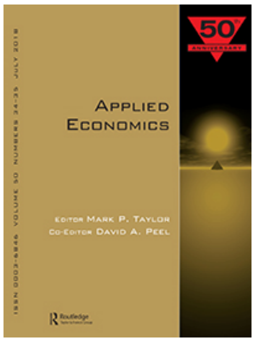

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Policy uncertainty and international financial markets: the case of Brexit

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ABSTRACT

This study assesses the impact of the Brexit probability on both the UK and on international financial markets, for the first and the second statistical moments. As financial markets are by nature highly interlinked, one might expect that the uncertainty engendered by Brexit also has an impact on financial markets in several other countries. We first estimate the time-varying interactions between UK policy uncertainty, which to a large extent is attributed to uncertainty about Brexit and UK financial market volatilities. Second, we use two other measures of the perceived probability of Brexit before the referendum, namely daily data released by Betfair and results of polls published by Bloomberg. Based on these data sets, and using both panel and single-country SUR estimation methods, we analyse the Brexit effect on levels of stock returns, sovereign CDS, 10-year interest rates in 19 predominantly European countries, and those of the British pound and the euro. We show that Brexit-induced policy uncertainty will continue to cause instability in key financial markets and has the potential to damage the real economy in both the UK and other European countries. The main losers outside the UK are the 'GIIPS' economies: Greece, Ireland, Italy, Portugal and Spain.

KEYWORDS
Brexit; causality tests; financial instability; uncertainty; spillovers

JEL CLASSIFICATION
E44; F36; G15

I. Introduction

The majority of the British citizens have decided that the UK should leave the European Union (EU) in the near future. Quite apart from the consequences for the UK, this can be seen as a political disaster for the EU, as for the first time ever, a member state is actually going to leave. Numerous institutions, academics and politicians have warned of negative economic effects for both the UK and Europe, arguing that Britain's departure will generate a 'lose–lose' situation.[1]

As Brexit can be regarded as the most significant political issue in the first half of 2016, poll updates, as well as the actual result on 24 June, greatly affected international financial markets (European Commission 2016). By analysing the impact of Brexit on financial markets, we might get insights about market's expectations about the magnitude of the economic impact beyond the UK and which country beyond the UK may be mostly affected.

In our view, the topic is too complex to just check for trade and financial linkages in order to determine the most affected countries partly because the institutional framework of the EU and the Euro area has generated additional dependencies between countries. According to the dividend discount model (Gordon and Shapiro 1956), *expectations about future effects* on the real economy generated by Brexit will immediately affect stock returns and several other financial market variables. We, therefore, give a short overview of the possible effects of enduring Brexit uncertainty on the real economy of the UK and other countries, particularly the remaining EU countries. Of course, any increase in policy uncertainty itself can be expected to affect financial markets as well. Among others, this kind of uncertainty typically leads to option value effects, i.e. a 'wait-and-see attitude' towards investment-type decisions.

In the empirical part of the article, we will contribute to the literature on policy uncertainty effects in the following ways. First, we will analyse the magnitude and direction of policy uncertainty spillovers onto financial volatility (second statistical moment) in the UK itself. The chosen empirical approach based on Hafner and

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[1]For a survey of the related arguments, see, for instance, London School of Economics (2016).

Herwartz (2008) and Diebold and Yilmaz (2009; 2012) allows us to investigate effects of policy uncertainty taking into account the non-trivial interlinkages within financial markets and possible time-varying structure of the underlying relationships. Our second research question is whether we can expect contagion from the UK to other countries. For this purpose, we empirically check for spillovers of Brexit uncertainty to a variety of asset classes on international financial markets. Employing both panel and single-country SUR estimation methods as well as exploiting two other measures of the perceived probability of a Brexit vote, namely daily data released by Betfair and (aggregated) results of polls published by Bloomberg, we provide further insights into the international effects induced by the Brexit referendum outcome's uncertainty.

The remainder of this article is organized as follows. The next section provides a brief overview of the possible effects of enduring Brexit uncertainty on the UK and other countries' real economy. In Section III, we investigate the effect of Brexit on the UK's financial market volatilities. In Section IV, we empirically assess the impact of Brexit on international financial markets and a variety of asset categories. Section V finally concludes.

II. Potential effects of enduring Brexit uncertainty on the UK's and other countries' real economy

Leaving the EU can be expected to have large implications for the British economy through the following channels: trade in goods and services, investment, immigration, productivity and fiscal costs.[2] As Brexit is a political novelty, it is difficult to estimate the effect of each channel as well as the overall impact on the British economy. Uncertainty around the effects is further increased by the fact that the British government and the EU will have to completely re-evaluate the political and economic relationship. Furthermore, the British government will have to make significant political decisions, e.g. regarding prudential and regulatory laws.

As a starting point of our empirical study, it is important to note that, except for a weaker pound and lower UK interest rates, the referendum has not caused much of an enduring impact (Gros 2016). One may argue that '(t)he United Kingdom's vote to "Brexit" the EU is of course to become the year's biggest non-event' (Gros 2016). But how to explain the current lack of impact? It may just be because Brexit has not yet happened (Begg 2016). Hence, a big economic impact of Brexit can still not be excluded for the future. Furthermore, initial CEIC Data for July 2016 already indicated that business and consumer confidence has declined by about 4% and 12%, respectively.

Regarding the trade channel, the most important aspect is that the UK will most probably lose its access to the European Single Market. Apart from an absence of tariffs, the single market guarantees the principle of mutual recognition and the so-called single passport (EC, 2016). The financial sector of the UK[3] would lose significantly if it could no longer generate access to the European Single Market.

The effects will crucially depend on the results of the negotiations between the UK and EU about the future economic (and political) relationship. If the UK keeps its access to the single market, the effects via trade might be small.[4] However, in the worst scenario, trade relationships default to the WTO framework (Blockmans and Emerson 2016). In that event, it appears to be highly probable that trading linkages between the UK and the EU will be weakened or even disrupted, generating decreases in UK incomes from export.[5] Whether the UK might be able to offset the decrease in trade with the EU and corresponding national income by focusing its trade ambitions on other (faster growing) markets remains questionable.

Moreover, it appears reasonable to assume that the amount of Foreign Direct Investment (FDI) coming from the EU will be adversely affected since a strong link between EU membership and inward FDI has

[2]In the following, we do not discuss the various arguments surrounding immigration and fiscal costs. For a broad survey on the potential economic impacts of Brexit, see International Monetary Fund (2016).

[3]The UK is the world leader in fixed-income and derivatives transactions and far ahead of EU peers in private equity, hedge funds and cross-border bank lending (Bank of England 2016). The UK's insurance industry is the largest in Europe and the third largest in the world.

[4]An alternative might be the Norwegian model (EEA) or the Swiss model.

[5]This view is backed by empirical results underscoring that the reduction in trade barriers due to EU membership has increased UK incomes (Crafts 2016; Campos, Coricelli, and Moretti 2014).

been documented by several studies (Barrett et al. 2015; Fournier et al. 2015; Bruno et al. 2016; Dhingra, Ottaviano, and Sampson 2015; McGrattan and Waddle 2017). Furthermore, FDI from outside the EU might decrease as well, as the UK can no longer provide a gateway to the single market.

Critics of the EU argue that many regulations imposed by EU institution are costly, inflexible and are limiting business opportunities for companies. OpenEurope (2015) argue that benefits from deregulation might compensate trade losses. However, according to OECD, the UK ranks at a level with the United States with regard to product market liberalization. Labour market flexibility is relatively high – especially compared with European countries like France and Germany. Therefore, it appears questionable whether this limited potential of deregulation will boost productivity enough to offset trade losses.[6]

Figure 1 represents a survey of studies which attempt to quantify the long- and short-term effects for 2018 in the case of Brexit. While some studies even indicate positive (long-term) effects, the majority of studies predict large negative short- and long-term effects.

It has already been shown in the literature that during crises and particular political events, financial market volatility generally increases sharply and spills over across markets. Thus, Brexit uncertainty and the consequent decision to leave the EU might not only directly influence stock and exchange markets but might also be a trigger for increased spillovers across them. Financial instabilities, such as an increase in FX volatilities, pose further potential adverse effects for the economy, implying that firms will postpone new investments and hiring decisions into the future benefiting from the so-called option value of waiting (Belke and Gros 2002). Given the important nexus between financial volatility and output, investment and consumption described above, we will estimate the Brexit uncertainty effects on the UK financial markets' volatilities in Section III.

The potential effects of Brexit are of course not limited to the UK. Obviously, there is a large potential of spillover especially for the other EU countries via trade and financial linkages. According to a vast majority of papers, other countries are likely to lose economically. Based on trade linkages, Ireland, The Netherlands and Belgium are primarily exposed. Regarding banking linkages, the Irish, Dutch, Swedish and German banking sectors are highly connected with the British. Based on capital market linkages (FDI and portfolio investment), Ireland, The Netherlands, Luxembourg and France are mostly exposed.

