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The Chronology of Brexit and UK Monetary Policy*

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Abstract

The outcome of the referendum on the UK's membership of the European Union in June 2016 was largely unanticipated by politicians and pundits alike. Even after the "Leave" vote, the uncertainty surrounding the withdrawal process might have affected the UK economy. We draw on an official list of political events published by the House of Commons Library and daily data on UK stock prices, exchange rates, and economic policy uncertainty to construct a novel instrument for Brexit shocks. Including a monthly aggregate of this time series into a vector-autoregressive model of the UK economy, we find that Brexit shocks were quantitatively important drivers of the business cycle in the aftermath of the referendum that lowered gross domestic product, consumer confidence, and monetary policy rates while raising CPI inflation. A counterfactual experiment, in which we shut down the endogenous response of UK monetary policy to Brexit shocks, reveals that the Bank of England fended off a stronger contraction of output in 2016 and 2018.

Keywords: Brexit, business cycle, economic policy uncertainty, high-frequency identification, monetary policy

JEL classification: E02, E31, E32, E44, E58, F15

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1 Introduction

Following several last-minute extensions of its membership, the United Kingdom of Great Britain and Northern Ireland (UK) eventually left the European Union (EU) on January 31, 2020. While "Brexit" is commonly considered as a self-contained event that coincides chronologically with the UK referendum on its EU membership on June 23, 2016, Figure 1 highlights that the time period between the referendum and the withdrawal agreement saw repeated spikes in economic policy uncertainty, many of which coincided with political and diplomatic events related to Brexit. In this paper, we draw on an official timeline of "events leading to the UK's exit from the European Union" published by the House of Commons Library to construct a novel instrument for *Brexit shocks*.

We sign and quantify each event by the average changes in daily data on UK stock prices, exchange rates, and economic policy uncertainty around the day of the event. The resulting instrument series covers the period between the first mentioning of an in-out referendum by Prime Minister David Cameron in a speech at Bloomberg on January 23, 2013 and December 24, 2020, when the EU-UK Trade and Cooperation Agreement (a.k.a. the "Brexit deal") was sealed. While the referendum sticks out as the single most important event, Brexit-related events seem to be roughly evenly distributed between June 2016 and December 2020 and can be both adverse and favorable.

We use our instrument to investigate the effects of Brexit shocks on the UK economy. Incorporating a monthly time aggregate of the daily instrument in a structural vector-autoregressive (VAR) model, we find that a typical Brexit shock has moderate adverse effects on output and puts upward pressure on consumer price inflation with some delay. Effects on the Bank of England's monetary policy stance, as measured by the UK shadow short rate (SSR) of Krippner (2015), and consumer confidence are much more pronounced. Qualitatively, the effects of a typical Brexit shock are reminiscent of an uncertainty shock that shifts the aggregate demand curve, albeit the former tends to raise rather than lower CPI inflation after six to twelve months. With regard to UK output, consumer confidence, and interest rates, the transmission of Brexit shocks is rather swift, which may be due to the salient nature of Brexit-related events and their coverage by the media.

Historical decompositions of UK GDP, CPI inflation, and consumer confidence reveal that Brexit shocks contributed to their fluctuations to a similar magnitude as conventional macroeconomic shocks, that is aggregate demand (AD), aggregate supply (AS), and monetary policy (MP) shocks. During the most intense phases in Brexit negotiations and the public debate, in 2016 and 2018, Brexit shocks represented the quantitatively most important source of UK business cycle volatility. While the existing literature primarily focuses on the referendum — also due to sample limitations — our findings suggest that the chronology of Brexit shocks is key to understanding the macroeconomic consequences of the "Leave" vote.

Our historical decompositions further reveal particularly large negative contributions of Brexit shocks to fluctuations of the SSR in the second half of 2016 and during 2018, indicating an endogenous response of UK monetary policy despite the zero lower bound. Applying quantitative text analysis to the Bank of England's "Monetary Policy Summary and minutes of the Monetary Policy Committee meetings", we show that the relative frequency of terms relating to inflation, output, and financial markets changes exactly during these episodes, suggesting that our findings reflect a shift in priorities away from stabilizing inflation and towards stabilizing financial markets and output, respectively. Motivated by this narrative evidence, we construct *counterfactual* impulse response functions and historical decompositions, in which we shut down the endogenous response of the SSR to Brexit shocks. According to our structural VAR model, the Bank of England fended off an even stronger contraction of output and prices in the second half of 2016 and of output, in particular, during 2018.

Our work relates to several strands of literature. First and foremost, it is motivated by earlier studies on the economic consequences of Brexit. Among the articles studying the impact of the EU membership referendum, Born et al. (2019) quantify the total output loss associated with the "Leave" vote, while Breinlich et al. (2021) investigate the effects on the UK price level and living standards. To identify Brexit shocks, we build on recent contributions documenting the negative conditional comovement of UK asset prices and uncertainty. Analyzing survey data from UK firms, for example, Bloom et al. (2019) document a broad and persistent increase in uncertainty in the aftermath of the referendum. Forbes et al. (2018) identify the referendum as an important driver of the sharp depreciation of the pound sterling during 2016. Considering only a limited number of individual events related to Brexit, Hudson et al. (2020) finally show that such news are quickly incorporated into UK stock prices.

Our econometric approach to identifying Brexit shocks is motivated by the popular identification of monetary policy shocks using high-frequency data on asset price changes, originating with Kuttner (2001), Faust et al. (2004), and Gürkaynak et al. (2005a,b). The intuition is to identify and quantify monetary policy surprises from changes in asset prices in a tight window around monetary policy announcements. In this paper, we apply the same idea to events associated with Brexit and follow recent advances in the identification of monetary policy shocks that distinguish between a signalling channel of monetary policy and exogenous changes in the federal funds rate, such as Jarociński and Karadi (2020), by exploiting the comovement in multiple high-frequency time series to characterize shocks. Specifically, we consider UK asset prices and economic policy uncertainty to sign and quantify the importance of a large number of political and diplomatic events related to Brexit. Similar to our paper, which applies the logic of high-frequency identification of monetary policy shocks in a different context, Känzig (2021a,b) exploits high-frequency changes in crude oil futures and carbon emission certificates in response to announcements of changes in OPEC production quotas and EU carbon taxes in order to gauge the effects of oil supply news and carbon policy shocks, respectively.

Our use of narrative information and legislative documents to identify macroeconomic shocks is inspired by Romer and Romer (2004, 2010), among others. In the latter, they exploit qualitative data sources, such as presidential speeches and Congressional reports to identify the timing, size, and motivation of tax policies. Our work may also be seen in the tradition of research exploiting episodes of high political uncertainty or turmoil as instruments for macroeconomic shocks. Piffer and Podstawski (2018), for example, identify uncertainty shocks using intra-day changes in the price of gold around geopolitical events. Lagerborg et al. (2022) investigate the effects of consumer sentiment shocks on the U.S. macroeconomy, instrumenting changes in U.S. consumer confidence by fatalities of mass shootings. Similarly, we construct an instrument based on extraneous information about the timing of Brexit-related events and introduce this instrument into a structural VAR model of the UK economy.

The rest of the paper is structured as follows. Section 2 describes the construction of our Brexit instrument and discusses its properties and implications for daily changes in UK economic policy uncertainty and asset prices. Section 3 details the estimation and identification of the structural VAR model. Section 4 presents the VAR-based empirical results, discusses their policy implications, and presents the results of a counterfactual experiment, in which we shut down the endogenous response of UK monetary policy to Brexit shocks. In Section 5, we discuss the results of a number of robustness checks regarding the construction of our Brexit instrument, the identification or monetary policy shocks, and the choice of UK macroeconomic indicators. Section 6 concludes.

2 Constructing a Brexit Instrument

In this section, we describe the construction of our Brexit instrument, starting with the data and the econometric methodology. We discuss the properties of our instrument and its monthly time aggregate, which we then embed into a structural VAR model of the UK economy in Section 3.

2.1 Brexit events, policy uncertainty and asset prices

The starting point for our Brexit instrument is an official list of noteworthy political and diplomatic events summarized in the *House of Common's Briefing Paper* Number 7960 by Nigel Walker, entitled "Brexit timeline: events leading to the UK's exit from the European Union" and dated January 6, 2021. This document lists and briefly describes 443 political events between January 23, 2013 and March 8–11, 2021 (scheduled at the time the Briefing Paper was released), including the Brexit referendum on June 23, 2016. It is important to note that some of the events may take place on more than one day, such as the European Council meeting on June 28–29, 2016, for example.[1] To quantify the importance of each of these events, we consider daily changes in UK economic policy uncertainty and asset prices, building on recent advances in the identification of monetary policy shocks based on high-frequency interest rate changes.

[1] These days are treated as separate events at the daily frequency, while our weighting scheme prevents double-counting events in the monthly time aggregate of the Brexit instrument series.

As a measure of UK economic policy uncertainty (EPU), we employ the daily version of the newspaper-based EPU index for the United Kingdom constructed as discussed in Baker et al. (2016).[2] The daily UK EPU index peaks in the aftermath of the Brexit referendum as well as on May 17, 2017, for example, after the Labour party had launched its 2017 General Election manifesto, pledging to scrap the Conservatives' Brexit White Paper and replace it with fresh negotiating priorities to retain the benefits of the Single Market and the Customs Union and to guarantee existing rights for all EU nationals living in Britain (see Figure 1).

Fluctuations in the demand for UK financial assets and the general confidence in the UK economy are measured by daily changes in the nominal effective exchange rate (NEER) of the pound sterling against the currencies of 60 economies trading with the UK. Daily quotes of this broad NEER concept are provided by the Bank for International Settlements (BIS) starting in April 1996.

As a proxy for changes in current and expected future discounted profits of UK firms, we consider daily changes in the closing prices of the FTSE 100 stock market index. It is important to note that the FTSE 100 is not strongly trending during our sample period, climbing from 6,277 in January 2013 to 7,286 index points in January 2020. All variables are standardized before quantifying the importance of Brexit-related events.

2.2 Quantifying Brexit events

Given the large number of Brexit-related events listed — on average an event occurred every 6.6 days — we quantify them according to their immediate effects. For this purpose, we propose a novel approach based on daily observations of UK asset prices, exchange rates, and the EPU index constructed in Baker et al. (2016), motivated by the high-frequency identification of monetary policy shocks.

In the literature, bad news related to Brexit have been found to result in an increase in economic policy uncertainty (Bloom et al., 2019), a depreciation of the pound sterling

[2] The index draws on the digital archives of *Access World News'* NewsBank service, which features about 650 large national and small local UK newspapers, starts in 2001, and is publicly available from www.policyuncertainty.com. The index is based on the daily count of articles mentioning at least one term from each of three sets, i.e. 1. economic or economy, 2. uncertain or uncertainty, and 3. spending, deficit, regulation, budget, tax, policy, or Bank of England, and is normalized by the total number of articles published to control for the growing number of newspapers featured in NewsBank over time.

(Forbes et al., 2018), and a deterioration of the UK stock market (Hudson et al., 2020). In the spirit of Jarociński and Karadi (2020), we consider more than one dimension of high-frequency data in order to sign and quantify the importance of Brexit-related events.[3] Specifically, we weight each event by the arithmetic mean of the subsequent *increase* in the UK EPU index and *decrease* in the NEER and FTSE 100, respectively, expressed in terms of their sample standard deviations. A positive value of one thus indicates that the EPU index increased, while the NEER and the FTSE 100 fell by one standard deviation, on average, signalling bad news related to Brexit. Conversely, a negative value indicates rather favorable news related to Brexit, given that at least one of the variables moves in the opposite direction. Thus, a minor increase in the EPU index may be more than offset by a simultaneous increase in the NEER or FTSE 100, and vice versa.

Like Känzig (2021a,b), who studies OPEC announcements, we consider daily changes rather than changes in a narrow *intra-day* time window around the events for two main reasons. First, there is no intra-day data on economic policy uncertainty, which is crucial for our quantifying strategy. Second, in contrast to the official announcements following each monetary policy meeting by the U.S. Federal Open Market Committee (FOMC) or the Governing Council of the European Central Bank (ECB), for example, which follow a regular schedule and may thus be timed precisely even within the day of their occurrence, the events on the Brexit timeline differ both in their nature and timing within the day(s) of their occurrence.[4] Focusing on a shorter time window is therefore impracticable.

The fact that we rely on the newspaper-based UK EPU index of Baker et al. (2016) moreover implies that potentially important events may be covered by the national press and thus show up in their index *with a lag* of at least one (business) day. For this reason, we sign and quantify each event based on the arithmetic mean of the cumulated change in the EPU index and the closing prices of the UK NEER and FTSE 100 between day

[3]Jarociński and Karadi (2020) impose opposite sign restrictions on the impulse responses of federal funds rate futures and the S&P 500 in a narrow time window around the U.S. Federal Reserve's FOMC announcements to distinguish between exogenous interest rate changes and a signalling or information channel of monetary policy. Similarly, we assume that relevant news related to the Brexit referendum and subsequent negotiations induce a negative comovement of UK policy uncertainty and asset prices around the time of the event.

[4]For example, David Cameron announced his intention to resign as UK Prime Minister following the referendum outcome on Friday morning, June 24, 2016, whereas the fourth round of negotiations on the UK-EU future relationship lasted for four days on June 2–5, 2020.

