Financial Shocks, Credit Spreads, and the International Credit Channel[☆]

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Abstract

We provide evidence on the international transmission of US financial shocks, and compare their effects to monetary policy and central bank information shocks in a two-country SVAR for the US and the UK. Adverse financial shocks trigger a contraction in the US economy and an increase in credit spreads. The tightening in US credit conditions is quickly transmitted internationally, leading to an increase in credit spreads and a slowdown in economic activity in the UK. As for monetary policy and central bank information shocks, cross-country comovement in credit spreads amplifies the impact of financial shocks on the real economy. Our findings support the notion of an 'international credit channel' as a key transmission mechanism for cross-country spillovers.

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https://sites.google.com/site/ambropo/CS_IntlCredChannel_OnlineAppendix.pdf.

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1 Introduction

Unexpected changes in the Federal Reserve's monetary policy stance are quickly transmitted across borders and lead to synchronized movements in risky asset prices, credit growth, capital flows, leverage, and credit spreads across countries. Since traditional open economy models—which emphasize demand, expenditure switching, and risk-sharing channels—are silent on this fact, Rey (2016) conjectured the existence of an 'international credit channel' of monetary policy. This channel rests on the interaction between three main ingredients: a domestic credit channel of monetary policy (Bernanke and Gertler, 1995), high levels of international financial market integration, and the dominance of the US dollar as an international currency. With agency costs between borrowers and lenders and dollar-denominated balance sheets, US monetary policy affects the net worth of economic agents world-wide and, in turn, generates strong co-movement of financial conditions across the globe.[1]

This paper investigates whether US *financial* shocks also transmit across borders via an international credit channel and, if so, how they compare to the Fed's actions and words. Recent research has shown that financial shocks—broadly defined as exogenous changes to the net worth of financially-constrained agents or their degree of risk aversion—can play a key role in explaining business cycle fluctuations.[2] Financial shocks, however, are hard to identify in the data. Notably, when monetary policy works via an information (or signalling) channel, it can lead to dynamics that are observationally equivalent to those induced by financial shocks. Financial shocks can also behave like other aggregate shocks, which complicates any identification attempt where restrictions are imposed on

[1] Rey (2016) coined the expression 'international credit channel' in her influential 2014 Mundell-Fleming lecture. Some of the mechanisms underlying it have been analyzed in an earlier body of literature. For example, Cespedes et al. (2004) and Gertler et al. (2007) show how foreign-currency denominated debt can generate fluctuations in the net worth of economic agents (and hence their ability to borrow or lend via collateral effects). Krugman (2003) shows that credit market imperfections and internationally integrated financial markets can lead to highly synchronized movements in asset prices and credit spreads.

[2] See, for example, Gertler and Kiyotaki (2010) among many others.

the signs of their effects.

To address these issues, we develop a new econometric approach that allows us to separately identify monetary policy, central bank information, and financial shocks by combining the information from external instruments and sign restrictions in a structural VAR.[3] Our approach consists of two steps. First, we jointly identify US monetary policy and central bank information shocks using the external instruments approach. Following Jarocinski and Karadi (2020), we decompose high-frequency interest rate surprises around FOMC announcements into a monetary policy component and an information component, which we then employ as external instruments in a structural VAR. Second, and conditional on the identified monetary policy and information shocks, we derive from economic theory a minimum set of sign restrictions that can be imposed to uniquely identify a broad class of financial shocks.

To investigate the international transmission of these US shocks, we embed our novel identification approach in a 2-country structural VAR for the US and the UK. We focus on the UK as it is a relatively large small open economy with a well-established inflation targeting regime, a freely floating exchange rate, and a well-developed financial sector, which makes it a good laboratory where to explore our main question of interest.