Apart from direct economic linkages, Brexit might also generate political and institutional uncertainty about the EU. This might damage the reputation of the EU as a sustainable and irrevocable institution decreasing its political power, influence and ability to negotiate new supranational contracts like Free Trade Agreements (FTA)s. Political uncertainty may spread across Europe especially affecting countries whose

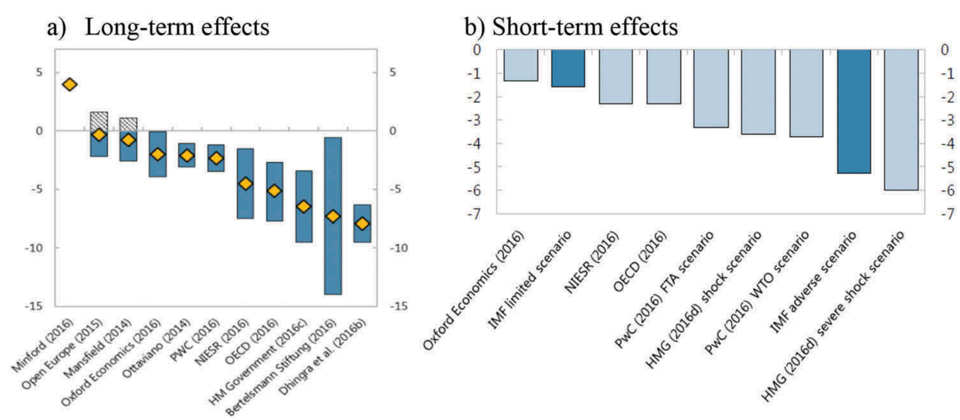

Figure 1. Economic effects of Brexit on the UK GDP.
Source: IMF (2016).
Deviation from baseline, which assumes that the UK remains in the EU. Short-run values for 2018. The long-term effects are the accumulated effects on GDP (time horizon depends on the individual study, roughly 5 years).

[6]LSE (2016) concludes that the UK is already deregulated and a more skilled workforce and a better infrastructure are more potent sources of further productivity enhancements.

sovereign solvency is heavily linked with the existence of the EU and the Euro area – namely Spain, Portugal, Italy and Greece. Furthermore, these countries are still struggling to reach a moderate level of growth and still have troubles in its banking sectors, especially Italy. Therefore, existing trade and financial linkages might deliver an incomplete picture about the (relative) magnitude of country-specific spillover effects.[7]

Since the Brexit referendum was held just in the recent past, the first assessments of the Brexit were dedicated to the financial markets' effects. Raddant (2016) analyses financial data of the UK, Germany, France, Spain and Italy. In contrast to our study, he focuses more on the immediate impact after the referendum and shows that stock markets fell after Brexit having similar effects across Europe. The second relevant study for our research is the short paper by Krause, Noth and Tonzer (2016). They argue that the referendum in the UK created a high degree of uncertainty and this could also be seen in financial markets in the run-up to the referendum. According to their empirical investigation, poll results pointing towards Brexit produced short-term declines in returns of bank indices and strong depreciation of the UK Sterling. However, the results of Krause, Noth and Tonzer (2016) cannot be compared in quantitative terms with ours due to differences in the variables measuring the Brexit probability. They employ a pure dummy variable using poll results from 'whatukthinks.org' amounting to 0 if the probability falls below 50% and 1 otherwise. In our view, this risks being a too crude measure for the likelihood of Brexit. A general critique against measuring Brexit effects using poll results is presented by Gerlach (2016). He argues that poll data do not contribute much to the explanation of financial market developments. Therefore, we utilize more sophistic measures by using the probability of Brexit based on data from betting agencies. The third, again less comprehensive, study comparable to ours is Gerlach and Di Giamberardino (2016). They exploit bookmakers' odds of Brexit and come up with the result that the outcome of the UK's referendum could have a significant effect on the Pound Sterling. We use an almost identical approach but do not restrict our estimations on the effects on exchange rates.

III. Brexit and its effect on UK financial market volatilities

Data

In this section, we estimate the magnitude and the sign of short-run Brexit effects which are related to an environment of increased policy uncertainty during the time preceding the referendum and directly after Brexit vote on UK financial markets. Our focus here is on financial market's volatilities (second statistical moments) rather than returns (first statistical moment).

As a measure of uncertainty, we employ the Economic Policy Uncertainty index (EPU) developed by Baker et al. (2015)[8] for the UK. Policy-driven uncertainty is shown to raise during political turmoil, as well as during the implementation of major policies and programmes, and reflects the level of doubt and confusion in the private sector caused by government policies. According to its definition, using the EPU index should be a good proxy for the estimations of Brexit uncertainty and Brexit-vote effects. The other index provided by the same source – the Brexit Uncertainty index – is calculated by multiplying the EPU index by the share of EPU articles that contain 'Brexit' and 'EU' and is available until May 2016. Figure 2 shows that the both EPU and Brexit uncertainty indices hovered at their highest points close to referendum.

In our empirical estimations, we will use the EPU index instead of Brexit uncertainty for two reasons. First, the EPU index is highly correlated with the Brexit uncertainty index during the time preceding the referendum. In contrast to Brexit uncertainty index, EPU data are also available for the after-referendum time and, thus, allow us to estimate the effects of the uncertainty triggered by the Brexit vote. Second, since financial markets are very flexible and able to react to news immediately, using daily

[7]Gros (2016), however, puts the assessment of the literature reviewed in Section II into perspective and states: '(b)eyond a weaker pound and lower UK interest rates, the referendum has not had much of a lasting impact. Financial markets wobbled for a few weeks after the referendum, but have since recovered. Consumer spending remains unmoved'. While it is true that consumer spending stayed rather untouched, we report in this section that business and consumer confidence went down. See also our remarks in Section IV.

[8]See http://www.policyuncertainty.com/index.html.

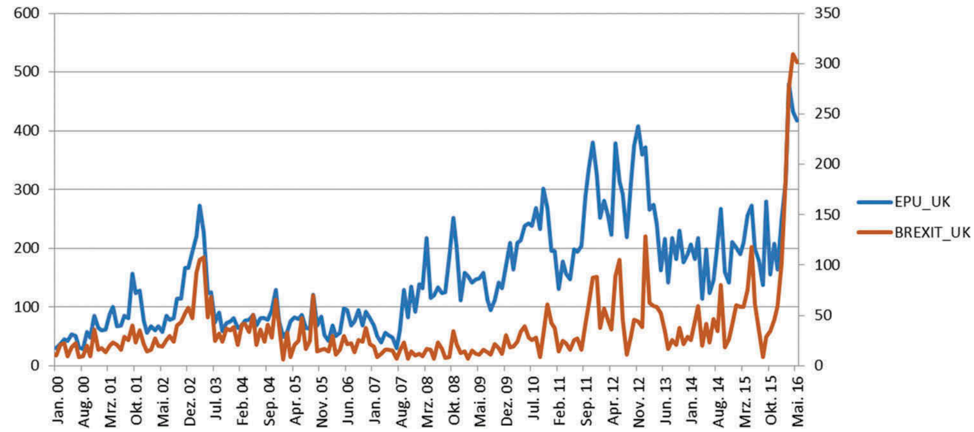

Figure 2. UK economic policy uncertainty and Brexit uncertainty.

EPU data could be beneficial comparing to Brexit uncertainty data which is only available monthly.S

Our model includes the following variables:

- Daily stock market volatility[9] calculated as the annualized daily per cent SD of daily high and low FTSE 250 prices[10]:

$$FTSE250v_t = 100\sqrt{365 \times 0.361 \times \left[ln\left(FTSE250_t^{high}\right) - ln\left(FTSE250_t^{low}\right)\right]^2}$$

- Daily volatility of the British Pound calculated as the annualized daily per cent SD of intraday high and low exchange rate GBP/USD:

$$FXv_t = 100\sqrt{365 \times 0.361 \times \left[ln\left(FX_t^{high}\right) - ln\left(FX_t^{low}\right)\right]^2}$$

- Daily EPU index[11] constructed by Baker et al. (2015).

Additionally, in order to disentangle domestic policy uncertainty from global uncertainty, we have included the CBOE Volatility Index (VIX Index)[12] as an exogenous variable.

The sample contains 4105 observations, from 01 January 2001 to 23 September 2016; all variables are taken in logs and plotted in Figure 3.

In Figure 3, we observe that both stock prices and exchange rate went through a major period of volatility during the global financial crisis. Stock prices have also experienced an increased amount of volatility around August 2011, which could be explained by the effects of the euro crisis (Gros 2011). Moreover, there is a considerable upward spike at the time of the referendum (23 June 2016 marked as a vertical line) for all variables under consideration as magnitudes reach levels comparable to previous maxima.

Estimation approach

In order to estimate the effect of policy uncertainty on volatility in financial markets, we will use the empirical approach proposed by Diebold and Yilmaz (2009; 2012) based on VAR variance decompositions.[13]

First, we estimate the VAR(p) model:

$$x_t = \sum_{i=1}^{p} \Phi_i x_{t-i} + \varepsilon_t, \quad (1)$$

[9]For more details about the construction of daily volatilities, please refer to Alizadeh, Brandt, and Diebold (2002).

[10]We have decided to consider FTSE 250 prices instead of FTSE 100 since the first might be a better gauge of domestically oriented share prices than the FTSE 100 which is dominated by multinationals of which some have little exposure to the UK economy (Sheffield 2016).

[11]In cases when the index was equal to 0, we have replaced it with the value from the previous day.

[12]Empirical realizations of the VIX index, intraday high and low values of FTSE250 and the GBP/USD exchange rate are obtained from the Datastream database.

[13]Alternatively, Hafner and Herwartz (2006b) propose a concept of impulse response functions tracing the effects of independent shocks on volatility and then consider the effect of historical shocks, such as 'Black Wednesday' and an announcement by the European Community finance ministers on 2 August 1993, on the foreign exchange market. However, we believe that the identification of a 'Brexit shock' is not trivial and should not be constrained only to the day of the announcement of the referendum results but should include the days preceding the referendum as well. Moreover, the approach taken in our article allows us to take into account the time-varying volatility of multivariate financial time series.

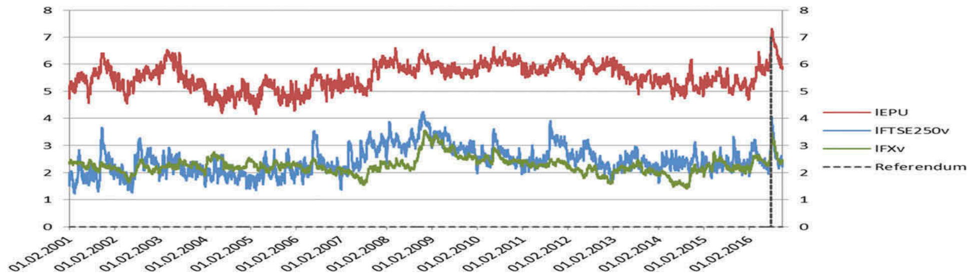

Figure 3. Financial volatilities and EPU index, logs.

where $\varepsilon \in (0, \Sigma)$ is the i.i.d. errors vector.

