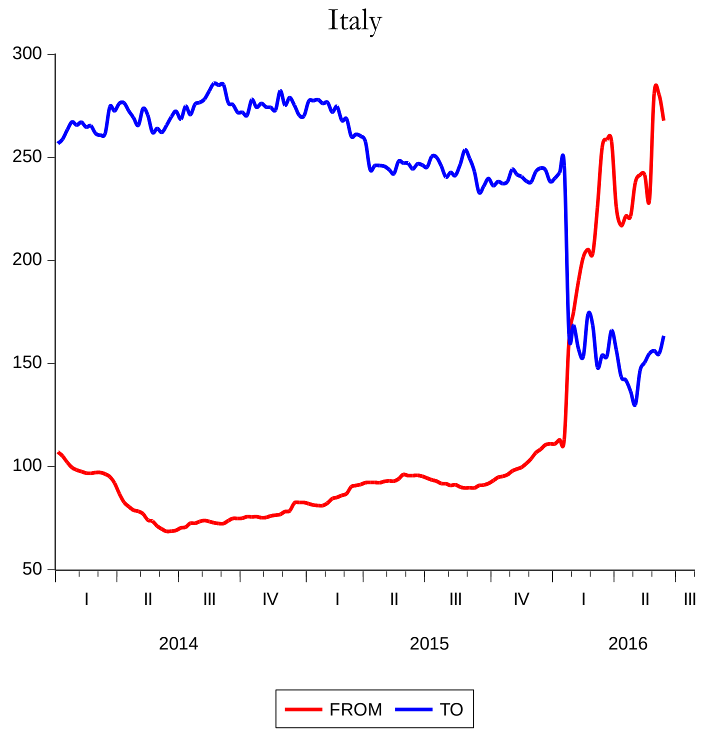
Italy
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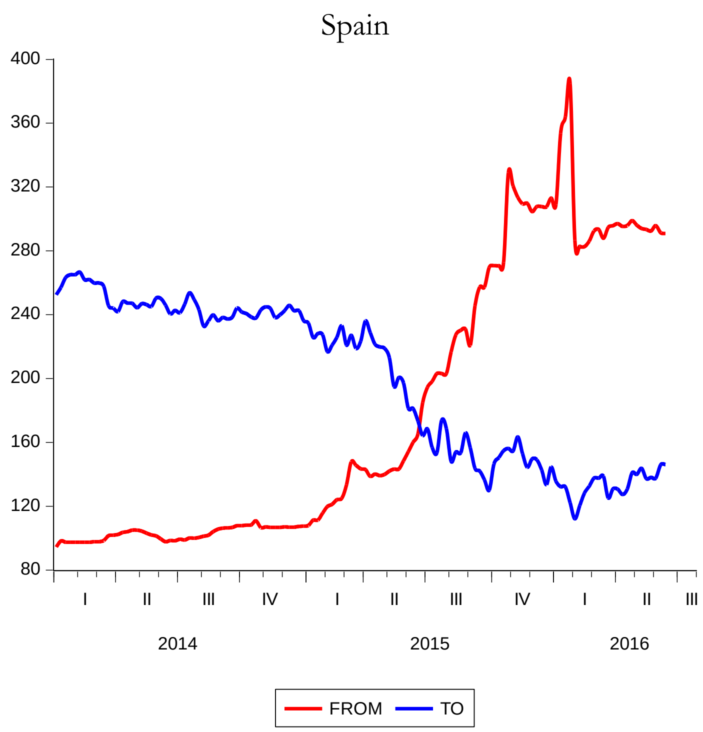
Spain
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280
240
200
160
120
80
I
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II
III
IV
I
II
III
2014
2015
2016
FROM
TO

Then, we determine the "average net directional spillovers" which is the difference between the "contribution to others" and the "contribution from others". This task permits to identify which from the investigated CDS markets seems the most influential in exporting volatilities to the other countries during the Brexit fallout. The results summarized in Table 4 confirm that with an average net directional return spillover of 38.7%, the UK CDS market appears the strongest transmitter of risk, followed by Italy (33%) and Spain (18.1%). However, the French and the German CDS spreads –with negative volatility spillover indexes (-38.9% and -43.3%, respectively) – can be viewed as "potential net receivers". These findings are of particular interest of both regulators and investors. Investors can enhance their hedging and portfolio diversification by exploiting its knowledge with respect the way the CDS risks over Brexit fears can be transmitted from one market to another. Having accurate insights about the volatility spillovers would undoubtedly be fruitful for policy makers. Providing useful information regarding the directional spillovers can help them in undertaking decoupling policies to insulate the economy from risk spillovers effects and thus mitigating future spread of crisis and preserving the stability of financial system. To lighten the risk transmission across CDS markets over Brexit, regulators can, for example, put forth preventive strategies by foregrounding the most influential volatility exporters (UK, Italy and Spain).