The paper has three main results. First, our empirical evidence provides strong support for the existence of an international credit channel in the transmission of US financial shocks. Adverse financial shocks trigger a contraction in the US economy, and an increase in US credit spreads. Crucially, this tightening in US credit conditions is quickly transmitted internationally, leading to an increase in credit spreads in the UK, as well as a fall in prices and economic activity. The increase in UK spreads happens despite the accommodating response of domestic monetary policy, which acts to reduce credit spreads via

[3] Our new methodology is general and can be easily applied to a wide variety of different questions. For example, Cesa-Bianchi and Ferrero (2020) employ this approach to disentangle oil shocks from aggregate supply and aggregate demand shocks.

a domestic credit channel.

Second, our empirical evidence corroborates previous results on the international credit channel of US monetary policy for the specific case of the UK, and does so using an improved measure of US monetary policy shocks that also controls for central bank information effects (Jarocinski, 2020). Our impulse responses show that a US monetary policy tightening not only reduces demand and increases credit spreads in the US, but also tightens credit conditions internationally (Rey, 2016). Moreover, and in line with the findings in Kalemli-Ozcan (2019) for a group of advanced economies, US monetary policy shocks lead to a significant fall in the UK-US short-term (and also long-term) interest rate differential.[4]

Third, we show that central bank information shocks lead to strong cross-country spillovers which—like monetary policy and financial shocks—are also transmitted via an international credit channel. An increase in interest rates that signals a better-than-expected US outlook leads to a boom in the US economy and a compression in US credit spreads, which quickly spills over to UK credit conditions. Our evidence is complementary to Miranda-Agrippino and Rey (2020a), who provide evidence for a strong information component of FOMC announcements in the post-2009 period.

To further corroborate our evidence on the international credit channel, we perform two additional exercises. First, we explore the quantitative role of the international credit channel with a simple counterfactual exercise. Specifically, we re-compute the effects of financial, monetary policy, and information shocks while keeping US and UK credit spreads constant at their long-run values. For all shocks, our results point to a powerful amplification role played by credit spreads. Second, we investigate how credit spreads based on different asset classes (namely mortgages and interbank loans) respond to the identified financial, monetary, and information shocks. The impulse responses show that, consistent

[4] In contrast, for emerging market economies, Kalemli-Ozcan (2019) finds that the short-term interest rate differential vis-à-vis the US increases markedly.

with our baseline results, credit spreads strongly comove internationally conditional on all shocks.

Literature. Our findings contribute to a burgeoning literature on the international transmission of financial shocks, an established literature on the international transmission of monetary policy shocks, and a nascent literature on the international transmission of central bank information shocks. Helbling et al. (2011) study the international transmission of credit supply shocks originating in the US in a factor-augmented VAR (FAVAR) identified with a combination of zero and sign restrictions. Despite the different identification restrictions, they find that credit shocks play an important role in driving economic activity, especially during global recessions. Eickmeier and Ng (2015) also use sign restrictions to study how US credit supply shocks are transmitted internationally using a Global VAR model, and find that US credit supply shocks have strong international spillovers. Exploiting granular bank-level data for Turkey, Baskaya et al. (2017, 2021) show that, during periods of high risk appetite and large capital inflows, banks that mostly fund themselves through non-core liabilities expand their credit supply and reduce the real cost of borrowing. Relative to these studies, we not only provide an alternative approach for the identification of financial shocks, but we also more narrowly focus on the international credit channel and on the comparison of financial shocks with monetary policy and central bank information shocks.

The literature on the international transmission mechanism of monetary policy is vast.[5] A recent strand of this literature focuses on the spillovers from US monetary policy via an international credit channel. Rey (2016), Passari and Rey (2015), and Gerko and Rey (2017) show that US monetary policy shocks lead to synchronized movements in the mortgage and corporate bond spreads. Kalemli-Ozcan (2019) shows the US monetary policy affects credit costs internationally through its effect on global investors' risk perceptions.

[5]Some early empirical contributions focused on the real effects of US monetary policy shocks, finding large effects—see for example Kim (2001), Faust and Rogers (2003), Canova (2005); and more recently Georgiadis and Mehl (2015) and Dedola et al. (2017).