$t-1$ and day $t+1$, where t indicates the day of the event. Thus, we interpret rather generously the term "high-frequency", since we are ultimately interested in the impulse response functions of UK macroeconomic aggregates at the monthly frequency.[5]

Formally, our quantitative measure of the effect of an event on variable x is given by

$$quant_t^x = event_t \cdot \frac{1}{2} \cdot \sum_{i=0}^{1} \left(\frac{x_{t+i} - x_{t-1}}{\sigma_x} \right), \qquad x \in \{EPU, NEER, FTSE\} \tag{1}$$

where $event_t$ denotes an indicator variable that equals unity, if the official Brexit timeline lists an event on day t and zero else, while σ_x denotes the sample standard deviation of daily changes in the variable x. The daily Brexit instrument is then computed as

$$quant_t^{all} = \frac{1}{3} \cdot \left(quant_t^{EPU} - quant_t^{NEER} - quant_t^{FTSE} \right). \tag{2}$$

A monthly time aggregate of this instrument is included in the structural VAR model of the UK economy described in Section 3 below.[6]

2.3 Inter-day changes around Brexit events

Before evaluating the dynamic effects of our Brexit instrument on the UK macroeconomy, we inspect the properties of the former. Given that the official timeline of Brexit events was compiled to inform policy makers, it is not obvious ex ante that the listed events are also economically meaningful. We therefore investigate whether Brexit event days are systematically different from "normal" days.

Figure A.2 plots the kernel density estimates of daily changes in the UK EPU, NEER, and FTSE 100 and illustrates that financial markets are substantially more volatile both upwards and downwards following Brexit event days relative to days without a Brexit-related event. In the latter case, the distribution of innovations in the NEER and FTSE 100 is much more concentrated around zero with thinner tails, indicating that event days are associated with larger-than-normal changes in asset prices, on average.

[5] Considering changes in the EPU index and closing prices between day $t-1$ and day t, instead, we are likely to underweight events, the news about which became public *after markets closed* on day t. In the robustness checks, we replicate our main results based on this shorter alternative observation window.

[6] This approach to quantifying Brexit-related events has the advantage that the monthly instrument introduced in the VAR model is observed rather than estimated and thus *not a generated regressor*.

Panel (a) of Figure 2 plots the daily time series of Brexit events quantified as described in equations (1) and (2). While the events are spread across the entire period following the referendum, and our measurement yields adverse and favorable events, the "Leave" vote apparently dwarves all other events in terms of its simultaneous effects on the UK EPU, NEER, and FTSE 100. Figure A.3 in the appendix plots the impulse responses of daily changes in the EPU, NEER, and FTSE 100 to a one-standard-deviation Brexit event and illustrates that, on average over the sample period, an adverse event significantly raises economic policy uncertainty and lowers asset prices both on day t and day $t+1$.

Panel (b) of Figure 2 illustrates that, once we aggregate the quantified daily events to monthly frequency, the referendum remains the largest realization by far. It is important to note that the monthly series in panel (b) is a time aggregate of the daily events in panel (a) rather than quantified based on monthly UK EPU, NEER, and FTSE 100 data. This monthly time series serves as an instrument for Brexit shocks in our structural VAR model of the UK economy.

Next we check for potential anticipation effects. An obvious concern is that many of the Brexit-related events on the official timeline were publicly known well in advance of the scheduled date.[7] While this is equally true for scheduled FOMC meetings used in the identification of monetary policy shocks (see, e.g., Jarociński and Karadi, 2020) and OPEC announcements used to identify oil supply news shocks (see Känzig, 2021a), one may be concerned that the *outcomes* of political and diplomatic events are anticipated at least partially by the press, the public, or financial markets. Given that we quantify Brexit events only by their unanticipated effects on the UK EPU, NEER, and FTSE 100, our findings are likely conservative estimates of the overall effects of these events.

In order to test for anticipation effects, we reconsider the distributions of daily changes in the UK EPU, NEER, and FTSE 100 leading up to Brexit event days and compare them with the distributions of daily changes prior to "normal" days. Figure A.4 in the appendix plots the corresponding Kernel density estimates and illustrates that, in contrast with those *following* Brexit event dates in Figure A.2, we find little evidence of abnormal returns on the NEER and FTSE 100 *prior to* Brexit events. If anything, daily

[7]This does not hold for the Emergency Debates in the House of Commons in December 2018 or the Prime Minister's request for an extension of the Article 50 period to June 30 in a letter to the European Council's President Donald Tusk on March 20, 2019, for example.

changes in the FTSE 100 are somewhat more concentrated around zero on the two days leading up to a Brexit event relative to days with no Brexit event.

Moreover, we extend the Jordà (2005) projection results in Figure A.3 by including seven leads (rather than just lags) in our regression of daily changes in the UK EPU, NEER, and FTSE 100 on the Brexit instrument. Figure A.5 plots the corresponding impulse response functions with one- and two-standard-error block bootstrap confidence bands. While we observe a few statistically significant coefficient estimates on the Brexit instrument for the UK EPU and NEER, they are of the opposite sign, i.e. negative at lead 1 for the EPU and positive at lead 4 for the NEER. Instead, the FTSE 100 does not display any abnormal returns during the seven days leading up to a Brexit event.

We therefore conclude that Brexit-related political and diplomatic events are economically meaningful, leading to abnormal returns on the UK nominal effective exchange rate and the FTSE 100, and reveal new information to the press and financial markets on (or directly after) event days rather than during the days leading up to an event.

3 The VAR Model

In this section, we discuss the macroeconomic indicators and the econometric methodology used in our structural vector-autoregressive (VAR) model of the UK economy.

3.1 UK macroeconomic indicators

To quantify the potential effects of Brexit shocks on the UK economy, we employ a structural VAR approach featuring indicators of national output, inflation, and interest rates at the monthly frequency. As a measure of national output, we use the monthly estimate of gross domestic product (GDP) at constant prices for the UK provided by the Office for National Statistics (ONS). To capture price dynamics in the UK, we consider the consumer price index (CPI) for all items provided by the ONS.[8]

Since our sample period largely coincides with the zero lower bound (ZLB) episode, the UK official interest rate is unlikely to reflect adequately the monetary policy stance

[8] Alongside other short-term indicators, the ONS provides a rare monthly estimate of UK GDP. The monthly GDP estimate (MGDP) is available here. The CPI index for all items (L522) is available here.

of the Bank of England.[9] For this reason, and following a large literature considering shadow rates as an appropriate proxy for the policy stance inside and outside the ZLB (see e.g. Ramey, 2016; Bernanke, 2020), we instead consider the UK shadow short rate (SSR) by Krippner (2015). The SSR captures the Bank of England's monetary policy stance in both conventional and unconventional monetary policy environments, and may also take on negative values.[10] Figure A.6 in the appendix plots the UK SSR against the Bank of England base rate and illustrates that both series are similar prior to the ZLB while they diverge after 2009 where the latter is close to zero.

Finally, we capture fluctuations in private households' expectations about economic conditions by including a survey measure of UK consumer confidence constructed by the GfK and made available through the OECD among our macroeconomic indicators.

3.2 Model and identifying assumptions

In this subsection, we lay out the identifying assumptions and Bayesian estimation algorithm for our structural VAR model of the UK macroeconomy. Consider first its structural representation,

$$A_0 x_t = \alpha + \sum_{l=1}^{p} A_l x_{t-l} + \varepsilon_t, \tag{3}$$

where x_t denotes the vector of endogenous variables, α a vector of intercept terms, A_l the matrix of structural coefficients at lag l, and ε_t a vector of serially and mutually uncorrelated structural shocks. In our baseline specification, the vector of endogenous variables, x_t, contains month-t observations of the Brexit instrument series in Section 2, the year-on-year growth rate of monthly GDP, the CPI inflation rate, Krippner (2015)'s

[9] After the global financial crisis, central banks were effectively constrained by the ZLB and resorted to unconventional monetary policy tools such as (more) explicit forward guidance and quantitative easing, for example. Following the bankruptcy of Lehman Brothers in September 2008, the Bank of England set the UK official interest rate at or close to zero for the remainder of our sample period (see, e.g., a recent Research Briefing from the House of Commons Library).

[10] Krippner (2015) applies the two-factor arbitrage-free model of Nelson and Siegel (1987) to market-quoted interest rates of different maturity in order to separate a "physical currency option effect" from an effectively unconstrained "shadow yield curve" (see Krippner, 2020). The SSR represents the shortest-maturity interest rate on this shadow yield curve. While it is an estimated rather than an observed market rate, at which borrowers and lenders can transact, it has the intuition of a single interest rate and provides a consistent measure for the stance of UK monetary policy during our sample period. The regularly updated estimates of the UK SSR and a documentation of its construction are available from the author's webpage.

shadow short rate, and the consumer confidence indicator for the UK. We use year-on-year growth rates of the GDP index and CPI, as these variables are trending over time. The chosen transformations are intended to facilitate meaningful historical decompositions, which require that all variables are stationary (see Kilian and Lütkepohl, 2017).

The reduced-form representation of the structural VAR model in (3) is given by

$$x_t = c + \sum_{l=1}^{p} B_l x_{t-l} + e_t, \tag{4}$$

where c denotes the vector of reduced-form intercept terms, B_l the matrix of reduced-form coefficients at lag l, and e_t a vector of possibly contemporaneously correlated residuals with covariance matrix $\Sigma_e = E(e_t e_t')$. We estimate the VAR model using Bayesian methods and imposing a flat prior. We consider $p = 12$ lags in monthly data to allow for a delayed transmission of Brexit shocks to the UK economy.

Our identifying strategy aims at tracing and characterizing the effects of Brexit shocks on UK macroeconomic aggregates. To gauge their quantitative importance and allow for counterfactual experiments, we furthermore identify a set of conventional macroeconomic shocks with combination of zero and sign restrictions. Plagborg-Møller and Wolf (2021) show that a block-recursive identification scheme with the instrument ordered first yields consistent impulse response functions even in the presence of measurement error. Moreover, the combination of zero and sign restrictions permits variance decompositions, which are readily comparable across different structural shocks. Table 1 summarizes our identifying restrictions. The block-recursive structure presumes that the Brexit instrument is *contemporanously predetermined* with respect to UK domestic variables, which seems plausible, as the former is derived from extraneous information and daily data. We do not impose any further restrictions on the impulse responses to a typical Brexit shock.

Within the UK domestic block, we identify conventional macroeconomic shocks using sign restrictions on impulse response functions in line with economic theory, as proposed by Uhlig (2005). In response to an adverse aggregate demand (AD) shock, economic activity and inflation must decline. We thus restrict UK GDP growth and CPI inflation to fall. According to a standard Taylor rule, the central bank responds to this shock by lowering the interest rate. Hence, we further restrict the UK SSR to fall. An aggregate supply (AS) shock — i.e. an exogenous shift of the Phillips curve, such as a price mark-up shock, wage mark-up shock, or technology shock (see, e.g., Smets and Wouters, 2007) — moves economic activity and inflation in opposite directions. In line with this prediction, we restrict GDP growth to fall and CPI inflation to rise, while we do not restrict the response of the SSR. Finally, UK monetary policy (MP) shocks are identified by a surprise increase in the SSR and a simultaneous fall in GDP growth and CPI inflation. All sign restrictions are consistent with standard New Keynesian DSGE models (see, e.g., Smets and Wouters, 2005, 2007) and commonly used in the empirical business cycle literature (Fry and Pagan, 2011). They are imposed as weak inequality restrictions on impact and for three consecutive months.

Given the recent critique that the approach of Uhlig (2005) "retains many structural parameters with improbable implications for the systematic response of monetary policy to output" (Arias et al., 2019), we augment our identification of MP shocks based on traditional sign restrictions with extraneous information about the UK monetary policy stance during selected historical episodes by imposing so-called *narrative sign restrictions* (Antolín-Díaz and Rubio-Ramírez, 2018; Ludvigson et al., 2021). Specifically, we assume that the effect of MP shocks on the UK SSR was negative in August 2001, February 2003, and November 2008, consistent with the results in both Cloyne and Hürtgen (2016) and Cesa-Bianchi et al. (2020) based on a narrative identification approach à la Romer and Romer (2004) and high-frequency identification à la Gürkaynak et al. (2005a,b), respectively.[11] Figure A.7 in the appendix illustrates that the Bank of England base rate and the UK SSR comove closely during all three historical episodes.

3.3 Estimation algorithm

We estimate the reduced-form VAR model using Bayesian techniques. Assuming that the data are generated by a multivariate Gaussian process and that the prior distribution has a flat Normal-Wishart density, the posterior distribution is also Normal-Wishart distributed. The location parameters of the posterior distribution are summarized by the

[11] It is important to note that neither the narrative data sources used in Cloyne and Hürtgen (2016) nor the high-frequency data used in Cesa-Bianchi et al. (2020) are readily available for the period after the UK referendum on EU membership. For this reason, we rely on narrative sign restrictions.

coefficient matrix $B = [B_1, \ldots, B_L]'$ and the covariance matrix Σ_e.

To identify structural shocks using both zero and sign restrictions on impulse response functions and narrative restrictions, we apply the algorithm proposed by Arias et al. (2018) and Arias et al. (2019), which yields a set of permissible models, for which the structural shocks are mutually orthogonal and all sign and zero restrictions are satisfied simultaneously. The procedure is as follows: Draw a set of parameters from the posterior distribution of the reduced-form VAR model. Multiply the Cholesky factor P of the reduced-form covariance matrix $\Sigma_e = PP'$ by a random orthogonal matrix Q, where $Q'Q = I$ and the zero restrictions in Table 1 hold by construction, to obtain the alternative decomposition $\Sigma_e = PQQ'P'$ of the covariance matrix. Pre-multiplying the reduced-form shocks by $(PQ)^{-1}$ then yields a new set of mutually orthogonal shocks, $\epsilon_t = (PQ)^{-1}e_t$, for which we can check whether the sign restrictions on impulse response functions and the narrative restrictions are satisfied. Since the restrictions truncate the likelihood function of the reduced-form parameters, we follow Arias et al. (2018) and Arias et al. (2019), and reweigh the posterior distribution of the structural parameters through appropriate importance weights. We iterate this algorithm a large number of times and obtain more than 1,000 admissible models for each specifications.[12]

4 Empirical Results

In this section, we present the empirical results based on monthly data and the structural VAR model of the UK economy in Section 3.