The moving average representation, thus, could be written as

$$x_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i}, \qquad (2)$$

where $A_i = \sum_{k=1}^{p} \Phi_k A_{i-k}$, A_0 is the identity matrix $I_{N\times N}$ and $A_i = 0$ for $i < 0$.

Our further analysis relies on variance decompositions which allow assessing the fraction of the H-step-ahead error variance in forecasting x_i that is due to shocks to x_j. In order to deal with contemporaneous correlations of VAR shocks, we use the generalized VAR framework, which produces variance decompositions which are invariant to the choice of ordering.

The H-step-ahead forecast error variance decomposition is calculated as

$$\theta_{ij}^{g}(H) = \frac{\sigma_{ii}^{-1} \sum_{h=0}^{H-1} \left(e_i' A_h e_j\right)^2}{\sum_{h=0}^{H-1} \left(e_i' A_h \Sigma A_h e_i\right)}, \qquad (3)$$

where Σ is the variance matrix for the errors ε, σ_{ii} is the SD of the error term for the ith equation of VAR and e_i is a vector which contains one as ith element and zeros otherwise.

The *total volatility spillover index* is then constructed as

$$S^{g}(H) = \frac{\sum_{i,j=1, i\neq j}^{N} \tilde{\theta}_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{ij}^{g}(H)} \times 100, \qquad (4)$$

where $\tilde{\theta}_{ij}^{g}(H)$ is normalized value for $\theta_{ij}^{g}(H)$ so that $\tilde{\theta}_{ij}^{g}(H) = \frac{\theta_{ij}^{g}(H)}{\sum_{j=1}^{N} \theta_{ij}^{g}(H)}$. The total spillover index, thus, measures the contribution of spillovers of shocks across variables under consideration to the total forecast error variance.

In order to investigate the direction of spillovers across financial volatilities and policy uncertainty, i.e. the portion of the total spillover that comes from x_i to all other variables, *the directional spillover* is applied:

$$S_{i}^{g}(H) = \frac{\sum_{j=1, j\neq i}^{N} \tilde{\theta}_{ji}^{g}(H)}{\sum_{j=1}^{N} \tilde{\theta}_{ji}^{g}(H)} \times 100 \qquad (5)$$

The net spillover from variable i to all other variables j is obtained as the difference between gross shocks transmitted to and gross shocks received from all other markets:

$$S_{i}^{g}(H) = \left(\frac{\sum_{j=1, j\neq i}^{N} \tilde{\theta}_{ji}^{g}(H)}{\sum_{j=1}^{N} \tilde{\theta}_{ji}^{g}(H)} - \frac{\sum_{j=1, j\neq i}^{N} \tilde{\theta}_{ij}^{g}(H)}{\sum_{j=1}^{N} \tilde{\theta}_{ij}^{g}(H)} \right) \times 100 \qquad (6)$$

The last spillover measure of interest is *the net pairwise spillover* index between variables x_i and x_j which is defined as the difference between gross shocks transmitted from x_i to x_j and gross shocks transmitted from x_j to x_i:

$$S_{i}^{g}(H) = \left(\frac{\tilde{\theta}_{ij}^{g}(H)}{\sum_{k=1}^{N} \tilde{\theta}_{ik}^{g}(H)} - \frac{\tilde{\theta}_{ji}^{g}(H)}{\sum_{k=1}^{N} \tilde{\theta}_{jk}^{g}(H)} \right) \times 100 \qquad (7)$$

The approach allows us to investigate the dynamics of spillovers in form of rolling regressions and, thus, the time variations of total, directional, net and net-pairwise spillovers in the periods before and after the Brexit referendum, which are of particular interest of this study.

The generalized impulse responses are significant and display the expected signs[14] (Figure 4).

According to the Granger causality test whose results are presented in Table 1, policy uncertainty indeed Granger-causes stock and exchange rate volatilities. In the recent empirical literature, a number of new causality-in-variance tests have been developed, for instance, a Portmanteau test of Cheung and Ng (1996), a Lagrange Multiplier Test of Hafner and Herwartz (2006a) and a Wald test of Hafner and Herwartz (2008). Based on Monte Carlo investigations, the latter two methodologies are shown to be preferable for applied work (Hafner and Herwartz 2006a; Hafner and Herwartz 2008). In this study, we perform a causality test based on Quasi maximum likelihood methods proposed by Hafner and Herwartz (2008). The approach relies on multivariate GARCH estimations and consequent Wald testing of appropriate coefficients' set. Our test results (see Table 1) indicate some evidence of bi-directional causality between the policy uncertainty and financial volatilities which mean that not only policy uncertainty affects financial markets, but also financial volatility adds to uncertainty about policy measures to support the economy and thereby mitigate downside risks.

Estimation results

According to Table 2, policy uncertainty shocks contributed 4.1% (3rd column, first row) and 3.2% (3rd column, second row) to the variance decompositions

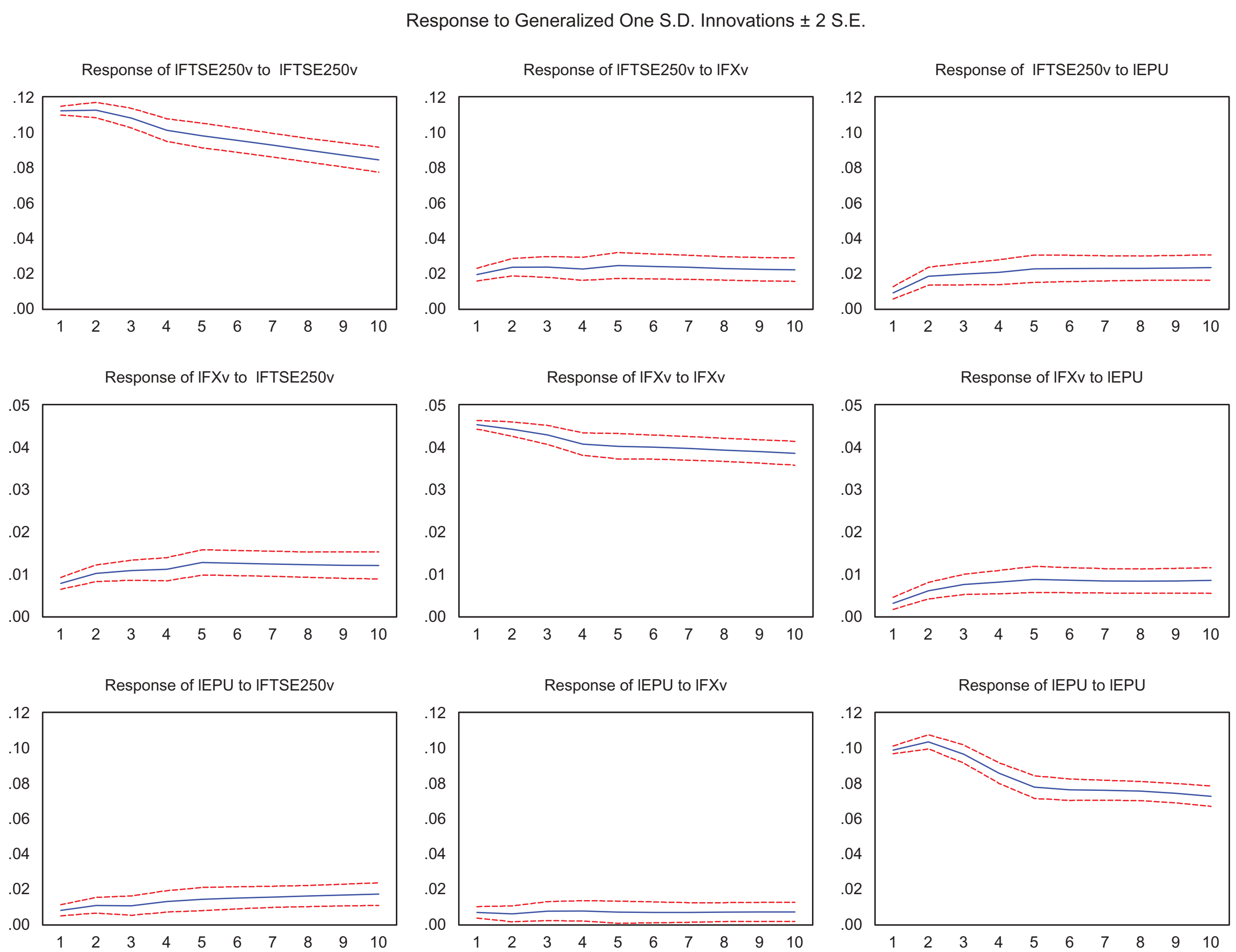

Figure 4. Generalized impulse responses functions, full-sample estimations.

[14]VAR specification tests are plausible and available upon request. Different Cholesky orderings do not change the signs and the significance of the impulse responses.

Table 1. Causality tests.