Different from these papers, we study the international transmission of monetary policy using an instrument that explicitly controls for information effects. Our approach is therefore more similar in spirit to Degasperi et al. (2020), and our evidence on the international credit channel of US monetary policy is complementary to the findings in these studies.

Finally, a few papers focus on the international transmission of monetary policy via an information channel (Stavrakeva and Tang, 2019, Miranda-Agrippino and Rey, 2020a). Relative to these papers, we use a different identification technique to extract information shocks, and provide complementary evidence that focuses on their real effects via an international credit channel. Our work is closely related to Jarocinski (2020), who analyzes the spillover effects of central bank information shocks between the US and the euro area in a VAR setting.

The remainder of the paper is structured as follows. Section 2 presents our identification strategy, the empirical model, and the data we use in our application. Section 3 shows how to derive from theory a set of sign restrictions that are consistent with a broad class of financial shocks. Section 4 reports the impulse response functions to US financial shocks, and compares them to the effects of monetary and central bank information shocks. Section 5 provides additional evidence to support our interpretation of the results. Section 6 concludes. An Appendix describes the data and reports some additional results. An Online Appendix reports additional information on the model, further results, and an extensive set of robustness checks of our main findings.

2 Econometric Approach

Our empirical strategy consists in combining the external instruments approach (Stock and Watson, 2012, Mertens and Ravn, 2013) with sign restrictions (Faust, 1998, Uhlig, 2005, Rubio-Ramirez et al., 2010, Fry and Pagan, 2011) to identify shocks in a 2-country structural vector autoregressive model (SVAR). In section 2.1 we describe the general methodology underlying our identification strategy. In section 2.2 we show how this identification strategy can be embedded within a 2-country VAR for the analysis of the international transmission of shocks. Finally, in section 2.3 we describe in detail the model specification and data we use in our application.

2.1 Identification Strategy

Let y_t be an $n \times 1$ vector of observables. We assume that the dynamics of the observables are described by the following structural VAR model:

$$y_t = \Phi(L) y_{t-1} + Be_t \tag{1}$$

where $\Phi(\cdot)$ and B are $n \times n$ matrices of coefficients, L is the lag operator, and e_t is an $n \times 1$ vector of (unobserved) structural shocks with $\mathbb{E}[e_t] = 0$, $\mathbb{E}[e_t, e_t'] = I_n$, $\mathbb{E}[e_t, e_s'] = 0$ for $s \neq t$, where I_n is the identity matrix. The specification in (1) omits deterministic terms and exogenous regressors for notational brevity. Let the $n \times 1$ vector u_t denote the reduced-form residuals, which are related to the unobserved structural shocks by:

$$u_t = Be_t. \tag{2}$$

Since $\mathbb{E}[u_t u_t'] = \Sigma_u = BB'$, an estimate of the covariance matrix of u_t provides $n(n+1)/2$ independent identifying restrictions. However, identification of the elements of at least one of the columns of B requires more identifying restrictions.

Our identification strategy combines the recently developed external instruments approach with a standard sign restrictions approach. The external instrument approach has proven to be a very successful identification strategy when good instruments are available. On the other hand, the sign restrictions approach, despite only delivering set identification, allows us to identify shocks that are consistent with economic theory and that affect many variables contemporaneously. This is particularly important in models with financial variables, where typical timing assumptions (e.g. Cholesky) would be too restrictive, or outright implausible.

In the general case, it is possible to identify $k < n$ structural shocks (labeled e_t^{IV}) with the external instruments approach, and the remaining $n - k$ ones with sign restrictions. In our application, we will use two instruments, so $k = 2$.[6] For simplicity, we reorder the VAR such that the first k structural shocks are associated with the first k equations, so we set $e_t^{IV} \equiv (e'_{1t}, ..., e'_{k,t})'$. The remaining $n - k$ shocks, namely $e_t^{SR} \equiv (e'_{k+1,t}, ..., e'_{n,t})'$, are then identified with sign restrictions.