4.1 Impulse response analysis

We now turn to the results based on the structural VAR model of the UK economy in (3). Figure 3 plots the impulse response functions of the endogenous variables in the vector x_t to a typical, i.e. one-standard deviation, positive innovation in the Brexit instrument

[12]Given that the model is set-identified, the prior is only flat over the reduced-form coefficients but not necessarily over the structural coefficients, as the decomposition of the variance-covariance matrix Σ_e using random orthogonal matrices Q, where $Q'Q = I$, incorporates an implicit prior distribution (see Baumeister and Hamilton, 2015). However, Giacomini and Kitagawa (2021) show that inference is less sensitive to the distribution of Q, if zero restrictions are imposed in addition to sign restrictions, as in our model.

as well as to a negative aggregate demand, negative aggregate supply, and contractionary monetary policy shock, respectively. We report point-wise medians together with the 66^{th} and 90^{th} percentiles of the posterior distribution of impulse response functions based on all admissible models. It is important to note that UK GDP and CPI are transformed to *year-on-year* growth rates.

Considering first the impulse responses to conventional aggregate demand (AD), aggregate supply (AS), and monetary policy (MP) shocks, we find that they are consistent with stylized business cycle facts and well in line with the literature (see Fry and Pagan, 2011; Geiger and Scharler, 2021). The impulse response functions of GDP growth are most persistent for a typical AS shock, whereas the MP shock exerts a relatively short-lived effect. The effect of a typical AS shock on the shadow short rate (SSR) is ambiguous. While the SSR follows a hump-shaped response, as the shock sets in, it undershoots after approximately six months, as the inflation rate returns to its long-run mean. Consistent with the negative effect on GDP growth, a typical AS shock also exerts downward pressure on UK consumer confidence that is particularly pronounced around six months after the shock.

We are mainly interested in the macroeconomic implications of a typical Brexit shock in the first line of Figure 3. Recall that this shock is identified by the block-recursive structure of the VAR model, while we do *not* impose any sign or zero restrictions on the impulse response functions of the endogenous variables. The leftmost panel illustrates that a typical Brexit shock exerts a modest and temporary negative effect on UK GDP growth. In the short run, CPI inflation tends to fall slightly, yet picks up approximately six months after the shock. Both for the drop in GDP growth and CPI inflation, the zero line is not included in the 66% posterior credible sets of the impulse response functions. Interestingly, we observe a more pronounced and persistent effect on the UK SSR, the impulse response function of which drops gradually and remains negative for at least one year, indicating a pronounced accommodative monetary policy response by the Bank of England. Similarly, UK consumer confidence drops sharply, in particular after one and two months, and tends to remain in negative territory. In either case, the zero line is not included in the 90% posterior credible sets for at least part of the subsequent year.

In the literature, Brexit is often associated with an exogenous increase in economic and political uncertainty. Consistently, in this paper, Brexit shocks are partly identified by their high-frequency effects on the daily EPU index of Baker et al. (2016). It is therefore conceivable that an adverse Brexit shock is primarily propagated through a reduction in aggregate demand. In fact, Leduc and Liu (2015) characterize uncertainty shocks as AD shocks. While the impulse responses of GDP growth, the SSR, and consumer confidence are qualitatively in line with an exogenous shift of the AD curve along the AS curve, the dynamics are somewhat different. The fact that all impulse response functions peak within one to three months after the shock indicates that the pass-through of Brexit shocks is rather swift, which might not be surprising given the salient nature of Brexit developments and media coverage. In contrast to a conventional AD shock, the Brexit shock also tends to raise rather than lower CPI inflation in the medium run, which might be due to Brexit-induced changes in the UK's terms of trade, for example.[13]

4.2 Historical decompositions

Next we investigate the importance of Brexit shocks relative to conventional macroeconomic shocks in the UK business cycle. Figure 4 plots the contribution of Brexit shocks to historical fluctuations of UK macroeconomic variables, where each line corresponds to the contribution of a structural shock to the deviation of the respective variable from the model's base projection in the absence of shocks. As before, we report point-wise medians of the estimated posterior distribution of admissible models. The contributions of AD, AS, and MP shocks are included as a benchmark against which we gauge the historical importance of Brexit shocks.

Consider first the contributions to fluctuations in UK GDP growth. Following the referendum in June 2016, Brexit shocks exerted substantial downward pressure on UK GDP growth. During 2017, the contribution reverted to zero and even remained slightly positive during 2017, before dropping off sharply in 2018. Interestingly, we observe the largest and most persistent effects on UK GDP growth during 2018, after a sequence of quantitatively small adverse shocks had hit the UK economy. The largest individual drop in year-on-year real GDP growth of $-.69\%$ occurs in February 2018. This corroborates

[13] In the robustness checks, we replace CPI inflation by PPI inflation to investigate this channel further.

the notion that the economic costs of Brexit are the result of a slowly evolving process of disintegration rather than the result of the "Leave" vote itself.

Turning to fluctuations in CPI inflation illustrates that the relatively minor impulse responses to a typical Brexit shock in Figure 3 accumulate to non-trivial contributions to the historical decomposition in Figure 4. The short-lived downward pressure on CPI inflation in the direct aftermath of the referendum is quickly offset by quantitatively large inflationary pressures during 2017, consistent with the overshooting pattern of impulse response functions. In comparison with conventional macroeconomic shocks, Brexit shocks seem to be the dominant driver of CPI inflation during 2017. On average over the sample period, we observe more inflationary than deflationary episodes due to Brexit shocks.

As discussed above, the impulse response function of the UK shadow short rate (SSR) — a proxy for the Bank of England's monetary policy stance at the zero lower bound — to a typical Brexit shock is surprisingly large and persistent. This finding translates into a large contribution to the historical fluctuations in the SSR in Figure 4 both in absolute and relative terms. During the second half of 2016 and throughout 2018, the Bank of England appears to respond to Brexit shocks by substantially easing its monetary stance, as indicated by a reduction in the SSR by up to -0.67 and -0.57 percentage points in 2016 and 2018, respectively. Following either episode, the contribution to the SSR returned to zero only gradually and turned positive in the second half of 2017.

We finally consider to the contribution of Brexit shocks to fluctuations in UK consumer confidence. The bottom-right panel of Figure 4 illustrates that Brexit shocks had strong and predominantly negative effects on consumer confidence both in absolute terms and relative to conventional macroeconomic shocks. Following the referendum in June 2016 as well as between mid-2017 and mid-2018, in particular, consumer confidence was depressed by up -2.86 and -3.52 index points, respectively, while the contributions of AD, AS, and MP shocks were moderately positive or close to zero. Even though the cumulated effects of Brexit shocks to historical fluctuations may seem somewhat erratic, their repeated occurrence exerted substantial drag on UK consumer confidence after the referendum.

Summing up, the withdrawal process likely contributed substantially to the UK business cycle in the period after the referendum. During certain episodes, Brexit shocks were the single most important driver of fluctuations in UK output, inflation, interest rates, and consumer confidence. Moreover, our historical decompositions suggest that focusing on the referendum as a self-contained event while ignoring the subsequent negotiations between the UK and the EU does not fully account for the economic volatility and costs that were due to the withdrawal process.

4.3 Discussion of results

Important recent contributions (see, e.g., Born et al., 2019; Faccini and Palombo, 2021) consider Brexit as a self-contained shock to the UK macroeconomy that coincides chronologically with the EU membership referendum on June 23, 2016, while the effects of this shock materialized gradually over time. However, this seems at odds with the notion that the economic and political consequences of "Brexit" became clear only *after* the referendum, as UK and EU representatives started to negotiate the conditions of a withdrawal agreement. Given the extent of the challenge, it comes as no surprise that UK-EU negotiations necessitated a multitude of rounds leading to slow progress and occasional regress, subsumed under the term *Brexit shocks* in this paper.

Figure A.1 in the appendix suggests that the UK economic policy uncertainty (EPU) index of Baker et al. (2016), the nominal effective exchange rate, and the FTSE 100 were jointly affected around numerous political events related to Brexit. While the referendum in June 2016 emerges as the single most important event both at the daily and monthly frequency in Figure 2, our instrument series builds on more than 400 events related to Brexit between January 2013 and December 2020.

Accordingly, our regression-based estimates in Figure 3 show that, after controlling for conventional macroeconomic shocks in a structural VAR model of the UK economy, a typical Brexit shock has a moderate negative effect on year-on-year real GDP growth, while an initial drop is followed by a pronounced increase in CPI inflation during the subsequent twelve months. Most importantly, the shock exerts strong downward pressure on Krippner (2015)'s UK shadow short rate (SSR) and consumer confidence. In contrast to Born et al. (2019), for example, we find that Brexit shocks predominantly lead to lower consumer confidence in the short and higher CPI inflation in the medium run, while a larger effect on GDP growth might have been avoided by means of an endogenous monetary policy easing in an environment of historically low interest rates.

Consistently, the VAR-based historical decompositions in Figure 4 suggest that Brexit shocks exerted persistent downward pressure on UK GDP and the SSR during the second half of 2016 and throughout 2018. In contrast, the contribution to historical fluctuations of CPI inflation turned from negative in the months directly following the EU membership referendum to large and positive from 2017 onwards. The contribution of Brexit shocks to UK consumer confidence was generally negative from mid-2016 until mid-2019.

4.4 Narrative evidence

Our VAR-based results suggest that the Bank of England may have fended off a stronger contraction of UK GDP at the expense of transitorily higher CPI inflation during 2017. Implicitly, this corresponds with a shift in its monetary policy paradigm from stabilizing inflation towards stabilizing output. To see whether there is narrative evidence for such a shift, we conduct a quantitative text analysis of the Bank of England's "Monetary Policy Summary and minutes of the Monetary Policy Committee (MPC) meetings", searching each MPC meeting's summary and minutes for a fixed set of terms relating to Brexit, inflation, output, and financial markets, respectively, and computed their frequencies as a fraction of total words.[14] The search terms are summarized in Table A.2 in the appendix, while the resulting indices are plotted in Figure 5.

Panel (a) of Figure 5 illustrates that the relative frequency of terms relating to Brexit, including very general terms such as "European Union" or "membership", for example, rose sharply on the eve of the referendum in 2016 and spiked again during its aftermath, in particular during 2019. Panel (b) shows that terms relating to "inflation", "output", and "financial markets", respectively, accounted for a relatively stable fraction of total words prior to the referendum. Following a moderate increase in the first half of 2016, the frequency of terms relating to financial markets, including "exchange rate", spiked in June and September, attaining higher levels than during the Great Financial Crisis. During 2017 and 2018, the fraction of terms relating to financial markets roughly returned to its average pre-referendum level. With regard to terms relating to "inflation" and "output",

[14] The respective documents are available since the July 1997 meeting from www.bankofengland.co.uk.

we observe qualitatively different dynamics. While both word counts display a tendency to increase in the aftermath of the referendum, the relative frequency of terms relating to inflation drops off sharply in 2018, whereas that of terms relating to output continues to increase throughout the rest of our sample period.

Interpreting these frequencies as indicators for the Bank of England's priorities in the conduct of monetary policy or, in theoretical terms, as the relative size of the Taylor-rule coefficients on inflation, the output gap, and financial markets, the negotiations on the withdrawal agreement indeed seem to coincide with two shifts in the Bank's paradigm — directly after the referendum from stabilizing inflation and output to stabilizing financial markets, and in 2018 from stabilizing inflation to stabilizing output. The changes in the relative importance of our three word count indices also coincide with the two episodes of monetary policy easing attributed to Brexit shocks in Figure 4.[15] Moreover, they are consistent with the MPC's own assessment, as documented by the following quote from the Monetary Policy Summary of February 2017:

> *Attempting to offset fully the effect of weaker sterling on inflation would be achievable only at the cost of higher unemployment and, in all likelihood, even weaker income growth. For this reason, the MPC's remit specifies that in such exceptional circumstances the Committee must balance the trade-off between the speed with which it intends to return inflation to the target and the support that monetary policy provides to jobs and activity. At its February meeting, the MPC continued to judge that it remained appropriate to seek to return inflation to the target over a somewhat longer period than usual, and that the current stance of monetary policy remained appropriate to balance the demands of the Committee's remit.*

4.5 Counterfactual experiment

Our previous findings suggest that the Bank of England fought against the contraction of UK output in the aftermath of the referendum. To investigate whether this interpreta-

[15]This is particularly notable, given that the Bank of England was among the first central banks to adopt inflation targeting in October 1992, after the UK had left the European Exchange Rate Mechanism. In 1998, the MPC was given sole responsibility for setting interest rates in order to meet an inflation target of 2.5% for the retail price index, which was lowered to 2.0% in December 2003.

tion is consistent with our structural VAR model and quantify its potentially stabilizing effects, we conduct a counterfactual experiment, in which we shut down the endogenous response of UK monetary policy to Brexit shocks. Specifically, we replicate the impulse response functions in Figure 3 and the contributions to historical fluctuations of UK macroeconomic variables in Figure 4, while offsetting the effects of Brexit (BXT) shocks on the UK shadow short rate by a suitable sequence of monetary policy (MP) shocks.[16]

Figure 6 plots pointwise posterior medians of the counterfactual impulse response functions against our baseline estimates based on the structural VAR model in (3) and illustrates that, without the endogenous response of the Bank of England, the median response of year-on-year GDP growth falls by an additional 5 basis points relative to the baseline scenario and remains subdued over the subsequent 12 months. Similarly, the median response of year-on-year CPI inflation falls by more than in the baseline scenario and overshoots by less during the subsequent 12 months. In contrast, the marginal effect on the median response of consumer confidence is slightly positive.