VAR Granger Causality/Block Exogeneity Wald Tests											
Dependent variable: lFTSE250v				Dependent variable: lFXv				Dependent variable: lEPU			
Excluded	*Chi-sq.*	*df*	*Prob.*	*Excluded*	*Chi-sq.*	*df*	*Prob.*	*Excluded*	*Chi-sq.*	*df*	*Prob.*
lFXv	8.04	5	0.15	lFTSE250v	19.43	5	0.00	lFTSE250v	16.57	5	0.01
lEPU	37.31	5	0.00	lEPU	22.66	5	0.00	lFXv	3.13	5	0.68
All	*47.91*	*10*	*0.00*	*All*	*48.33*	*10*	*0.00*	*All*	*20.28*	*10*	*0.03*

Variance causality test based on Hafner and Herwartz (2008)

MV-GARCH, BEKK – Estimation by BFGS
1. Test for causality of EPU to FTSE250, FX
Chi-squared(4) = 46.35 or $F(4,*)$ = 11.59 with significance level 0.000
2. Test for causality of FTSE250, FX to EPU
Chi-squared(4) = 86.39 or $F(4,*)$ = 21.60 with significance level 0.000

Table 2. Full-sample spillover table.

	lFTSE250v	*lFXv*	*lEPU*	*From others*
lFTSE250v	91.0	4.9	4.1	*9.0*
lFXv	7.0	89.8	3.2	*10.2*
lEPU	2.6	0.6	96.7	*3.3*
Contribution to others	*9.7*	*5.5*	*7.3*	*22.5*
Contribution including own	*100.7*	*95.3*	*104*	*7.5%*

The *ij*th element of the table represents the estimated contribution to the forecast error variance of x_i coming from innovations to x_j.

of stock market and exchange rate volatilities, respectively, and itself was mostly affected by stock volatilities (2.63%), whereas the FX market does not seem to significantly induce policy uncertainty, since its contribution to the forecast error variance is only 0.64%. The total spillover index for all variables is thus equal to 7.5%. However, this value should be taken with caution, since the estimation was performed employing data for the full sample. Thus, the spillover index is only the average measure of spillovers in the period from January 2001 to September 2016. In order to assess the extent and nature of the *spillovers variation over time*, we continue with the rolling estimations.

Our rolling estimations[15] for total spillovers between stock volatility, FX volatility and policy uncertainty (see Figure 5) show an increase in spillovers during the period from the end of 2008 till the end of 2012 which could be attributed to the subprime-mortgage crisis, global financial crisis and sovereign debt crisis. But the consequent huge rise of the spillover index directly after Brexit referendum has exceeded all historical maxima.

In Figure 6, we observe that the spike of total spillover index at the end of our sample is indeed due to increased spillovers *from policy uncertainty to financial market volatilities*.

According to our results in Figure 7, starting in May 2004, the index of net spillovers from EPU to financial volatilities has a positive value apart from some minor exceptions. This means that since 2004, policy uncertainty has been a net shock contributor for financial market volatilities, or in other words, policy uncertainty shocks have influenced financial markets to a larger extent than it was affected by financial market volatility shocks itself. However, the value of the net spillover index changed dramatically after the Brexit vote and increased from 9% to 26% and remains dominant until the end of our sample.

Our final empirical exercise in this section is to look at the pairwise net spillovers. According to Figure 8, stock prices volatility was a net receiver of policy uncertainty shocks starting in February 2016 – the month, when the Brexit referendum was announced. Figure 9 provides the net spillovers between exchange rate volatility and EPU. Starting in May 2006, policy uncertainty shocks dominate in net terms apart from some exceptions. Similar to the net spillovers between stock volatility and EPU, the Brexit referendum resulted in an increase in net spillovers between FX volatility and policy uncertainty. From the net spillovers between stock and FX volatilities presented in Figure 10,[16] we observe that the time right before and after the Brexit vote does not exhibit any extraordinary patterns in the relationship between financial volatilities.

To conclude this section, we feel legitimized to state that the substantial role of policy uncertainty on financial market volatilities. Policy uncertainty after 23 June 2016 induced huge spillovers to financial markets which exceeded all previous historical

[15]For the rolling estimations, we have set a rolling window of 500 working days and a forecast horizon of 10 working days. As robustness check, we performed estimations with different lag length, rolling windows and forecast horizons – the results remain and are available upon request.
[16]For an overview of existing studies dealing with the interlinkages between stock prices and exchange rates, refer to Caporale, Hunter and Menla Ali (2014).

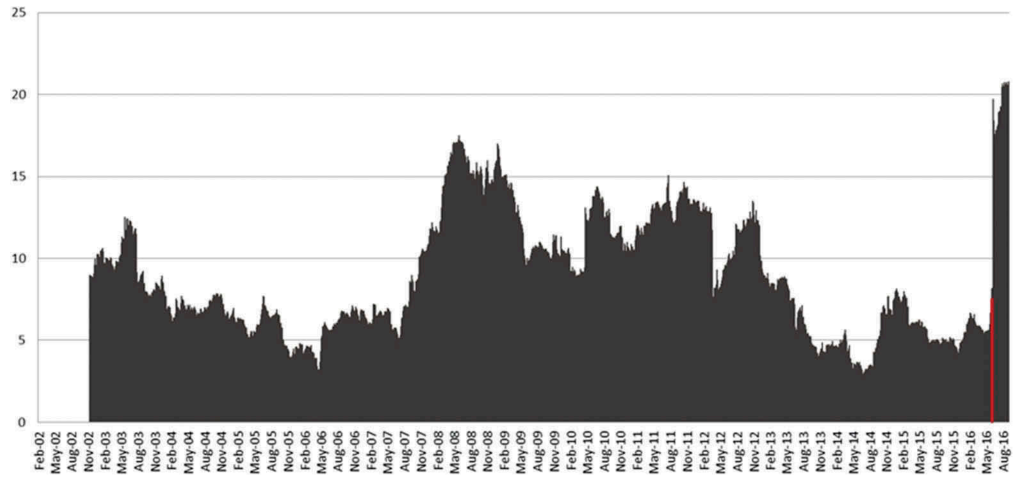

Figure 5. Total spillover index.

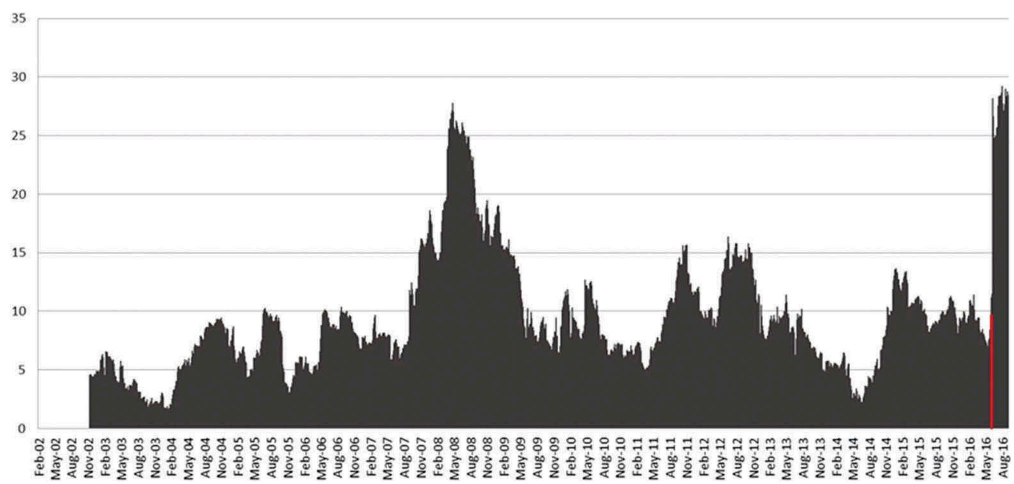

Figure 6. Directional spillovers from EPU to financial volatilities.

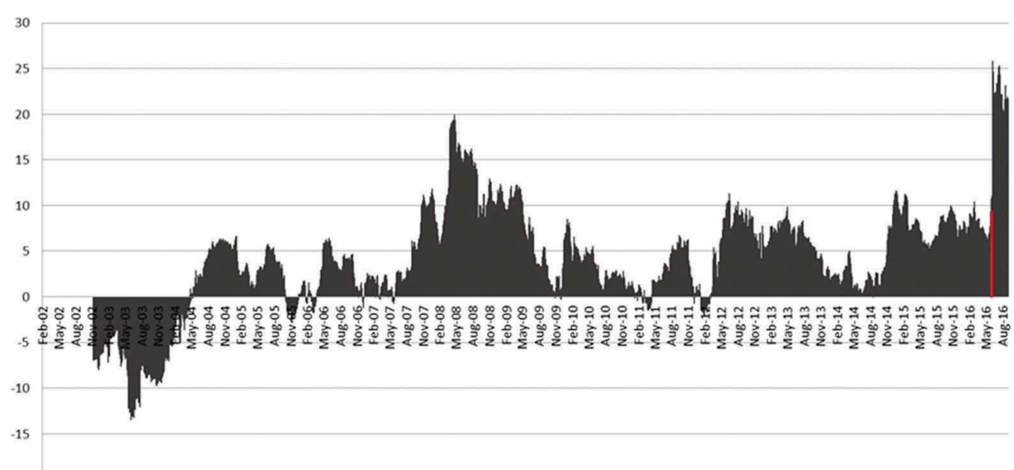

Figure 7. Net spillovers from EPU to financial volatilities.