Table 4. The average net directional volatility spillovers by country (in %)

	Contribution from others	Contribution to others	Average net directional spillover
UK	8.2	46.9	38.7
France	45.6	6.7	-38.9
Germany	51.4	8.1	-43.3
Italy	6.8	39.8	33.0
Spain	9.1	27.2	18.1

5. Robustness check

We carried out a series of robustness checks. First, we re-examine whether bubble periods can be detected in the prices of UK and European CDS regarding their past behaviors, and then the interdependence among CDS markets by replacing the overall CDS spreads by a sector-specific CDS. As companies have many financing needs and rely profoundly on banks and financial institutions, we expect that the financial sector in the countries studied would be harmfully influenced by the Brexit event. Hence, it may be important to evaluate if the considered CDSs often exhibit sharp build-ups during the referendum vote, and whether the net volatility transmitters remain the same when using Financials-related CDS. Second, to see whether our findings seem sensitive to the sample periods, we conduct the same steps ((1) testing for explosivity, (2) measuring the CDS volatility via ARMA-FIGARCH model and (3) following the Diebold and Yilmaz (2012)'s testing procedure to determine the directional volatility spillovers) but for a different period from January 01, 2015 to July, 28 2016. The results appear fairly robust to the use of an alternative CDS proxy and to changes in time periods[3]. Using a

[3] To keep the presentation simple, detailed results are available for readers upon request.

generalized form of the sup Augmented Dickey Fuller proposed by Phillips et al. (2013), we usually detect bubble period from the end of June 2016 (i.e., post-Brexit vote). This holds for all the countries under study. Also, we often show a significant risk spillover effects across UK and EU CDS markets over the period of increased Brexit fears. Although UK, Italy and Spain are viewed as stress transmitters, France and Germany appear as net risk receivers. This outcome may be explained fact that investors in UK, Italy and Spain wary more intensely of the ability of these countries to deal with the great uncertainty over the Brexit consequences and its implications for the performance of their markets and their economies.

6. Conclusions

This paper presents the first empirical evidence on the impact of uncertainty over Brexit on UK and European (France, Germany, Italy and Spain) CDS risk spillovers. It explores the dynamic conditional volatility interdependence of the underlined CDS spreads during the period from January 01, 2014 to July 28, 2016 – marked by an increased attention to Brexit via social media. For empirical aim, the initial step consists of applying a recursive GSADF test suggested by Phillips et al. (2013). This test enables to date-stamp the temporarily collapsing bubble periods that may characterize the behavior of UK and European CDS indexes. Then and to comprehend the dynamics and strength of risk spillovers across markets, we construct a volatility spillover index using an ARMA-FIGARCH and a generalized VAR variance decomposition. Ultimately, we evaluate the net directional volatility spillovers to establish which country appears the dominant volatility transmitter. Our results reveal that the prices of CDS across UK and Europe exhibit a significant explosivity regarding their past behaviors. In addition, we show that the uncertainty surrounding the UK's EU membership referendum undermines the credit-worthiness in both UK and Europe (with less extent, France and Germany). While UK seems the most powerful "net transmitter of volatility", followed by Italy and Spain, France and Germany are likely to be "stress receivers".

It is not easier to explain these heterogeneous outcomes since CDS contracts are relatively complex instruments due to the multiplicity of parameters that constituted part of the contractual arrangement (Brunnermeier et al. 2013). These parameters include, for instance, the types of market participants (hedge funds, Banks, asset managers, Fontana and Scheicher 2010), the size of the protection premium (Arora et al. 2012), the aggregate distribution of CDS market (i.e., whether the traded industries are cyclical or defensive) and the date from which any credit event is covered by the contract (Benos et al. 2013).