Regarding the counterfactual median contributions to the historical decomposition in Figure 7, shutting down the endogenous response of the UK shadow short rate temporarily leads to a substantially stronger negative contribution of Brexit shocks to UK GDP growth and CPI inflation in late 2016 and during 2018. Specifically, the contribution to GDP growth falls from $-.38$ to $-.66$ (74%) in July 2016 and from $-.69$ to $-.97$ (41%) in February 2018, while the contribution to CPI inflation falls from $-.25$ to $-.36$ (44%) in July 2016 and from $-.13$ to $-.22$ (41%) in May 2018.[17] Consistent with the counterfactual impulse response function in Figure 6, the marginal effect on UK consumer confidence

[16] Offsetting the effect of Brexit shocks on the impulse response function and historical decomposition of the UK shadow short rate ensures a unique solution for the required sequence of MP shocks. For a formal representation of the construction of the counterfactual, see Section A.1.1 in the appendix.

[17] From back-of-the-envelope calculations, the cumulated real GDP loss in July 2018 due to Brexit shocks in our baseline scenario amounts to

$$\left[\left(1+\hat{x}_{t,\mathrm{GDP}}^{\mathrm{BXT}}\right)\cdot\left(1+\hat{x}_{t-12,\mathrm{GDP}}^{\mathrm{BXT}}\right)\cdot\left(1+\hat{x}_{t-24,\mathrm{GDP}}^{\mathrm{BXT}}\right)-1\right]\cdot 100=-.79\%,$$

where $\hat{x}_{t,\mathrm{GDP}}^{\mathrm{BXT}}$ denotes the contribution of Brexit shocks to year-on-year real GDP growth in month t, as defined in equation (A.2) in the appendix. We set t to July 2018, so that $t-12$ denotes July 2017 and $t-24$ July 2016. Without the stabilizing response of UK monetary policy, the cumulated real GDP loss in July 2018 relative to the pre-referendum period equals -1.09%, or about half of the 1.7–2.4% drop in UK GDP associated with the "referendum shock" in Born et al. (2019). In contrast to the latter, the effects in this paper are based on the sequence of explicitly identified positive and negative Brexit shocks rather than a synthetic control approach, which requires the construction of a "Doppelganger" for the UK economy.

is less systematic and slightly positive in late 2016 and during 2018. Our counterfactual experiment therefore suggests that the Bank of England successfully stabilized both GDP growth and CPI inflation in late 2016 and during 2018.

5 Robustness and Additional Analyses

We conduct a number of robustness checks in order to evaluate the sensitivity of our results with respect to the construction of the Brexit instrument and the identification of the VAR model. In addition, we consider alternative measures of real economic activity and inflation. Figure 8 summarizes the corresponding impulse response functions to a typical adverse Brexit shocks. Moreover, we report the actual and counterfactual — i.e. shutting down the endogenous response of UK monetary policy — contributions of Brexit shocks to historical fluctuations of UK GDP growth, CPI inflation, the shadow short rate (SSR), and consumer confidence in Figures A.10 and A.11 in the appendix.

As a first series of checks, we replicate our main analysis using variations of the Brexit instrument, while leaving the specification of the structural VAR model unchanged. Panel (a) of Figure 8 plots the respective posterior median impulse response functions against the posterior distribution of impulse response functions for the baseline model. In our preferred version of the instrument, events related to Brexit are quantified based on average standardized changes in the daily UK economic policy uncertainty (EPU) index, the nominal effective exchange rate (NEER), and the FTSE 100 between day $t-1$ and day $t+1$. The green line with x-markers instead refers to a version of the instrument, which quantifies Brexit events based on standardized changes between $t-1$ and t, thus considering only the immediate reflection of the events in media coverage and asset prices *on the same day*. The blue broken line corresponds to a version of the instrument that only accounts for a subset of all events related to Brexit, for which we impose the expected comovement in the daily data — i.e. an increase in the EPU and decreases in the NEER and FTSE 100 in response to adverse news about Brexit, and vice versa for favorable news — as explicit sign restrictions, thus *selecting* rather than just *quantifying* events, which plausibly have a clear interpretation of being either adverse or favorable.[18] Figure A.9 in the appendix plots the monthly time series of *selected* Brexit events quantified according to (1) and (2) against our baseline Brexit instrument series. From Panel (a) it is evident that the impulse response functions to a typical adverse Brexit shock are qualitatively robust and quantitatively very similar to alternative approaches to quantifying and selecting events in the construction of the Brexit instrument. Interestingly, the endogenous response of UK monetary policy, as measure by the SSR appears to be more pronounced when we consider only a subset of events, indicating that these selected events are also more salient to policy makers.

Panel (b) depicts impulse response functions based on alternative combinations of narrative restrictions imposed to identify monetary policy (MP) shocks. The green marked line corresponds to an identification strategy without narrative restriction, the blue broken line corresponds to a single narrative restriction, which requires that the MP shock contributed negatively to the value of the SSR in November 2008, while the cyan solid line imposes the additional quantitative restriction that the MP shock accounted for the largest negative contribution to the value of the SSR in November 2008. Panel (b) of Figure 8 illustrates that alternative narrative restrictions on the historical contribution of MP shocks have virtually no effect on the impulse responses to a typical adverse Brexit shock. Given that the two shocks are orthogonal, while Brexit shocks are identified by a block-recursive ordering, this does not come as a major surprise. Importantly, the implementation of narrative restrictions does not affect qualitatively the role of UK monetary policy in cushioning the real effects of Brexit shocks (see Panel (b) of Figure A.10), even though impulse responses to a typical MP shock vary with different narrative restrictions (see Figure A.12). This robustness underlines the generality of our baseline results.

Panel (c) and (d) of Figure 8 depicts impulse response functions when the producer price index (PPI) replaces CPI inflation and annual employment growth replaces GDP growth, respectively. Interestingly, the effects of a typical Brexit shock are substantially more pronounced in either case. In light of the import dependence of UK industrial production and the implications of Brexit on aggregate supply, PPI inflation increases immediately and by more than CPI inflation following an adverse Brexit shock, indicat-

[18]Our choice of sign restrictions builds on the findings in Forbes et al. (2018), Bloom et al. (2019), and Hudson et al. (2020), among others.

ing a potential increase in trade barriers or a worsening of the terms of trade. Moreover, Brexit shocks may have encouraged foreign employees to leave the UK, potentially reenforcing the adverse effects on employment growth and real economic activity.

6 Conclusion

By the general public and in recent academic work, the UK referendum on its EU membership is commonly considered as a self-contained event. In this paper, we show that the extent of political and economic challenges en route to a withdrawal agreement emerged only gradually in the aftermath of the referendum. This is in stark contrast to the assumption that the referendum represented a single, self-contained shock, the effects of which materialized over time (see, e.g. Faccini and Palombo, 2021).

Exploiting the comovement in daily data on UK stock prices, exchange rates, and an index of economic policy uncertainty (EPU), we construct an instrument for Brexit shocks by signing and quantifying candidate events from an official list published by the House of Commons Library. The resulting instrument series is consistent with the notion of the referendum as the most important event, while displaying non-trivial adverse and favorable realizations en route to Brexit.

Aggregating our daily instrument to monthly frequency and incorporating this series into a small-scale structural vector-autoregressive (VAR) model of the UK macroeconomy, we find that Brexit shocks contributed to lower GDP growth and consumer confidence as well as higher CPI inflation in the aftermath of the referendum, consistent with their interpretation as uncertainty shocks. Moreover, the VAR model assigns a sizeable negative contribution on the UK shadow short rate — a proxy for the Bank of England's monetary policy stance at the zero lower bound (see Krippner, 2015) — to Brexit shocks in the second half of 2016 and during 2018, respectively.

The latter episodes coincide with noticeable changes in the relative frequency of terms relating to output, inflation, and financial markets in the Bank of England's "Monetary Policy Summary and minutes of the Monetary Policy Committee meetings". Interpreting these frequencies as the respective weights on stabilizing output, inflation, and financial markets in a hypothetical Taylor-type monetary policy rule, we therefore document fundamental shifts in UK monetary policy in response to Brexit shocks.

The fact that numerous Brexit-related events rather than the "Leave" vote alone drove the UK business cycle during the withdrawal period has important policy implications. Given that the outcome of the referendum caught most policy makers and their advisers off guard, they were ill-prepared to manage its economic and political consequences. Part of the adverse Brexit shocks identified by our model and their effects on the UK economy could have been avoided by planning ahead for an unexpected, yet possible scenario. At the same time, our findings suggest that successful negotiations and diplomatic breakthroughs, such as the favorable Brexit shocks associated with the first post-referendum meeting of the European Council and the passing of the withdrawal agreement in January 2020, helped stabilizing the UK economy. The results in this paper illustrate both the cost of policy uncertainty and the leverage of policy making associated with Brexit.

We finally conduct a counterfactual experiment, in which we shut down the endogenous response of the UK shadow short rate to Brexit shocks. Taken together, our results suggest that the Bank of England fended off a much stronger contraction of UK GDP growth and CPI inflation in the aftermath of the referendum. In light of the documented shifts in the Bank's communication, this rebalancing of hypothetical Taylor-rule weights might well be optimal from a central bank's perspective. At the same time, it once more calls into question the common assumption of time-invariant monetary policy rules in the theoretical literature.

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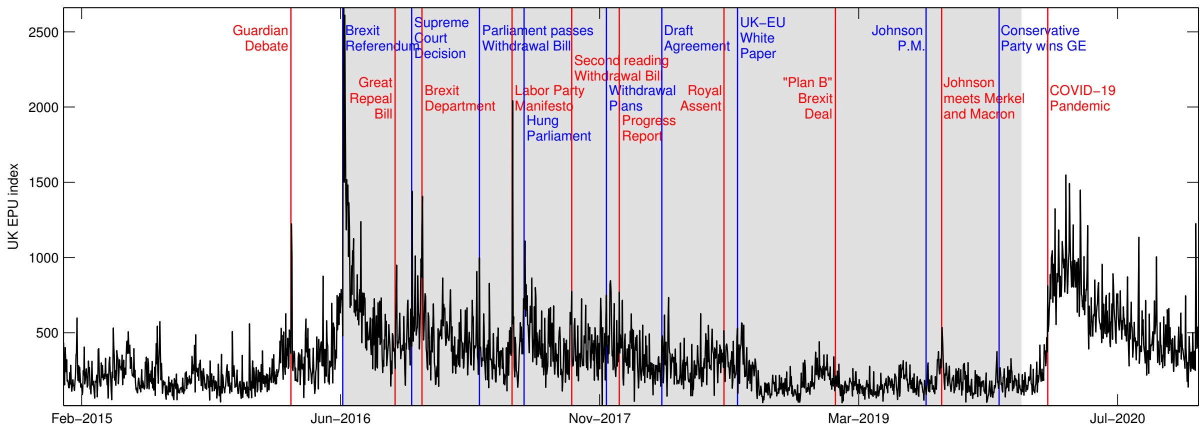
Tables and Figures

Table 1: Short-run zero and sign restrictions on VAR impulse response functions

	Structural shocks				
	BXT	AD	AS	MP	R
Brexit instrument	$\uparrow$	0	0	0	0
UK GDP growth		$\uparrow (0-3)$	$\uparrow (0-3)$	$\downarrow (0-3)$	
UK CPI inflation		$\uparrow (0-3)$	$\downarrow (0-3)$	$\downarrow (0-3)$	
UK shadow short rate		$\uparrow (0-3)$		$\uparrow (0-3)$	
UK consumer confidence					

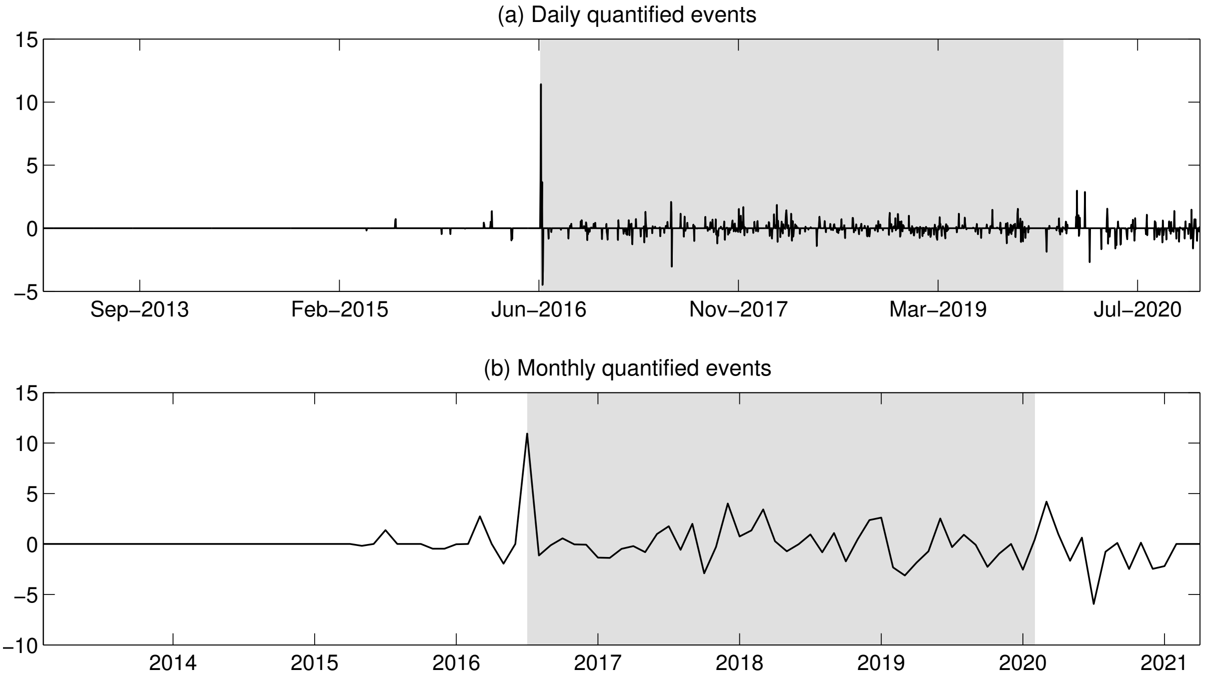
Notes: Brexit shocks exclusively affect the monthly instrument series on impact. AD, AS, and MP denote *other* UK aggregate demand, aggregate supply, and monetary policy shocks, respectively, while R denotes a general residual category. AS, AD, and MP shocks are identified by the sign restrictions in column on the variables in row, imposed on impact and for three consecutive months.