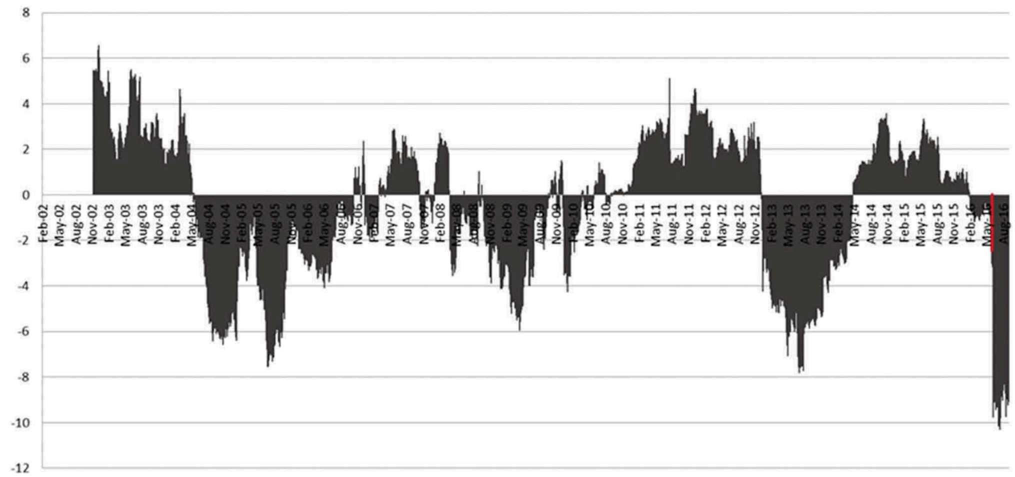

Figure 8. Net pairwise spillovers between stock volatility and EPU.

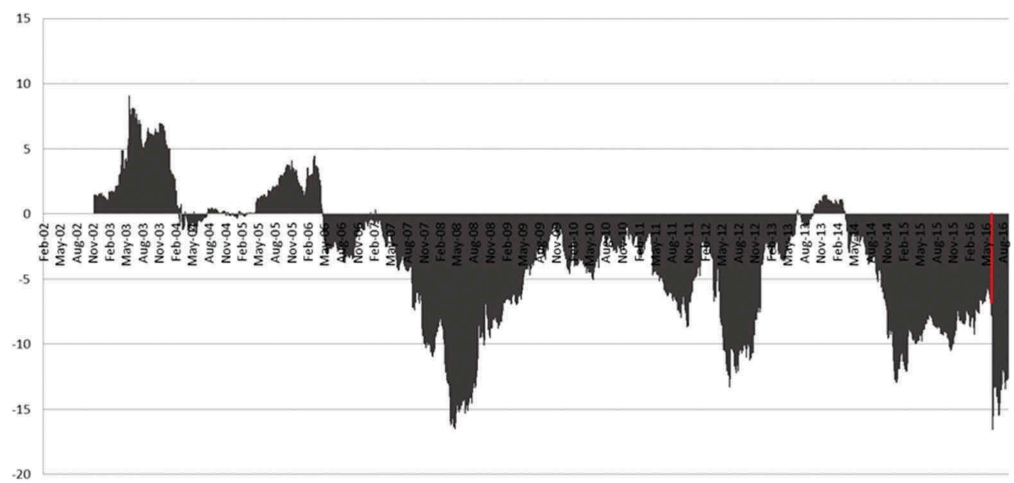

Figure 9. Net pairwise spillovers between FX volatility and EPU.

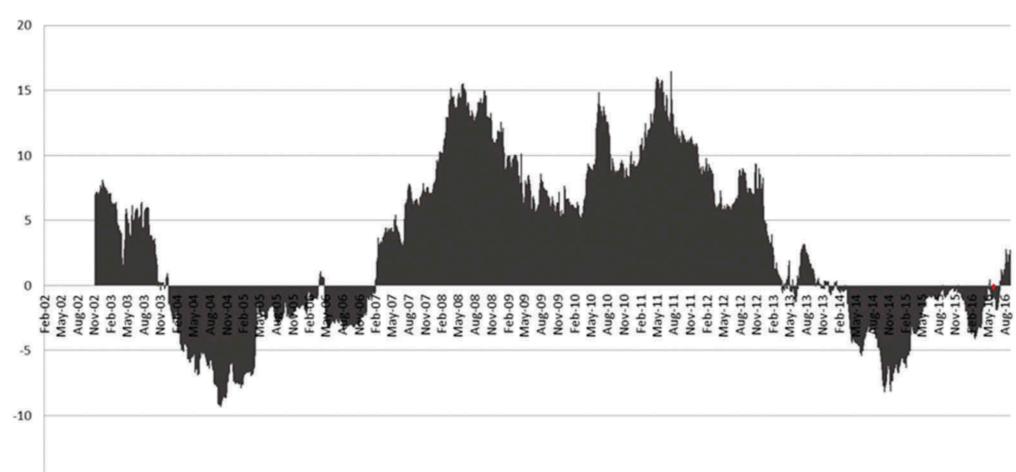

Figure 10. Net pairwise spillovers between stock volatility and FX volatility.

maxima. Interestingly, policy uncertainty spillovers have remained strong since then and could be considered as empirical evidence that policy uncertainty concerning the development of the relationship between the UK and the EU causes turbulence to financial markets even 3 months after the referendum which can further weaken investment and hiring in the UK (and Europe). Overall, we can corroborate the view of International Monetary Fund (2016) and others that Brexit uncertainty has caused instability in key financial markets. Our analysis, however, also provides evidence that the observed immediate effect has not disappeared and remains to be steadily high and, thus, might prevail also over the medium run.

IV. Brexit and its effects on international financial markets

Data

In this section, we analyse the effect of Brexit on international financial markets. In this context, we estimate the impact of an increase in the likelihood that the citizens of the UK will vote in favour of Brexit on several financial variables. We use daily data between 1 April and 22 June 2016. Thereby, we examine the critical phase before the EU referendum took place. We include data from the following countries: Austria, Belgium, Canada, Denmark, Finland, France, Germany, The Netherlands, Norway, Italy, Japan, Portugal, Spain, Sweden, Switzerland, UK and the United States.

Our measures of daily stock returns are based on closing prices of the most important stock indexes of the countries under observations (see Table 3). Furthermore, we analyse the impact on 10-year government yields and sovereign CDS for 10-year bonds which measure sovereign credit risk. In order to examine the impact of an increase in the probability of Brexit on the external value of the British currency, we use the exchange rate of the British pound vis-à-vis the Canadian Dollar, Danish Krone, Euro, Japanese Yen, Norwegian Krone, Swedish Krona, Swiss Franc and the US Dollar. When not stated otherwise, the data are obtained from Thomson Reuters Datastream.

The most crucial variables of this study are those which are supposed to track the probability of Brexit.

Table 3. National stock indices.

Country	Stock index	Country	Stock index
Austria	ATX	Ireland	ISEQ20
Belgium	Bel20	Italy	FTSE MIB
Canada	S&P/TSX Composite	Japan	Nikkei 225
Denmark	OMX Copenhagen 20	Portugal	PSI-20
Finland	OMX Helsinki 25	Spain	IBEX 35
France	CAC 40	Sweden	OMX Stockholm 30
Germany	DAX	Switzerland	SMI
Greece	ASE	UK	FTSE 100
The Netherlands	AEX	United States	S&P 500
Norway	OBX		

Because the corresponding coefficients are most relevant for answering our research question, we use two different measures in order to check for robustness of our results. First, we use probability data in percentage points (*Brexit_Prob*) based on decimal odds of the online betting exchange 'Betfair'. As probabilities vary intra-daily, we have to make a choice regarding the time of day. We use the 4 pm (GMT) values. As financial markets are considered to be very fast in processing new information, we assume that new information arriving at 4 pm (GMT) should be fully reflected in the daily closing prices.[17] Second, we attempt to measure the probability of Brexit by using survey (poll) data collected by Bloomberg (*Brexit_Poll*).[18]

Both indicators presented in Figures 11 and 12 show more or less a similar evolution. Although we include both Brexit variables alternatively in our estimations, we focus our analysis mainly on *Brexit_Prob*. As shown by Gerlach (2016), the information content of polls and survey data for explaining developments of financial variables is generally low. We can confirm this argument because the explanatory power of $Brexit\_Poll_t$ is low in general as indicated by the R^2 in our estimations.

While it can be assumed that changes in the probability of Brexit should have an impact on fast information processing markets, it is straightforward to assume that the timing also matters. An increase in the probability 3 months before the date of the referendum might have a smaller effect compared to a similar increase 1 day before the vote. Similarly, one may assume that during times of high public attention, the effects on financial markets might be stronger. Both aspects are highly interconnected because public interest

[17]Additionally, we performed several estimations using 12 pm (GMT) values and obtained nearly identical results.
[18]Further information can be found here: http://www.bloomberg.com/graphics/2016-brexit-watch/.

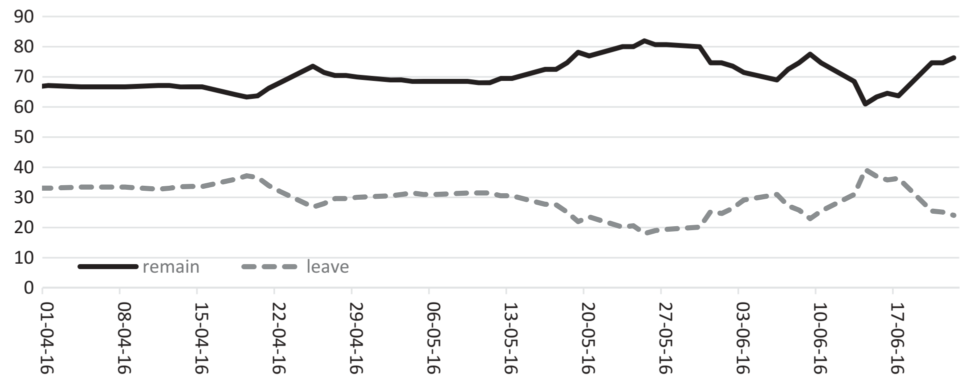

Figure 11. Probability of Brexit (in percentage points).
Source: Betfair.