We start by partitioning the matrix B into a $n \times k$ matrix B^{IV}, whose columns capture the impact of the e_t^{IV} shocks, and a $n \times (n-k)$ matrix B^{SR}, whose columns capture the impact of the remaining $(n-k)$ shocks (e_t^{SR}):

$$B = \begin{bmatrix} B^{IV} & B^{SR} \end{bmatrix}. \tag{3}$$

External instruments. We assume that there exist k instruments $z_t = (z'_{1,t}, \ldots, z'_{k,t})'$ that are correlated with the shocks of interest (e_t^{IV}) and uncorrelated with all other shocks (e_t^{SR}). It is then possible to obtain an estimate of the impact of the shocks of interest on all variables in the system, i.e. an estimate of B^{IV}. For details of this step, we refer to Mertens and Ravn (2013). The novel aspect of our approach is that we combine the external instruments and sign restrictions identification techniques, which is explained next.

Combining sign restrictions and external instruments. For the moment we assume that we can rely on theory to derive a unique set of sign restrictions that are consistent

[6] Specifically, we identify a monetary policy shock and a central bank information shock using as external instruments the monetary and information surprises developed by Jarocinski and Karadi (2020).

with the shocks (e_t^{SR}) that we want to identify.[7] To identify B^{SR} we proceed as follows. First, using (3), we rewrite the covariance matrix of the reduced-form residuals as:

$$\Sigma_u = BB' = \begin{bmatrix} B^{IV} & B^{SR} \end{bmatrix} \begin{bmatrix} B^{IV} & B^{SR} \end{bmatrix}'. \tag{4}$$

As is well known, this decomposition of the covariance matrix is not unique. Let C be the Cholesky decomposition of the covariance matrix Σ_u, and let Q be an orthonormal matrix such that $QQ' = I$. Then we can write:

$$\Sigma_u = CC' = CQQ'C' = (CQ)(CQ)' \tag{5}$$

Our strategy consists in obtaining a large number of orthonormal matrices Q that satisfy the following condition:

$$CQ = \begin{bmatrix} B^{IV} & B^{SR} \end{bmatrix}, \tag{6}$$

where B^{SR} also satisfies a set of sign restrictions (as derived, for example, from a theoretical model). We do that in three steps.

1. Find an orthonormal matrix q of dimension $n \times k$ that rotates the first k columns of C, the Cholesky decomposition of Σ_u, into the matrix B^{IV}. That is, we find a suitable

$$Cq = B^{IV}. \tag{7}$$

2. Given q, build the remaining $n - k$ columns of an orthonormal matrix Q following a standard Gram-Schmidt process.[8] That is, we find an $(n \times n - k)$ matrix $\mathcal{Q}$ such

[7] In the next section we show how we derive sign restrictions that uniquely identify a financial shock.

[8] Let j index the columns of Q. Let Q_{j-1} denote the first $j-1$ columns of Q, such that $Q_{2-1} = Q_1 = q_1$. Let x_j be a draw from a Normal distribution on $\mathbb{R}^N$. Then the $j-$th column of Q can be constructed as:

$$q_j = \frac{\left(I_N - Q_{j-1}Q'_{j-1}\right)x_j}{\left\|\left(I_N - Q_{j-1}Q'_{j-1}\right)x_j\right\|}.$$

that the following equality holds:

$$\begin{bmatrix} q & \mathcal{Q} \end{bmatrix} \begin{bmatrix} q & \mathcal{Q} \end{bmatrix}' = QQ' = I. \tag{8}$$

The matrix CQ then represents a candidate identification scheme because:

$$CQ = C \begin{bmatrix} q & \mathcal{Q} \end{bmatrix} = \begin{bmatrix} B^{IV} & B^{SR} \end{bmatrix} = B. \tag{9}$$

3. Check that B^{SR} satisfies our set of sign restrictions. If it does, we retain the matrix Q. If not, we discard the draw.