Figure 1: UK economic policy uncertainty and Brexit-related events



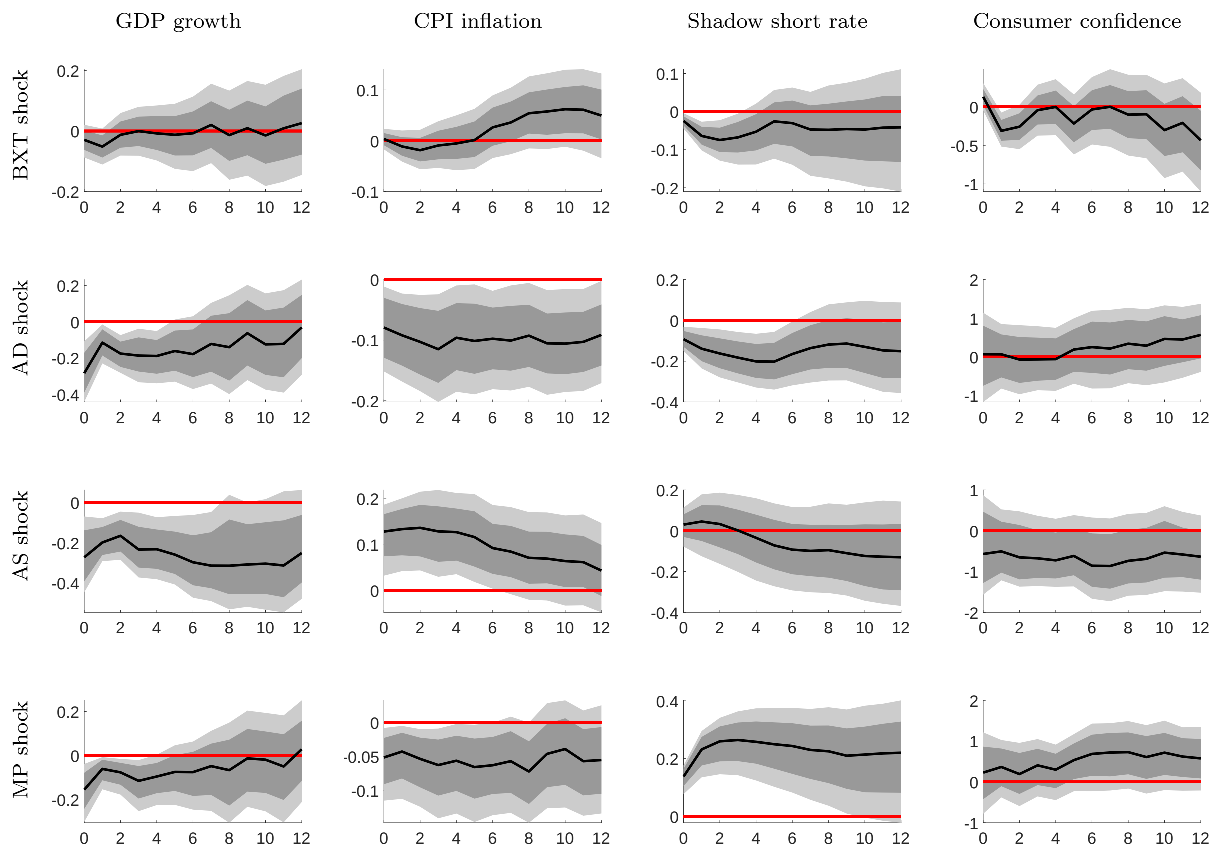
Note: Daily EPU index of Baker et al. (2016) for the United Kingdom and selected political and diplomatic events related to Brexit

Figure 2: Time series of Brexit events quantified as described in equations (1) and (2)



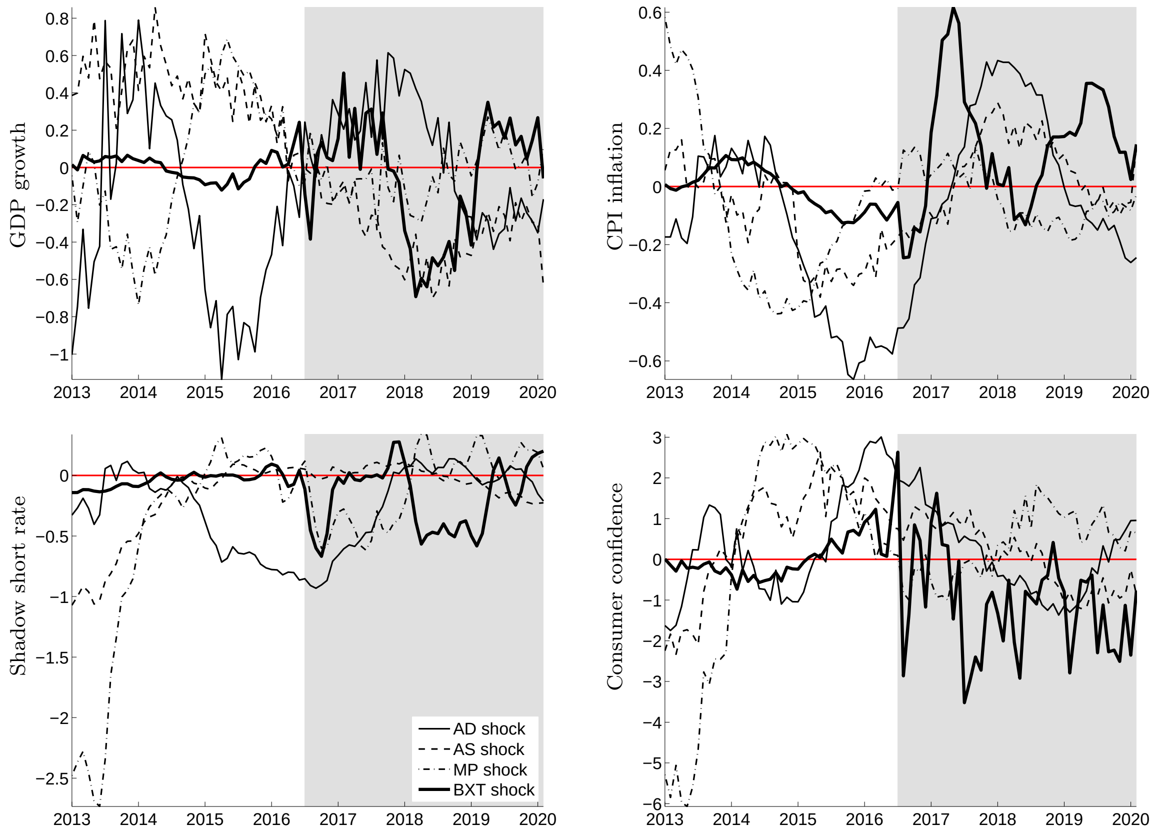
Note: Each Brexit event is quantified by the arithmetic mean of the average standardized change in the UK EPU, NEER, and FTSE 100 between day $t-1$ and day $t+1$. The daily quantified events are time-aggregated to monthly frequency.

Figure 3: Impulse response functions



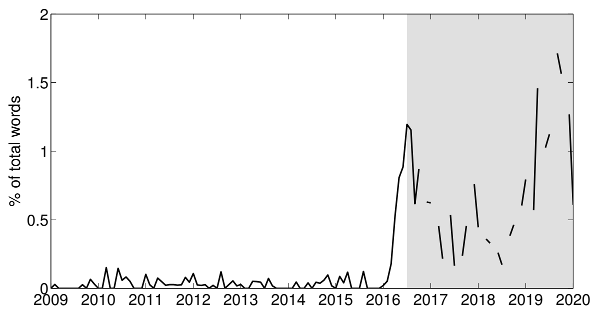
Note: Impulse responses of UK macroeconomic variables to a typical Brexit, AD, AS, and MP shock, respectively, based on the structural VAR model in (3). Solid black lines indicate pointwise median responses, while light- and dark-shaded areas indicate 66 and 90% posterior credible sets, respectively.

Figure 4: Historical decomposition of UK variables

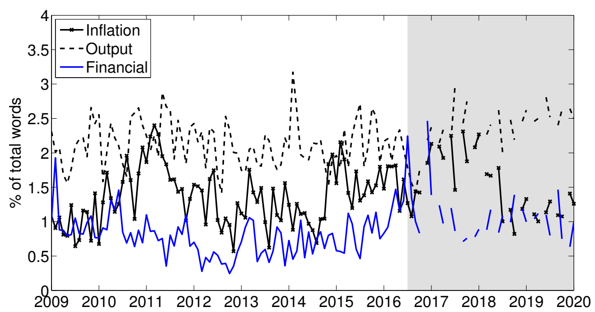


Note: Contributions of Brexit, AD, AS, and MP shocks, respectively, to historical fluctuations in UK macroeconomic variables based on the structural VAR model in (3). Pointwise median contributions based on 1,000 admissible model draws.

Figure 5: Time series of word counts in the Bank of England "Monetary Policy Summaries and Minutes"



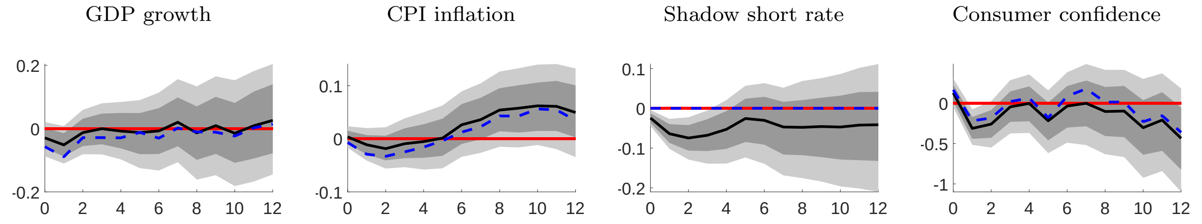
(a) Fraction of words relating to the referendum and Brexit



(b) Fraction of words relating to inflation, output, and financial markets

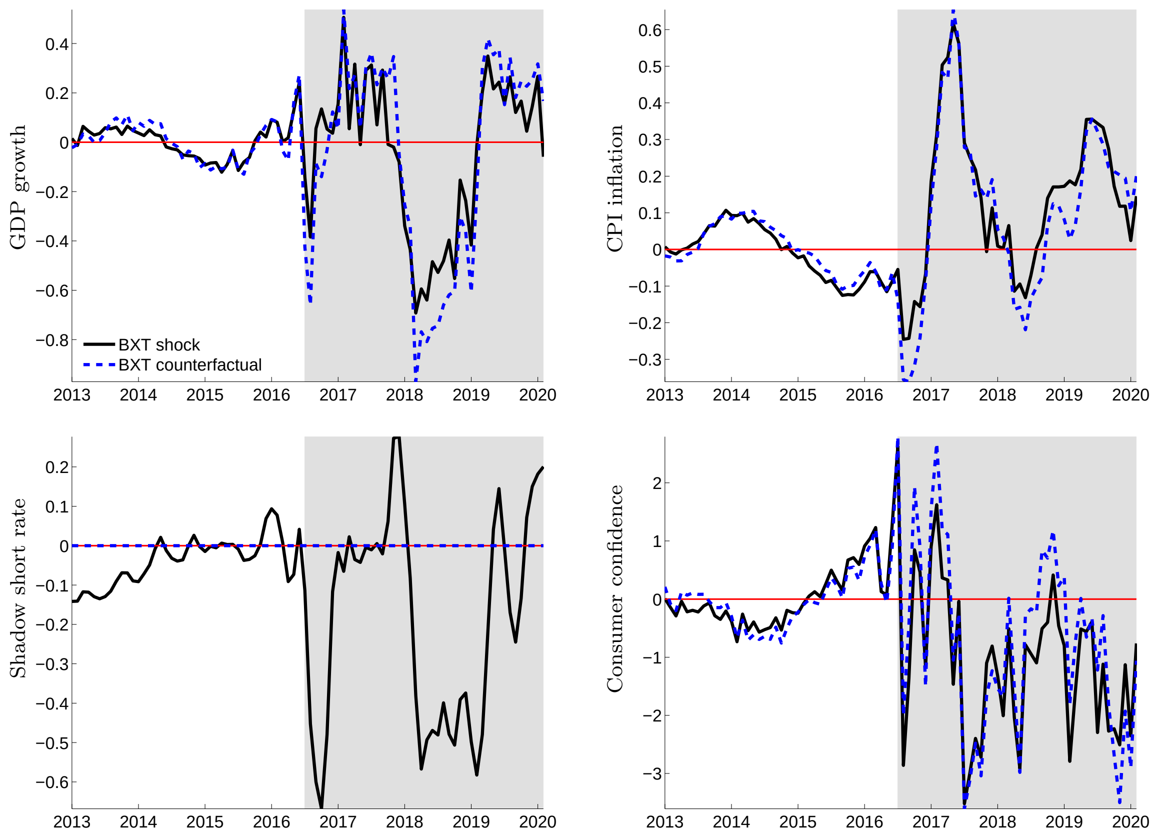
Note: Word count results for a fixed set of terms relating to Brexit, output, inflation, and financial markets, respectively. The sets are defined in Table A.2 in the appendix.

Figure 6: Counterfactual impulse response functions to a typical Brexit shock



Note: Impulse responses of UK macroeconomic variables to a one-standard-deviation Brexit shock based on the structural VAR model in (3). Solid black lines indicate pointwise median responses, while light- and dark-shaded areas indicate 66 and 90% posterior credible sets, respectively. Broken blue lines indicate the counterfactual responses, when the UK shadow short rate is held constant.