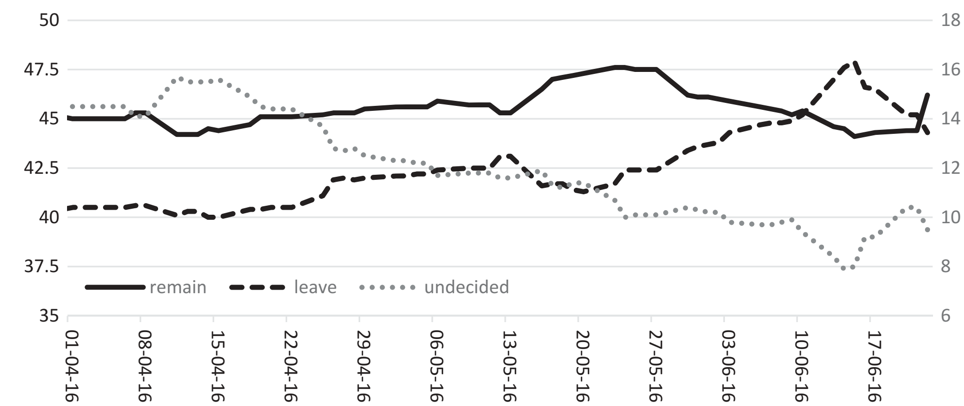

Figure 12. Summary of Brexit polls.
Source: Bloomberg.

should be at its high point just before the vote takes place.

In order to account for these aspects, we use Google Trends data to check for the public interest in Brexit based on Google search requests.[19] The values displayed in Figure 13 presents a measure of 'public attention' for Brexit in the entire UK and are calculated as ratios relative to the day with the highest attention within the time period.

Estimation procedures

In order to analyse the impact of Brexit, we use standard econometric procedures. As the first step

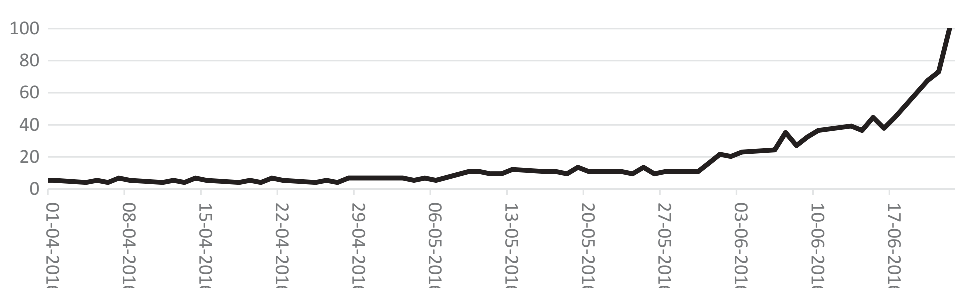

Figure 13. Public attention based on Google search requests.
Source: Google Trends.

[19]The values are based on the search topic: 'United Kingdom European Union membership referendum, 2016', which combines several different research requests corresponding with the Brexit topic. The following additional options are used: Search Category: 'News', Search: 'News-Search'.

of our analysis, panel estimation is used to obtain first results. As common in the literature, our choice of the specific panel estimator depends on the results of the Hausman test. In our study, the null hypothesis of the test is accepted for every specification. Therefore, we exclusively use the *random effects* estimator. Afterwards, we perform SUR estimations in order to obtain country-specific results. The SUR approach consists of several regression equations which are linked by allowing for cross-equation correlations of the error terms. This appears to be an appropriate assumption because financial markets are highly connected. Although every country-specific equation can be consistently estimated by GLS, the use of SUR estimation increases the efficiency of the estimations. Additionally, in order to account for the timing of the change in Brexit probability, we estimate specifications in which the observations points are weighed based on Google Trends data.

The financial variables used in this approach are not stationary in levels. Due to the small sample length, we cannot perform cointegration analysis. Therefore, we perform estimations in first differences. Due to the linearity of the model, the estimated coefficients generated by the model in first differences are the same coefficients generated by an unbiased estimation in levels.[20] Therefore, although we estimate the models in first differences, we can interpret the coefficients as level effects.

We include several control variables which are likely to affect financial variables. First, we control for changing expectations about the monetary policy by including 3-month futures of the 3-month interest rate ($Futures3x6_t^i$). For similar reasons, we include the national long-term interest yield ($IR10_t^i$) as explanatory variable in several specifications. Second, we use the S&P commodity price index ($COMM_t$) which is supposed to be an indicator of changing expectation about the performance of the global economy. Table 4 presents an overview of our variables.

Estimation results

Impact on international stock returns

Our first objective is to analyse the effect of the Brexit probability on international stock markets. Our prior is that the effect on stock markets can be assumed to be universally negative. However, there may be differences regarding the magnitude based on the strength of trade and financial linkages between the UK and the economy under observation.

In accordance with the assumption that financial markets and especially stock markets are (information) efficient, we do not include lagged values of the Brexit variables. Because all new information is supposed to be included into prices on arrival, information which has been available on previous days should have no effect on present-day stock market returns.[21]

The dividend discount model assumes that stock prices are not only influenced by the expected level of dividends (and therefore by expectation about the general economic development) but also by current and future (short term) interest rates. According to announcements made by the BoE and to a lesser extent the ECB, European Central Bank it could be expected that central banks would react to counterbalance potential adverse effects.[22] Therefore, the effect of the likelihood of a Brexit vote on the stock markets might be underestimated if a variable measuring expectations about the monetary policy is not included in the model.

Table 4. Overview of variables used in estimation.

Variable	Description	Variable	Description
$Brexit\_Prob_t$	The change in the Brexit probability in t	CDS_t^i	The per cent change in the CDS in t of country i
$Brexit\_Poll_t$	The change in the support for the leave campaign in t	$Comm_t$	The per cent change in commodity prices in t
$Stock_t^i$	The per cent change in stock prices in t in country i	ExR_t^i	The per cent change in the British Pound against the national currency of country i in t
$IR10_t^i$	The change in the 10-year interest yield in t for country i	$diff\_IR10_t^i$	The change in the long-term interest rate differential ($IR10_t^i - IR10_t^{UK}$) in t
$Future3x6_t^i$	The change in the 3-month future for the 3-month interest rate in t in country (currency area) i	$diff\_IR10_t^i$	The change in the 3-month future of the 3-month interest rate differential ($Future3x6_t^i - IFuture3x6_t^{UK}$) in t

[20]For a detailed derivation of this aspect, see Pankratz (1991).
[21]The same argument also applies to the other estimations in this section.
[22]In August 2016, the BoE decreased the bank rate to 0.25% justifying its decision by potential effects of the Brexit vote on future inflation and growth.

Our estimation results are presented in Tables 5 and 6. The estimated coefficients of the Brexit variables presented in both tables measure the effects of a one-percentage point increase in the Brexit probability $(Brexit\_Prob_t)$ or Brexit polls $(Brexit\_Poll_t)$ on stock prices, in per cent. Our panel estimations reveal significant evidence that an increase in the Brexit likelihood (based on both variables) has a strong negative effect on stock prices. For $Brexit\_Prob_t$, we find a decrease in stock prices of around 0.13%. A one-percentage point increase in $Brexit\_Poll_t$ leads to a decrease of around 0.42%. Both results appear to be robust to the inclusion of commodity prices as well as indicators of future monetary policy.

The SUR estimation results confirm the panel results but shed light on country differences. While the largest effects are found for UK stocks when measured in USD, effects on US and Canadian stock prices turn out to be weaker than the effects on the European economies. Regarding differences between European countries, the effects are overall similar. Therefore, it appears somewhat difficult to trace back the results to the strength of trade, banking or capital market linkages. However, we observe a tendency that the effects for the GIIPS[23] states are stronger with the exception of Greece. Based on the amount of economic ties between the UK and Ireland, it does not come as a surprise that Irish stock prices are strongly affected due to economic ties. For Italy, Spain and Portugal, the strong effect is surprising and cannot be solely explained by the strength of economic ties with the UK. When we weight the observation by Google Trends data, the effects are stronger and significant for all countries indicating that the timing does in fact matter.

Impact on long-term interest rates and sovereign credit risk

The impact on long-term interest rate and sovereign credit risk can be expected to show a larger degree of heterogeneity across countries. In this regard, some countries might benefit from increased uncertainty, because their bonds are considered to be a safe haven in times of market turmoil.

Table 7 presents the panel estimation results for the 10-year interest yield. Because we assume different effects, we divide the sample into two groups: While the first group contains countries which are considered to be nearly 'risk-free' indicated by a rating of AAA, the second group contains countries which have a credit rating of below AA.[24]

We find that a one-percentage point increase in the probability of a leave vote in Britain's EU referendum leads to a decrease of about 0.3 basis points in AAA bonds but increases interest rates of riskier countries by about 0.7 basis points. Again, our results are not driven by other developments as indicated by the results of regressions which include additional variables.

Table 8 presents the panel estimation results for CDS. Overall, our results confirm differences between the two groups. When $Brexit\_Prob_t$ is used, we find no effect on AAA countries. On the contrary, an increase in the likelihood of a Brexit vote has a significant effect on riskier countries. As presented, an increase in the probability of Brexit increases the CDS by around 0.1%. However, the results have to be interpreted with caution because our estimations explain only a small fraction of the variation in our data as indicated by the R^2 values.

Table 5. Effect of Brexit likelihood on stock markets ($Stock_t^i$); panel estimation.

	Random effects							
	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)
$Brexit\_Prob_t$	−0.1372 (0.000)	−0.1421 (0.000)	−0.1373 (0.000)	−0.1258 (0.000)				
$Brexit\_Poll_t$					−0.4243 (0.000)	−0.4385 (0.000)	−0.4163 (0.000)	−0.4052 (0.000)
$Future3x6_t^i$		−0.0207 (0.1284)				−0.0227 (0.2132)		
$IR10_t^i$			−0.0555 (0.000)				−0.5564 (0.000)	
$Comm_t$				0.2691 (0.000)				0.2780 (0.000)
Pseudo R^2	0.0791	0.0818	0.1348	0.1712	0.0209	0.0219	0.0788	0.1214
Hausman *p*-value		0.4123	0.9100			0.2876	0.8333	

Constants are included. *p*-Values are presented in brackets. The Newey–West estimator is used for the calculation of the covariance matrix. Individual and time effects are included.