But what appears intuitive is that the fears over Brexit feeds back into the financial sector by heavily influencing balance sheets of financial institutions and damaging banks' ratings. With a financial sector in distress, the governments guarantees lose credibility if creditworthiness fell, exacerbating the risk spillovers (Huang et al. 2009; De Bruyckere et al. 2012; Bouoiyour and Selmi 2016). In this way, the ability to trade credit risk in financial markets should help UK and EU regulators undertake preventive strategies to mitigate the volatility transmission from the UK and the peripheral Eurozone (Italy and Spain) to the rest of European countries. This requires an effective management of financial risks by ensuring adequate regulation, supervision, and surveillance, without ignoring the usefulness of cooperation and coordination across many regulatory levels (Caffagi and Miller 2013).This article' findings seem highly relevant for practical applications. In fact, the market participants could evaluate hedging against the impact of future credit rating announcements in one country to the event bordering countries. This information may be of paramount importance for the construction of portfolios sensitive to sovereign credit risk. Moreover, given the growing importance of the CDS market, which is perceived as a good indicator of credit risk, these results may also be helpful for policymakers when formulating new capital adequacy frameworks for individual countries and portfolios in sovereign credit risk markets.

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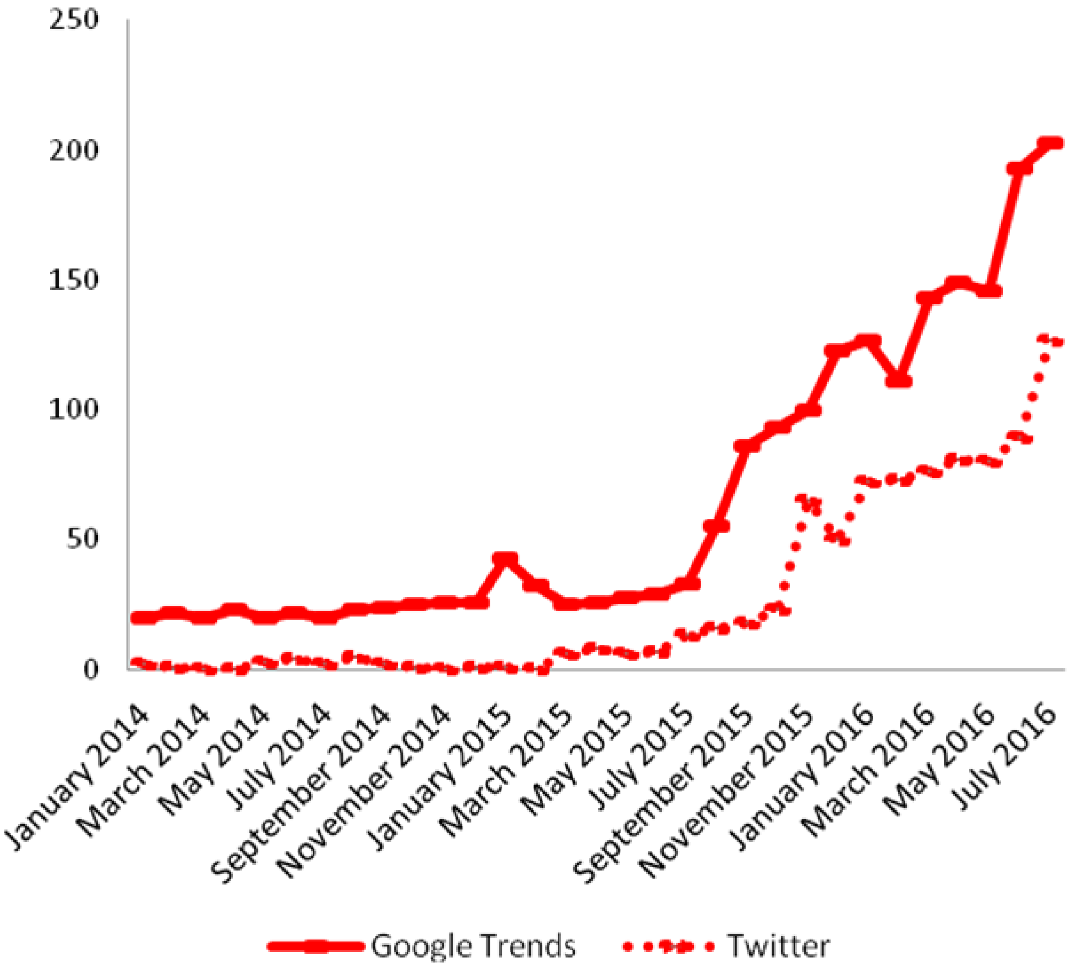
Appendices

Figure A. The attention to "Brexit" via Google Trends and Twitter from January 2014 to July 2016



Source: The search queries index for keyword "Brexit" has been retrieved from Google Trends (http://www.google.com/trends/). Note that in twitter, #Brexit was associated with the British exit; only Hashtags (#) were available in twitter.