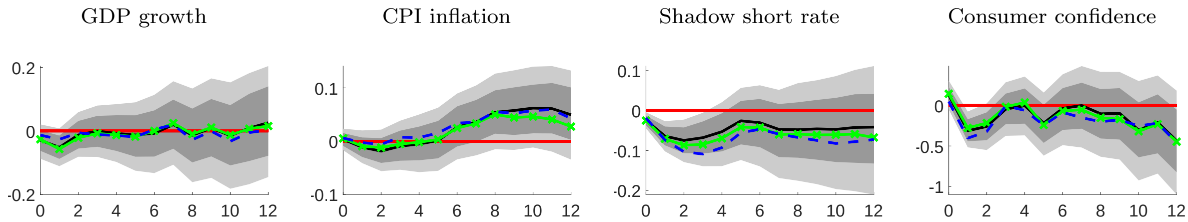
Figure 7: Counterfactual historical decomposition of UK variables



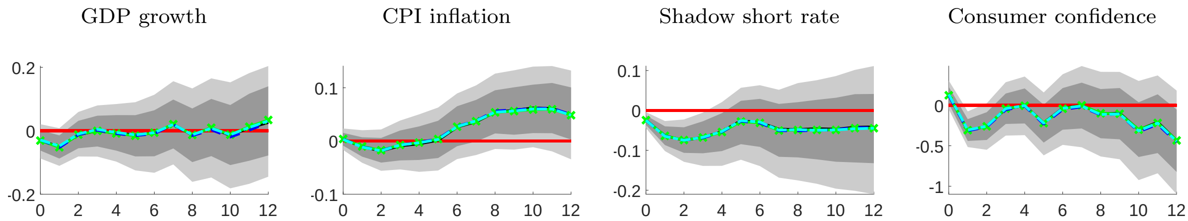
Note: Contributions of Brexit shocks to historical fluctuations in UK macroeconomic variables based on the structural VAR model in (3). Pointwise median contributions based on 1,000 admissible model draws. Broken blue lines indicate the counterfactual median contributions of Brexit shocks, when the UK shadow short rate is held constant.

Figure 8: Robustness checks and additional analyses — Impulse response functions

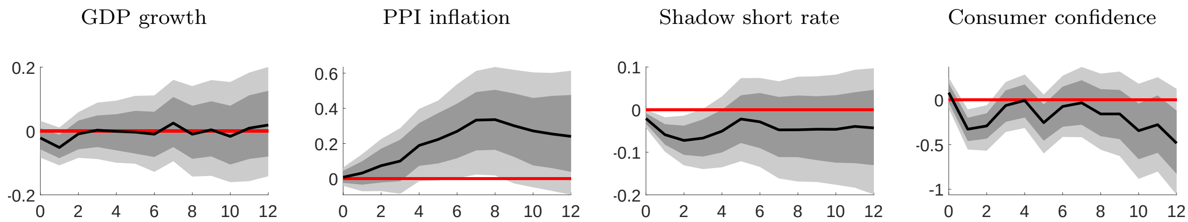
(a) Variants of the Brexit instrument



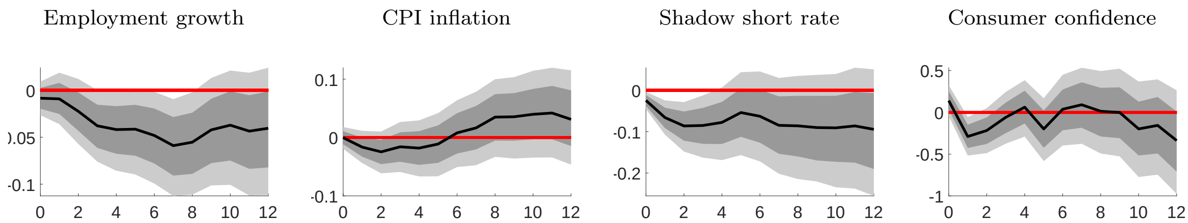
(b) Narrative restrictions on MP shocks



(c) Estimation with the producer price index



(d) Estimation with employment growth



Notes: Impulse responses of UK macroeconomic variables to a one-standard-deviation Brexit shock based on the structural VAR model in (3). Solid black lines indicate pointwise median responses, while light- and dark-shaded areas indicate 66 and 90% posterior credible sets, respectively. **Panel (a):** $t-1:t$ window for quantification, "Selected" Brexit-related events. **Panel (b):** No narrative restriction, November 2008 only, Quantitative narrative restriction on November 2008

Appendix

Figure A.1: UK high-frequency data and Brexit-related events

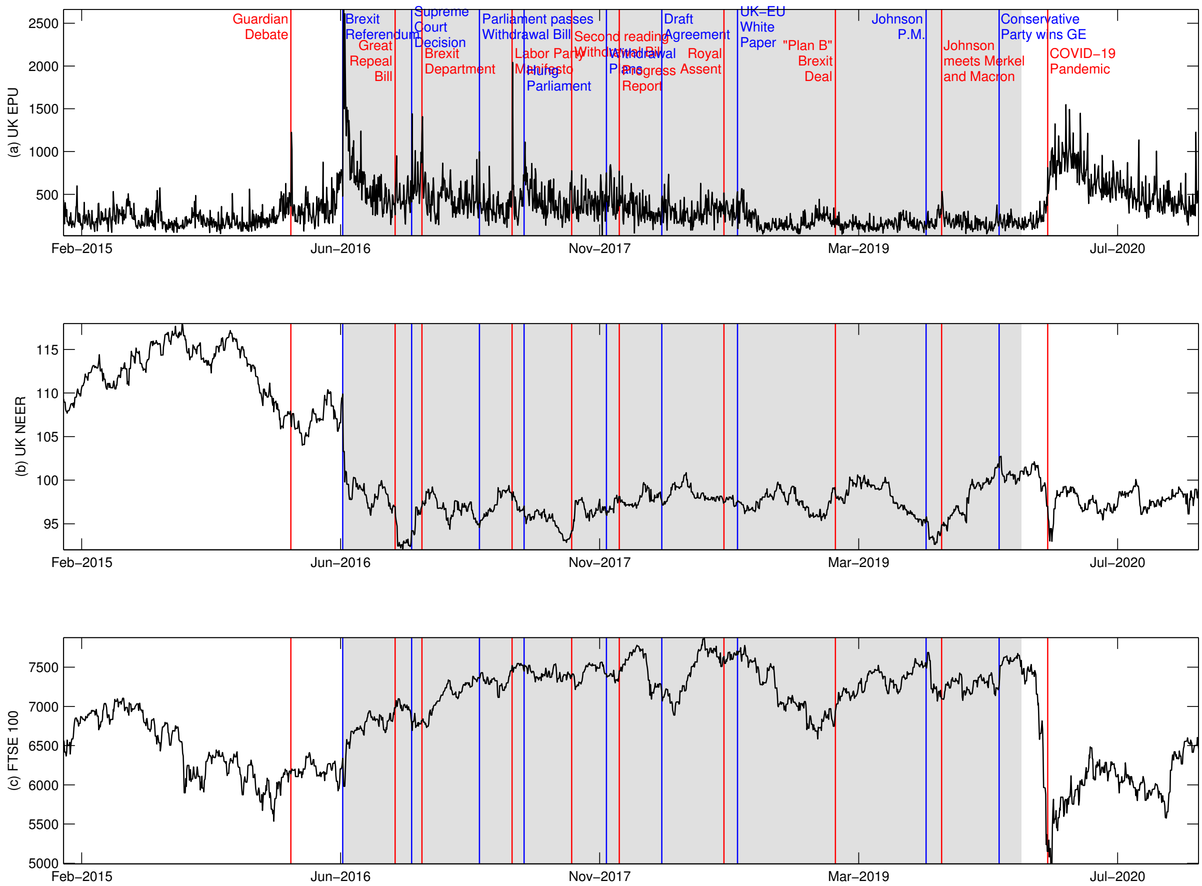
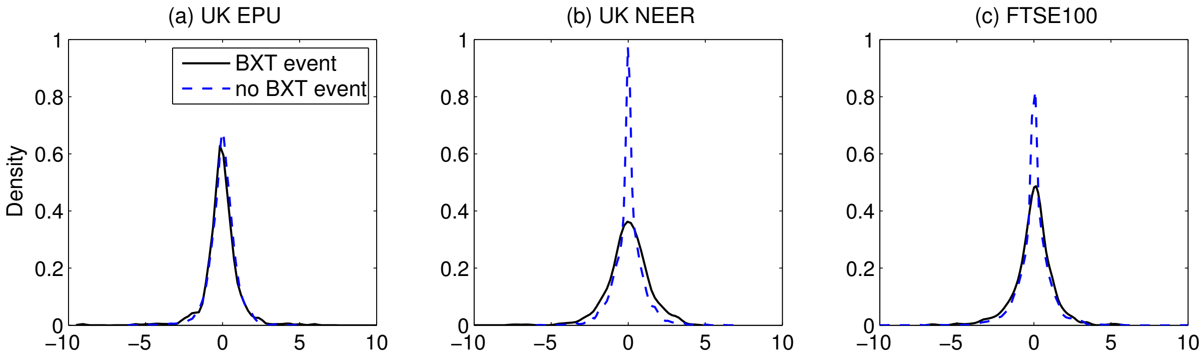


Table A.1: Largest quantified daily events related to Brexit

Date of event	Size	Description of event
June 23, 2016	3.700	The UK holds a referendum on its membership of the EU.
June 24, 2016	10.95	The result of the referendum is announced, with the majority of voters choosing to leave the EU.
June 27, 2016	4.633	David Cameron gives a statement to the House of Commons on the outcome of the EU Referendum.
June 28, 2016	−4.492	First European Council meeting since the referendum. After the meeting, the Prime Minister gives a statement and answers questions.
June 29, 2016	−3.358	David Cameron makes a statement to the House of Commons on the first EU Council meeting since the referendum.
Jan. 30, 2017	1.045	In the Irish Times, the Prime Minister sets out the Government's commitment to the UKs relationship with the Republic of Ireland
Feb. 8, 2017	−1.281	The European Union (Notification of Withdrawal) Bill passes its Third Reading in the House of Commons, by 494 votes to 122.
Mar. 10, 2017	−1.045	The Prime Minister meets EU leaders at the European Council in Brussels.
Mar. 13, 2017	1.157	Parliament passes the European Union (Notification of Withdrawal) Bill.
May 16, 2017	2.089	The Labour party launches its 2017 General Election manifesto.
May 17, 2017	1.240	The Liberal Democrat Party launches its election manifesto.
May 18, 2017	−3.040	The Conservative Party launches its manifesto for the upcoming General Election, including several policies related to Brexit.
June 9, 2017	1.106	Theresa May goes to the Queen and later, outside Downing St, announces she is forming a government.
July 13, 2017	−1,011	The Government introduces the European Union (Withdrawal) Bill.
Nov. 2, 2017	1.530	Government ministers meet with consumer groups to ensure consumer rights and protections are maintained once Britain leave the EU.
Jan. 29, 2018	1.078	The European Commission's new negotiating directives are adopted by the General Affairs (Article 50) Council.
Feb. 5, 2018	2.521	David Davis and Michel Barnier hold an informal meeting on the transition period, the Irish border and governance of withdrawal.
Feb. 7, 2018	−1.082	The European Commission publishes an amendable draft legal text on transition.
Feb. 28, 2018	1.173	The European Commission publishes the draft Withdrawal Agreement between the European Union and the United Kingdom.
Mar. 1, 2018	1.434	The Prime Minister meets European Council President Donald Tusk in Downing St.
Mar. 2, 2018	1.000	Theresa May gives a speech at Mansion House, on the UKs future economic partnership with the European Union.
Mar. 13, 2018	1.151	Further UK-EU Article 50 negotiations.
May 16, 2018	−1.411	The European Union (Withdrawal) Bill finishes its House of Lords stages and goes into parliamentary ping pong.
June 25, 2018	1.017	Northern Ireland Secretary Karen Bradley holds a series of meetings in Brussels.
Nov. 15, 2018	1.225	Brexit Secretary Dominic Raab resigns from the Cabinet, citing his opposition to the Prime Minister's draft Withdrawal Agreement.
Dec. 5, 2018	1.140	Following a Motion passed in the House of Commons, the Government publishes the Attorney Generals legal advice.
Dec. 6, 2018	1.127	The Prime Minister announces the formation of five new business councils to advise the UK post-Brexit.
May 7, 2019	1.152	Cabinet Office Minister David Lidington confirms the UK will take part in European Parliament elections on 23 May.
July 30, 2019	1.467	Boris Johnson speaks to Taoiseach Leo Varadkar and says that the British Government is committed to the Belfast Agreement.
Sep. 4, 2019	−1.203	MPs debate the European Union (Withdrawal) (No. 6) Bill and the bill passes its Second Reading and Committee stages.
Oct. 1, 2019	1.161	A licensing authority is set up jointly by the England, Scotland, Wales and Northern Ireland Fisheries Authorities (UKFAs).
Oct. 2, 2019	1.551	The Government publishes two documents setting out the Prime Ministers plan for an alternative to the backstop.
Oct. 10, 2019	−1.094	Boris Johnson and Leo Varadkar engage in three hours of Brexit talks in Liverpool, agreeing to 'see a pathway to a possible deal'.
Oct. 15, 2019	−1.050	The Scottish National Party conference takes place.
Dec. 13, 2019	−1.357	In a statement outside 10 Downing St, Prime Minister Boris Johnson pledges 'to get Brexit done' by 31.01.2020.