[23]The GIIPS states comprise Greece, Ireland, Italy, Portugal and Spain.
[24]Ratings are taken from Fitch Ratings. The AAA group contains Canada, Denmark, Germany, The Netherlands, Norway, Sweden, Switzerland and the United States. The second group contains only the so-called GIIPS states.

Table 6. Effect of Brexit – vote likelihood on stock markets $(Stock_t^i)$; SUR estimation.

Country \ Exo. variables	(1) $Brexit\_Prob_t$	(2)[a] $Brexit\_Prob_t Future3x6_t^i$	(3) $Brexit\_Prob_t IR10_t^i$	(4) $Brexit\_Prob_t$ $Comm_t$	(5) $Brexit\_Prob_t$ (weighted estimation)	(6) $Brexit\_Poll_t$
Austria	−0.1500 (0.004)	−0.1426 (0.012)	−0.1494 (0.005)	−0.1337 (0.001)	−0.2268 (0.000)	−0.5023 (0.062)
Belgium	−0.1503 (0.003)	−0.1473 (0.005)	−0.1524 (0.001)	−0.1395 (0.001)	−0.2292 (0.000)	−0.3684 (0.209)
Canada	−0.0452 (0.067)	−0.0452 (0.066)	−0.0316 (0.205)	−0.0318 (0.053)	−0.0690 (0.000)	−0.2503 (0.003)
Denmark	−0.1709 (0.001)	−0.1492 (0.000)	−0.1627 (0.001)	−0.1624 (0.001)	−0.2269 (0.000)	−0.3508 (0.005)
Finland	−0.0968 (0.182)	−0.0943 (0.203)	−0.1025 (0.150)	−0.0797 (0.193)	−0.2245 (0.000)	−0.4785 (0.000)
France	−0.1818 (0.002)	−0.1771 (0.002)	−0.1823 (0.001)	−0.1689 (0.000)	−0.2750 (0.000)	−0.4979 (0.063)
Germany	−0.1586 (0.006)	−0.1543 (0.008)	−0.1559 (0.008)	−0.1449 (0.002)	−0.2545 (0.000)	−0.5272 (0.040)
Greece	−0.1223 (0.246)	−0.1249 (0.233)	−0.0219 (0.803)	−0.1122 (0.294)	−0.0897 (0.000)	−0.6213 (0.401)
The Netherlands	−0.1692 (0.005)	−0.1640 (0.007)	−0.1734 (0.003)	−0.1548 (0.001)	−0.2626 (0.000)	−0.5415 (0.022)
Norway	−0.1225 (0.004)	−0.1220 (0.004)	−0.0938 (0.029)	−0.1053 (0.000)	−0.1935 (0.000)	−0.3352 (0.215)
Ireland	−0.1972 (0.002)	−0.2003 (0.002)	−0.1939 (0.001)	−0.1853 (0.001)	−0.3140 (0.000)	−0.6048 (0.015)
Italy	−0.2132 (0.005)	−0.2081 (0.004)	−0.1784 (0.006)	−0.1869 (0.003)	−0.2574 (0.000)	−0.3305 (0.338)
Japan	−0.1542 (0.002)	−0.1170 (0.025)	−0.1385 (0.012)	−0.1391 (0.002)	−0.1940 (0.000)	−0.5348 (0.243)
Portugal	−0.2003 (0.000)	−0.1999 (0.000)	−0.1768 (0.000)	−0.1852 (0.000)	−0.2823 (0.000)	−0.4811 (0.212)
Spain	−0.2076 (0.000)	−0.2125 (0.000)	−0.1921 (0.000)	−0.1881 (0.000)	−0.2871 (0.000)	−0.4336 (0.181)
Sweden	−0.1405 (0.013)	−0.1386 (0.013)	−0.1362 (0.017)	−0.1247 (0.007)	−0.2476 (0.000)	−0.5170 (0.008)
Switzerland	−0.1218 (0.013)	−0.1213 (0.0149)	−0.1180 (0.014)	−0.1112 (0.008)	−0.2026 (0.000)	−0.5954 (0.002)
UK	−0.1108 (0.074)	−0.1069 (0.063)	−0.1034 (0.092)	−0.0970 (0.068)	−0.2101 (0.000)	−0.4852 (0.007)
UK (in USD)	−0.2336 (0.008)	−0.2163 (0.006)	−0.2163 (0.009)	−0.2116 (0.004)	−0.3872 (0.000)	−0.6823 (0.009)
US	−0.0469 (0.048)	−0.0332 (0.215)	−0.0130 (0.548)	−0.0411 (0.046)	−0.0514 (0.000)	−0.1849 (0.151)
Average R^2	0.1121	0.1514	0.1412	0.2014	0.4152	0.0231

The reported values represent the estimated coefficient of the Brexit variable. The Newey–West estimator is used for the calculation of the covariance matrix.
[a]We gain very similar results for the 6- and 12-month futures of the 3-month interest rate.

Table 7. Effects on long-term interest rate $(IR10_t^i)$; panel estimations.

	Random effects							
	AAA				<AA (GIIPS)			
	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)
$Brexit\_Prob_t$	−0.3283 (0.000)	−0.2750 (0.000)	−0.3023 (0.000)		0.7246 (0.000)	0.7177 (0.000)	0.6991 (0.000)	
$Brexit\_Poll_t$				−0.5710 (0.000)				1.6459 (0.000)
$Future3x6_t^i$		0.4420 (0.000)				0.2412 (0.7315)		
$Comm_t$			0.3784 (0.000)				−0.5829 (0.0670)	
Pseudo R^2	0.0521	0.2022	0.0761	0.0098	0.0356	0.0360	0.0425	0.0051
Hausman p-value		0.3190					0.2151	

Constants are included. p-Values are presented in brackets. The Newey–West estimator is used for the calculation of the covariance matrix. Individual and time effects are included.

Table 8. Effects on sovereign credit risk perception (CDS_t^i); panel estimations.

	AAA				<AA (GIIPS)			
	(i)	(ii)	(iii)	(iv)	(vi)	(vii)	(viii)	(ix)
$Brexit\_Prob_t$	0.0064 (0.3847)	0.0068 (0.373)	0.0051 (0.454)		0.0923 (0.011)	0.1029 (0.002)	0.0847 (0.019)	
$Brexit\_Poll_t$				0.2127 (0.003)				0.6682 (0.015)
$Future3x6_t^i$		−0.0271 (0.278)				0.3706 (0.001)		
$Comm_t$			−0.0361 (0.064)				−0.1808 (0.001)	
Pseudo R^2	0.0191	0.0156	0.0171	0.0223	0.0117	0.0318	0.0251	0.0165
Hausman p-value		0.3521				0.9012		

Constants are included. p-Values are presented in brackets. The Newey–West estimator is used for calculation of the covariance matrix. Individual and time effects are included.

Regarding our SUR estimation results (Table 9), we observe a strong decrease in long-term interest rates for the UK, of around 0.6 basis points. Similar results for the UK yield are presented by BoE (2016). With respect to the other countries, we observe the same pattern as indicated by our panel estimation results with large increases for 'riskier' countries and decreases for 'risk-free' countries. For the remaining countries which can neither be considered 'risk-free' nor high-risk (according to our classification), the results are

Table 9. Effects on interest rates $IR10_t^i$ and sovereign credit risk (CDS_t^i); SUR estimation.

	Specification						
	10-year Interest yield				CDS		
	(1)	(2)	(3)	(4)	(1)	(2)	(3)
Country \ Exo. variables	*Brexit_Prob$_t$*	*Brexit_Prob$_t$Future3x6$_t^i$*	*Brexit_Prob$_t$* (weighted estimation)	*Brexit_Poll$_t$*	*Brexit_Prob$_t$*	*Brexit_Prob$_t$Comm$_t$*	*Brexit_Poll$_t$*
Austria	−0.0496 (0.583)	−0.0534 (0.568)	−0.0428 (0.002)	0.6360 (0.141)	0.0355 (0.107)	0.0331 (0.114)	0.1091 (0.240)
Belgium	−0.0566 (0.591)	−0.0558 (0.596)	−0.0465 (0.0082)	−0.0036 (0.991)	0.0673 (0.000)	0.0620 (0.000)	0.2258 (0.126)
Canada	−0.5540 (0.0050)	−0.5540 (0.0050)	−0.4596 (0.0000)	−1.2151 (0.009)	0.0001 (0.452)	0.0002 (0.379)	−0.0006 (0.546)
Denmark	−0.3125 (0.0010)	−0.2505 (0.030)	−0.2595 (0.0000)	−0.4096 (0.601)	−0.0114 (0.177)	−0.0143 (0.121)	0.0084 (0.761)
Finland	−0.1609 (0.0731)	−0.1385 (0.120)	−0.0288 (0.0057)	0.3705 (0.368)	−0.0126 (0.093)	−0.0132 (0.097)	0.0938 (0.216)
France	−0.0553 (0.5614)	−0.0588 (0.544)	0.0138 (0.4286)	0.5724 (0.230)	0.0301 (0.541)	0.0245 (0.607)	0.0244 (0.814)
Germany	−0.3151 (0.0002)	−0.3125 (0.0003)	−0.2636 (0.0000)	−0.2350 (0.683)	0.0495 (0.014)	0.0499 (0.012)	0.1547 (0.339)
Greece	2.0558 (0.0427)	2.1477 (0.0480)	1.4181 (0.0000)	2.0897 (0.725)	0.1662 (0.058)	0.1635 (0.059)	0.6272 (0.322)
The Netherlands	−0.1500 (0.0758)	−0.1386 (0.132)	−0.1137 (0.0000)	0.2526 (0.573)	0.0142 (0.516)	0.0100 (0.606)	0.1727 (0.474)
Norway	−0.3544 (0.0008)	−0.1647 (0.0247)	−0.3332 (0.0000)	−0.7217 (0.408)	−0.0144 (0.382)	−0.0159 (0.330)	−0.0408 (0.161)
Ireland	0.0955 (0.5931)	0.0346 (0.875)	0.3306 (0.0000)	1.0348 (0.058)	0.0488 (0.014)	0.0408 (0.092)	−0.2553 (0.561)
Italy	0.3450 (0.0851)	0.3324 (0.118)	0.6338 (0.0000)	1.0200 (0.076)	0.1982 (0.009)	0.1832 (0.006)	0.9263 (0.235)
Japan	−0.1334 (0.0722)	−0.2013 (0.0211)	−0.0567 (0.0000)	−0.3063 (0.020)	0.1730 (0.221)	0.1670 (0.235)	0.2501 (0.645)
Portugal	0.8974 (0.0084)	0.8931 (0.011)	1.4330 (0.0000)	2.4518 (0.055)	0.1561 (0.039)	0.1444 (0.046)	0.2880 (0.674)
Spain	0.3989 (0.0261)	0.4053 (0.033)	0.6732 (0.0000)	1.3719 (0.060)	0.1578 (0.000)	0.1489 (0.000)	0.1983 (0.630)
Sweden	−0.3199 (0.0070)	−0.3265 (0.004)	−0.3153 (0.0000)	−0.5805 (0.275)	−0.0028 (0.742)	−0.0049 (0.502)	0.0319 (0.614)
Switzerland	−0.2456 (0.0270)	−0.2458 (0.028)	−0.3398 (0.0000)	−0.8675 (0.200)	−0.0008 (0.339)	−0.0005 (0.475)	−0.0067 (0.146)
UK	−0.6039 (0.0000)	−0.5047 (0.0000)	−0.7194 (0.0000)	−1.5587 (0.067)	0.2109 (0.031)	0.2135 (0.027)	0.9386 (0.060)
United States	−0.4241 (0.001)	−0.2093 (0.0149)	−0.4281 (0.0015)	−1.0500 (0.026)	0.1303 (0.326)	0.1456 (0.300)	0.7226 (0.287)
Average R^2	0.0645	0.2224	0.3521	0.0098	0.0143	0.0254	0.0253