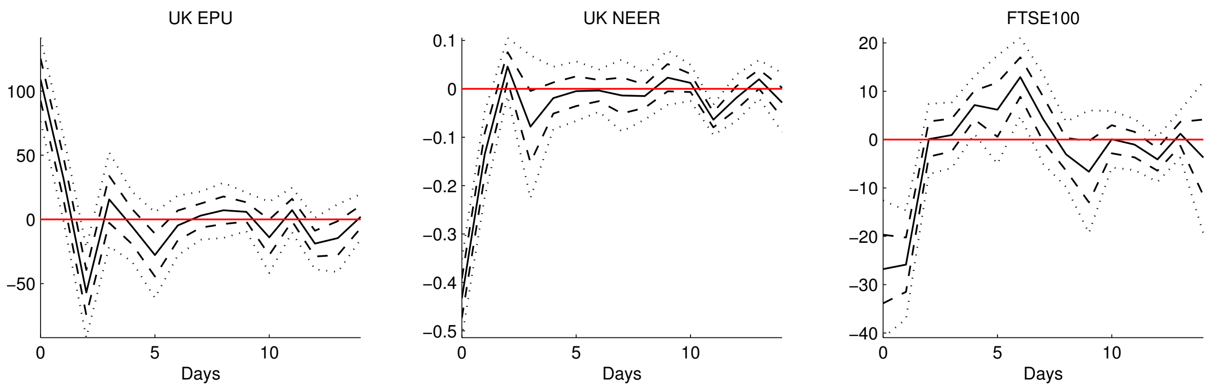
Note: List of all quantified daily events during January 1, 2013 and January 31, 2020, larger than one standard deviation according to (1) and (2).

Figure A.2: Kernel density estimates of daily changes in the UK EPU, NEER, and FTSE 100 *following* Brexit event days and days with no Brexit event



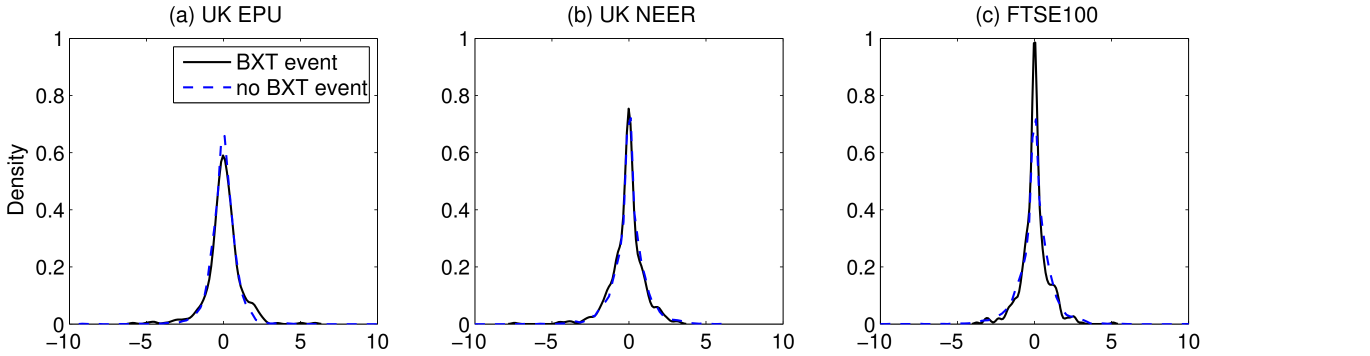
Note: Black solid lines plot Kernel density estimates for the distributions of daily changes in the UK EPU, NEER, and FTSE 100 following Brexit event days. Blue broken lines plot Kernel density estimates for the distributions of daily changes following "normal" days during January 2013–December 2020.

Figure A.3: Impulse responses of daily changes in the UK EPU, NEER, and FTSE 100 to a typical Brexit event quantified as described in equations (1) and (2)



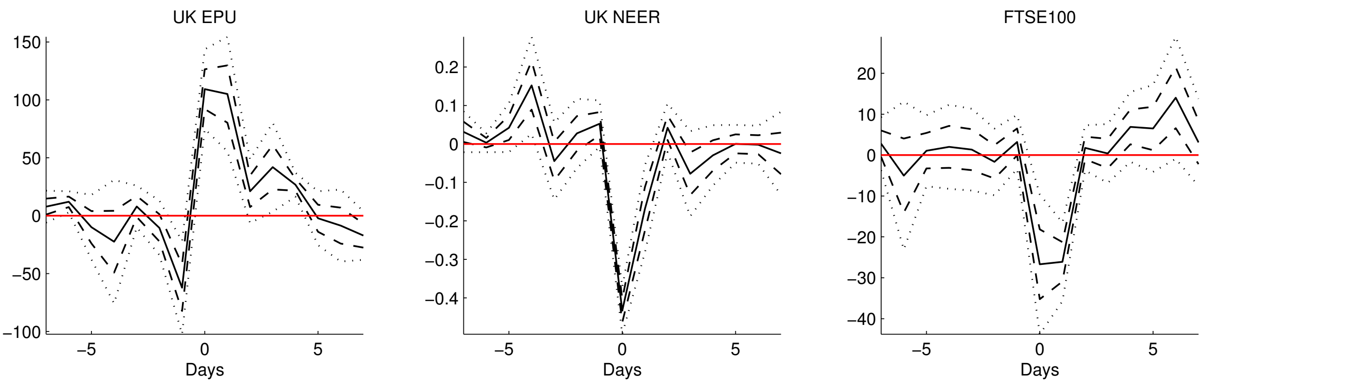
Note: Impulse response functions based on Jordà (2005) local projections on lags $0, \ldots, 7$ of the daily Brexit instrument with one- and two-standard-error confidence bands based on a block bootstrap with block size 7 in daily data. All regressions include 7 lags of the endogenous variable and 7 day-of-the-week dummies.

Figure A.4: Kernel density estimates of daily changes in the UK EPU, NEER, and FTSE 100 *prior to* Brexit event days and days with no Brexit event



Note: Black solid lines plot Kernel density estimates for the distributions of daily changes in the UK EPU, NEER, and FTSE 100 prior to Brexit event days. Blue broken lines plot Kernel density estimates for the distributions of daily changes prior to "normal" days during January 2013–December 2020.

Figure A.5: Impulse responses of daily changes in the UK EPU, NEER, and FTSE 100 to a typical Brexit event quantified as described in equations (1) and (2)



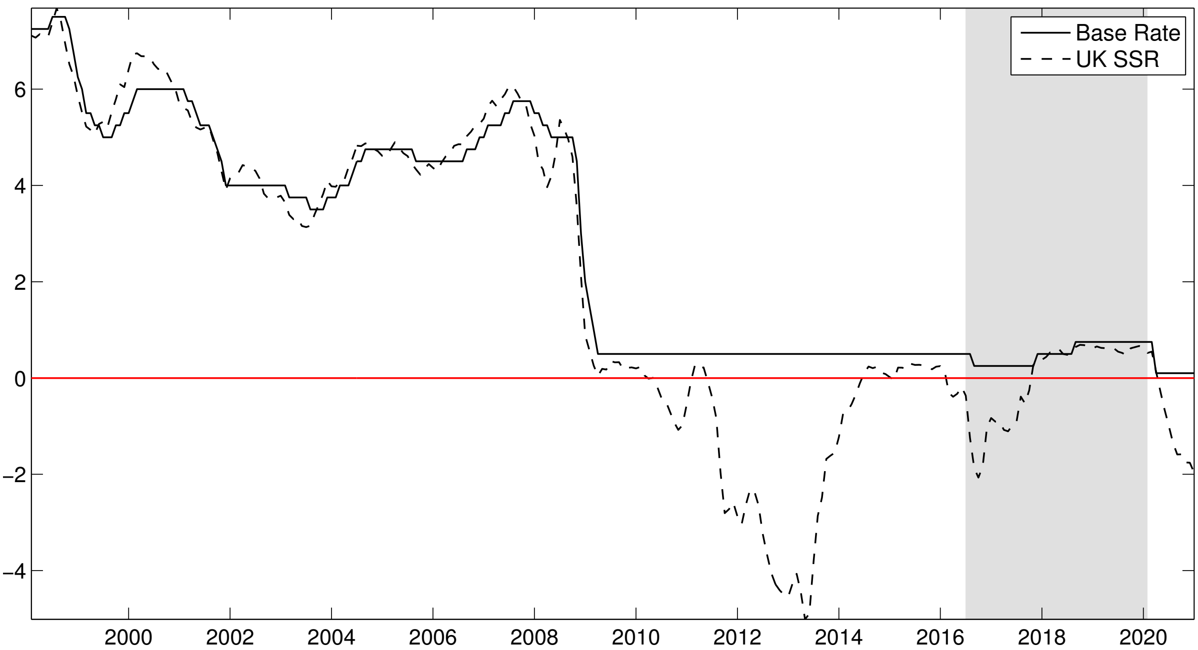
Note: Impulse response functions based on Jordà (2005) local projections on lags $-7, \ldots, 7$ of the daily Brexit instrument with one- and two-standard-error confidence bands based on a block bootstrap with block size 7 in daily data. All regressions include 7 lags of the endogenous variable and 7 day-of-the-week dummies.

Table A.2: Sets of terms used in quantitative text analysis in Section 4.3

Set	**Brexit**	**Inflation**	**Output**	**Financial markets**
1.	Brexit	inflation	activity	asset market
2.	EU	deflation	boost	asset price
3.	European Union	consumer price	consumption	appreciat∗
4.	exit (from the eu)	export price	GDP	depreciat∗
5.	leave(∗ the eu)	import price	growth	exchange rate
6.	deadline	producer price	output	foreign exchange
7.	membership	price expectation	production	financial condition
8.	no-deal	price pressure	recession	financial market
9.	no-transition	wage pressure	spending	financial stress
10.	referendum	target	consumer confidence	implied volatility
11.	economic uncertainty		consumer sentiment	market volatility
12.	policy uncertainty		business confidence	market sentiment
13.	political uncertainty		business sentiment	risk sentiment
14.	withdrawal		employment	sterling
15.			optimism	stock price
16.				stock market

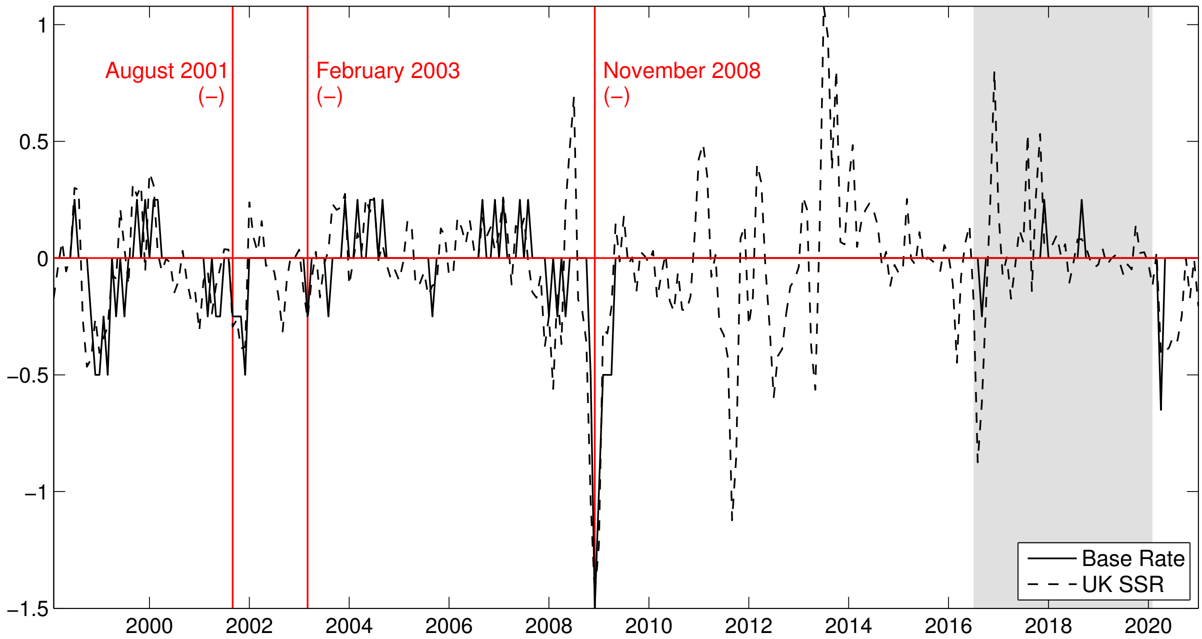
Notes: Terms relating to Brexit, inflation, output, and financial markets, respectively, used in text searches of the Bank of England's "Monetary Policy Summary and minutes of the Monetary Policy Committee (MPC) meetings". Capitalization ignored except for "EU". Terms in parentheses included in the search. ∗ indicates a wildcard character.

Figure A.6: Bank of England base rate and UK shadow short rate



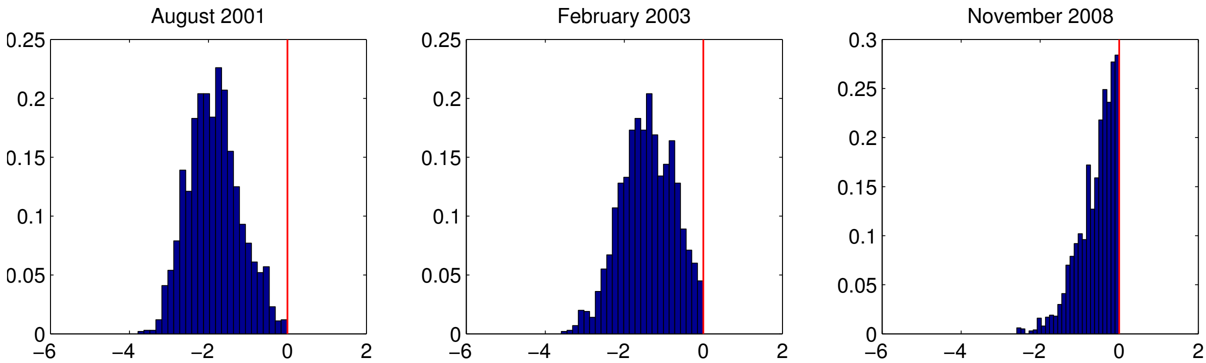
Note: Monthly averages of the Bank of England base rate and Krippner (2015)'s UK shadow short rate

Figure A.7: Changes in Bank of England base rate and UK shadow short rate



Note: First differences of the Bank of England base rate and Krippner (2015)'s UK shadow short rate. Vertical lines indicate episodes used as narrative sign restrictions for identifying monetary policy shocks.