The reported values present the coefficient of the Brexit variable. The Newey–West estimator is used for the calculation of the covariance matrix.

Table 10. Effects on the external value of the British pound ExR_t^i; panel estimations.

	Random effects					
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Brexit_Prob$_t$	−0.1217 (0.000)	−0.1183 (0.000)	−0.1118 (0.000)			
Brexit_Poll$_t$				−0.2306 (0.000)	−0.2100 (0.000)	−0.2063 (0.000)
Diff_Future3x6$_t^i$		−0.0557 (0.000)			−0.0551 (0.000)	
Diff_IR10$_t^i$			−0.0331 (0.000)			−0.0342 (0.000)
Pseudo R^2	0.1731	0.1788	0.1862	0.0148	0.0314	0.0517
Hausman test *p*-value		0.4998	0.5062		0.7213	0.7009

Constants are included. *p*-Values are presented in brackets. Newey–West estimator is used for the calculation of the covariance matrix. Individual and time effects are included.

Table 11. Effects on the external value of the British pound ExR_t^i; SUR estimations.

	Specification				
Country \ Exo. variables	(1) *Brexit_Prob$_t$*	(2) *Brexit_Prob$_t$Diff_Future3x6$_t^i$*	(3) *Brexit_Prob$_t$Diff_IR10$_t^i$*	(4) *Brexit_Prob$_t$* (weighted estimation)	(5) *Brexit_Poll$_t$*
Canadian Dollar	−0.1115 (0.001)	−0.1108 (0.001)	−0.1115 (0.001)	−0.1451 (0.000)	−0.2007 (0.209)
Danish Krone	−0.1057 (0.000)	−0.1032 (0.000)	−0.1059 (0.000)	−0.1370 (0.000)	−0.2115 (0.157)
Euro	−0.1055 (0.000)	−0.1021 (0.001)	−0.1051 (0.000)	−0.1367 (0.000)	−0.2082 (0.166)
Norwegian Krone	−0.0543 (0.109)	−0.0522 (0.119)	−0.0605 (0.069)	−0.0664 (0.000)	−0.1045 (0.421)
Japanese Yen	−0.1584 (0.000)	−0.1381 (0.000)	−0.1434 (0.002)	−0.2006 (0.000)	−0.1728 (0.581)
Swedish Krone	−0.0865 (0.005)	−0.0918 (0.005)	−0.0797 (0.016)	−0.1233 (0.000)	−0.2995 (0.035)
Swiss Franc	−0.1316 (0.000)	−0.1285 (0.001)	−0.1297 (0.000)	−0.1784 (0.000)	−0.3629 (0.041)
US Dollar	−0.1228 (0.001)	−0.1220 (0.001)	−0.1283 (0.000)	−0.1772 (0.000)	−0.2848 (0.159)
Average R^2	0.3321	0.2356	0.2252	0.3542	0.0142

The reported values present the coefficient of the Brexit variable. The Newey–West estimator is used for the calculation of the covariance matrix.

mainly insignificant, which further supports our argument of a safe haven effect. For Greece, we observe a very strong effect as a one-percentage point increase in the probability of a Brexit vote increases the Greek yield by 2 basis points. This does not come as a surprise as Greece has the worst rating in our sample (CCC).

The results for the sovereign credit risk reveal significant positive effects for the GIIPS countries, the UK, Germany and Belgium. While the effect on German CDS is significant, it is very small (0.05%). The largest effects are found for Italy, Spain, Greece and Portugal. Putting these results into perspective, the increases in yields appear to be driven by increases in sovereign credit risk. For the UK, we find the largest increase in CDS spreads indicating that markets assume that Brexit might have an effect on the creditworthiness of the UK.

Impact on the external value of the British pound

Because Brexit can be linked to uncertainty and the possibility of an economic decline in the UK in the future, an increase in the Brexit likelihood should cause a depreciation of the British pound. However, the exchange value is not only linked with expectations about the development of real economic variables and the level of uncertainty but also with interest rate differentials and expectations about (national) monetary policies.[25] In order to account for these aspects, we calculate the difference between the 3-month future of country *i* and the value for the UK ($\mathrm{Future3x6}_t^i - \mathrm{Future3x6}_t^{UK}$). We follow the same approach to calculate the (long term) interest rate differential.

According to our panel estimation results (Table 10), a one-percentage point increase of the probability of a Brexit vote decreases the value of the pound by around 0.12% (0.23% for $Brexit\_Poll_t$). For our control variables, we find the expected impact of the interest rate differentials.

Regarding the effect on the value of the British pound, we find similar results across currencies (Table 11). The weakest and sometimes insignificant effect is found for the Norwegian Krone. Again, when we account for the timing for the probability increase by weighting the observations, we find larger and very significant results. For the Euro, we find an appreciation of up to 0.14% against the British pound. For the USD, we find even stronger effects of up to 0.1772%.

In order to check for robustness of our results, we perform several addition estimations. We estimate (G) ARCH models in order to correct for potential volatility clusters which can be frequently observed in financial markets. However, our models do not find evidence of (G)ARCH effects. For the estimation of the stock market impacts, we use a different sample based on MSCI data. We find nearly identical results. We also use 6 and 9-month futures instead of the 3-month interest rate and obtain nearly identical results.

V. Conclusions

In this article, we assessed the impact of Brexit uncertainty on the UK and also on international financial markets, for the first and the second statistical moments. First, we estimated the time-varying interactions between UK policy uncertainty, which can to a large extent be attributed to uncertainty around the Brexit vote, and UK financial market volatilities (second statistical moment) and identified the substantial role of policy uncertainty for financial market volatilities. The policy uncertainty induced by the Brexit referendum resulted in huge spillovers to financial markets, with magnitudes that were never observed before. Moreover, the policy uncertainty spillovers have remained strong since then, suggesting that political uncertainty concerning the development of the relationship between the UK and the EU causes turbulence on financial markets even 3 months after the vote. On the whole, we thus feel legitimized to corroborate the view of the International Monetary Fund (2016) and others that Brexit-caused policy uncertainty will continue to cause instability in key financial markets and has the potential to do damage to the British (and, as shown in Section IV, also other European countries') real economy as well, even in the medium run.

Second, we used two other measures of the perceived probability of a Brexit vote, namely daily data between 1 April and 23 June 2016 of probabilities released by Betfair as well as (aggregated) results of polls published by Bloomberg. Based on these data sets, we analysed the Brexit effect on the levels of stock returns, sovereign CDS, 10-year interest rates in 19 different countries predominantly from Europe as well as the British pound and the euro (first

[25] In case of the Euro, we take German 10-year yields as a proxy of the 'European' interest rate. However, we do not find different results when Dutch, French or Finnish yields are used.

statistical moment). Here, we find evidence that an increase in the probability of Brexit has especially strong effects on European stock markets.

Regarding the effect on long-term interest rates and CDS, we observe a large heterogeneity across countries, which can be related to the differences in sovereign credit risk. The main cause of this pattern might be related to an expected decrease in economic activity that might further jeopardize the sustainability of government debt. As Brexit might have unforeseeable effects on the stability of the entire EU, the effects may simply be generated by an increase in, according to our view, the still low probability of a breakup of the euro area or the EU. Regarding the effect on the exchange rate, we find that an increase in the probability of a Brexit vote leads to a depreciation of the British pound. Based on the results, the main losers outside of the UK appear to be the GIIPS economies, which are already struggling with the legacy of the sovereign debt crisis. How, then, should we explain the current lack of an even bigger (real economic) impact? It may just be because Brexit has not happened yet.

Disclosure statement

No potential conflict of interest was reported by the authors.

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