Figure A.8: Posterior distribution of monetary policy shocks around historical events



Note: Histograms of posterior monetary policy shocks around events used in narrative sign restrictions. Vertical axes indicate the fraction of all admissible draws of the structural VAR model.

A.1 Construction of IRFs and HDs

Section 3 discusses how we identify the first row of the matrix of contemporaneous coefficients, A_0^{-1}, based on extraneous information about Brexit shocks, while the remaining rows of A_0^{-1} are *set-identified* using conventional sign restrictions on the impulse response functions (IRFs) of selected variables to aggregate demand (AD), aggregate supply (AS), and monetary policy (MP) shocks (see Table 1) and narrative restrictions on the contribution of MP shocks to historical fluctuations in the endogenous variables.

Based on the estimates of the reduced-form coefficients, $\hat{c}$ and $\hat{B}_l$, $l = 1, \ldots, p$, and a candidate draw of the (inverse) matrix of contemporaneous coefficients, $\tilde{A}_0^{-1}$, we can then construct the IRFs to each of the structural shocks in ε_t at horizon h as

$$\Psi_h \equiv \frac{\partial x_{t+h}}{\partial \varepsilon_t} = A_0^{-1} J \left(C\right)^h J' A_0^{-1}, \tag{A.1}$$

where J denotes an $(5 \times 5 \cdot p)$ selection vector and C the $(5 \cdot p \times 5 \cdot p)$ companion matrix

$$C \equiv \begin{bmatrix} A_0^{-1}A_1 & A_0^{-1}A_2 & \cdots & A_0^{-1}A_{p-1} & A_0^{-1}A_p \\ I_5 & 0 & \cdots & 0 & 0 \\ 0 & I_5 & \cdots & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & \cdots & I_5 & 0 \end{bmatrix}.$$

Each candidate draw $\tilde{A}_0^{-1}$, for which the IRFs in (A.1) satisfy the sign restrictions in Table 1 yields thus an admissible structural model used for our baseline empirical analysis in Section 4.

Using the IRFs and the structural shocks, we can compute the historical contributions of each shock to the evolution of each variable in x_t to perform a historical variance decomposition

$$\hat{x_t} = \sum_{h=0}^{t-1} \Psi_h \epsilon_{t-h}. \tag{A.2}$$

A.1.1 Counterfactual IRFs

Section 4.5 in the main text discusses the results of a counterfactual experiment, in which we hold the IRF of the UK shadow short rate (SSR) to a Brexit shocks and the contribution of the latter shock to the historical decomposition (HD) of the SSR equal to zero by exactly offsetting series of monetary policy (MP) shocks. This effectively neutralizes the endogenous response of the Bank of England to Brexit shocks and is thus informative about their effects in the absence of stabilizing monetary policy interventions.

Formally, we construct the counterfactual IRFs by solving for a series of MP shocks for each candidate model, such that

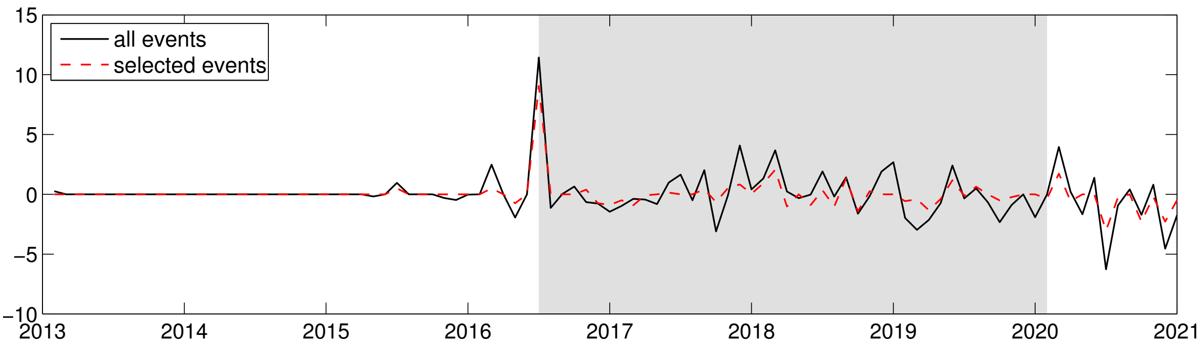
$$\tilde{\varepsilon}_0^{\mathrm{MP}} = -\frac{\Psi_{0,\mathrm{SSR}}^{\mathrm{BXT}}}{\Psi_{0,\mathrm{SSR}}^{\mathrm{MP}}} \quad \text{and} \quad \tilde{\varepsilon}_i^{\mathrm{MP}} = -\frac{\Psi_{i,\mathrm{SSR}}^{\mathrm{BXT}} + \sum_{j=1}^{i-1} \Psi_{j,SSR}^{\mathrm{MP}} \cdot \tilde{\varepsilon}_j^{\mathrm{MP}}}{\Psi_{0,\mathrm{SSR}}^{\mathrm{MP}}}, \quad i = 2, \ldots, h. \tag{A.3}$$

The counterfactual IRFs are then computed as the sum of the impulse responses to the baseline Brexit shock and the responses to the hypothetical MP shock series derived from (A.3). The resulting IRFs are plotted against the baseline IRFs in Figure 6.

In a next step, using the counterfactual IRFs to the Brexit shock instead of the actual one, we re-run the historical variance decomposition in Equation A.2.

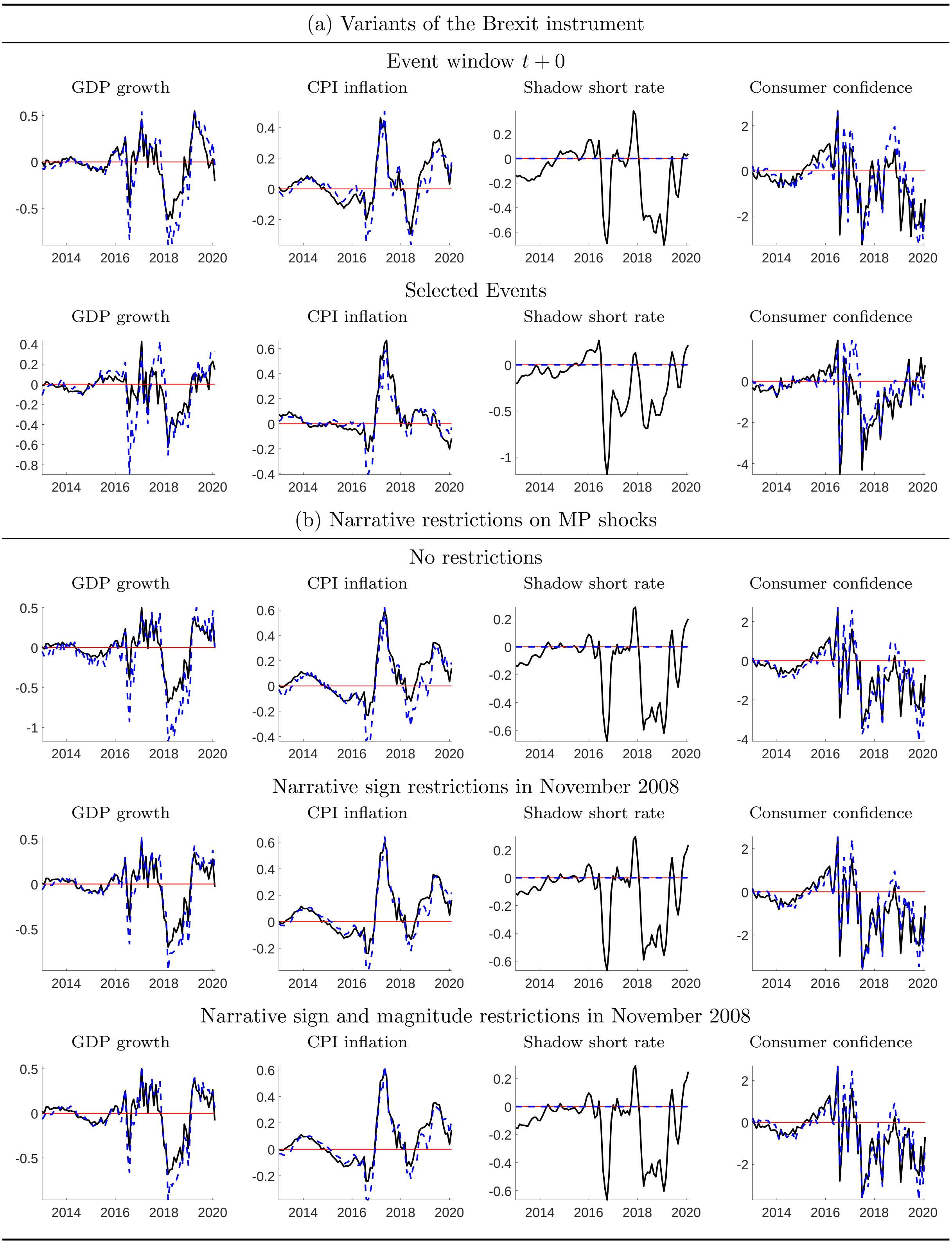
A.2 Robustness Checks

Figure A.9: Monthly time series of *all* and *selected* Brexit events quantified as described in equations (1) and (2)



Note: Each Brexit event is quantified by the arithmetic mean of the average standardized change in the UK EPU, NEER, and FTSE 100 between day $t-1$ and day $t+1$. *Selected* events furthermore induce a negative contemporaneous comovement of the EPU with the NEER and FTSE 100 at a daily frequency.

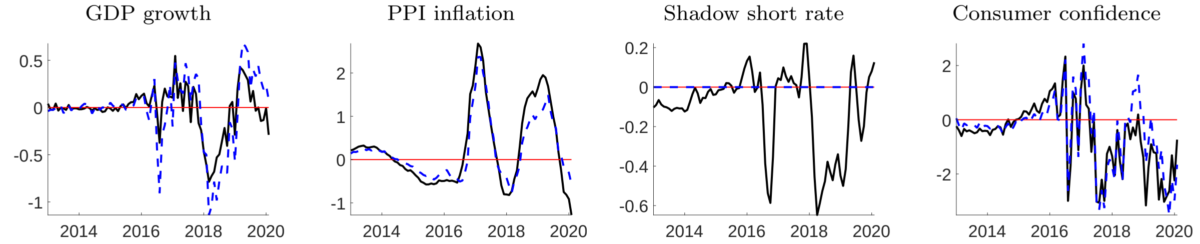
Figure A.10: Robustness checks and additional analyses — Counterfactual HD



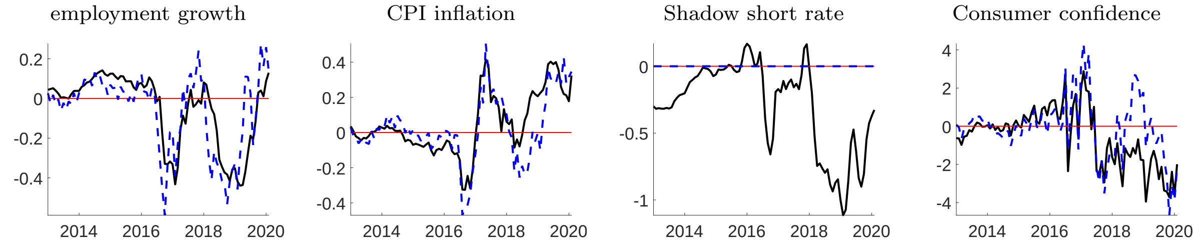
Note: Contributions of Brexit shocks to historical fluctuations in UK macroeconomic variables based on the structural VAR model in (3). Pointwise median contributions based on 1,000 admissible model draws. Broken blue lines indicate the counterfactual median contributions of Brexit shocks, when the UK shadow short rate is held constant.

Figure A.11: Robustness checks and additional analyses — Counterfactual HD (cont'd)

(c) Estimation with the producer price index

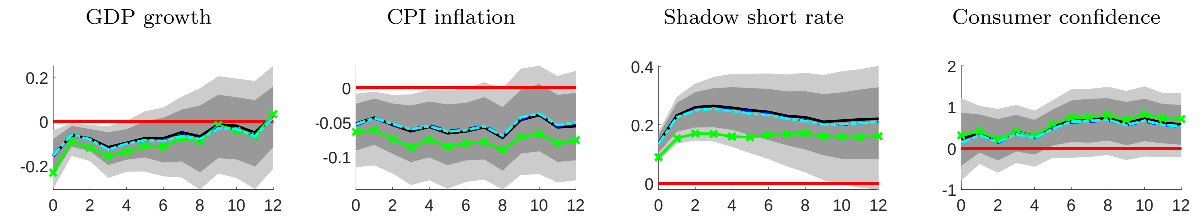


(d) Estimation with employment growth



Note: Contributions of Brexit shocks to historical fluctuations in UK macroeconomic variables based on the structural VAR model in (3). Pointwise median contributions based on 1,000 admissible model draws. Broken blue lines indicate the counterfactual median contributions of Brexit shocks, when the UK shadow short rate is held constant.

Figure A.12: Robustness checks — Impulse response functions to monetary policy shocks



Note: Impulse responses of UK macroeconomic variables to an MP shock based on the structural VAR model in (3). Solid black lines indicate pointwise median responses, while light- and dark-shaded areas indicate 66 and 90% posterior credible sets, respectively. **Robustness checks:** No narrative restriction, November 2008 only, Quantitative narrative restriction on November 2008