Note that fully implementing the algorithm described in Rubio-Ramirez et al. (2010) — after translation into our classical estimation setting — would require discarding the draw of C (or equivalently, Σ_u) if step (3) fails before repeating steps (1) and (2), to ensure that the resulting distribution of structural parameters is not distorted. But because it's much cheaper to construct matrices Q for a given C than bootstrap Σ_u, we adopt the following shortcut: for each bootstrap draw from the reduced-form parameters, we repeat steps (2) and (3) a fixed number of times , and store all matrices B consistent with our identification restrictions. In our results, we then report credible intervals for impulse responses based on all the stored matrices. This is somewhat reminiscent of an importance sampler, as each draw of the reduced-form parameters is more or less represented, depending on how many matrices Q for that particular draw satisfied the sign restrictions.[9]

[9] We have also verified that our results look almost identical when strictly following Rubio-Ramirez et al. (2010) and only drawing one matrix Q per bootstrap draw. This however requires considerably more bootstrap draws.

2.2 A Two-Country VAR

We now show how the above identification strategy can be embedded within a 2-country VAR model for the analysis of the international transmission of shocks. Consider a 2-country VAR model for the Home (H) and Foreign (F) economies (where we drop deterministic terms, such as constants or time trends, for ease of notation):

$$\begin{bmatrix} y_t^F \\ y_t^H \end{bmatrix} = \begin{bmatrix} \Phi_{FF}(L) & \Phi_{FH}(L) \\ \Phi_{HF}(L) & \Phi_{HH}(L) \end{bmatrix} \begin{bmatrix} y_{t-1}^F \\ y_{t-1}^H \end{bmatrix} + \begin{bmatrix} B_{FF} & B_{FH} \\ B_{HF} & B_{HH} \end{bmatrix} \begin{bmatrix} e_t^F \\ e_t^H \end{bmatrix} \tag{10}$$

where $y_t = (y_t^{F\prime}, y_t^{H\prime})'$ is an $(n^F + n^H) \times 1$ vector that collects the $n = n^F + n^H$ endogenous variables stacked by country; $\Phi(L)$ is a matrix polynomial in the lag operator; and $e_t = (e_t^{F\prime}, e_t^{H\prime})'$ is an $(n^F + n^H) \times 1$ vector that collects the structural shocks with covariance matrix $\mathbb{E}[e_t e_t'] = I$.

We treat the Home country as a small open economy by not allowing any feedback from Home variables onto Foreign ones. This is achieved by imposing a block exogeneity restriction on the Φ and B matrices, i.e. $\Phi_{FH}(L) = 0$ and $B_{FH} = 0$. The block exogeneity assumption has been widely used in the empirical literature in international economics (e.g. Dedola et al. (2017)).

The block exogeneity assumption conveniently de-couples the two countries. As a result, we break the estimation process into two steps. First, we estimate a reduced-form model for the Foreign economy and identify a subset of the structural shocks e_t^F with the identification strategy outlined above. We then estimate a reduced-form VAR for the Home country, where we treat lags of Foreign variables as additional exogenous variables.

To quantify the impact of Foreign structural shocks on Home variables (i.e., the matrix B_{HF}) we simply regress the Home reduced-form residuals, u_t^H, on the Foreign structural shocks e_t^F. The OLS coefficients of that regression will capture the response of Home variables to Foreign shocks, while the residuals will capture a linear combination of the Home structural shocks e_t^H.[10] The estimates we compute are equivalent to those obtained with the two-step approach of Canova (2005).

2.3 Data, Estimation, and Inference

In our application, the US is the Foreign economy and the UK the Home economy. For the specification of the US VAR, we draw from Gertler and Karadi (2015) and Jarocinski and Karadi (2020). Our baseline model includes the log of a monthly real GDP series, the log of the consumer price index, the one-year government bond rate (which we use as a monetary policy indicator), Gilchrist and Zakrajsek (2012)'s (henceforth GZ) Excess Bond Premium (EBP), as well as the level of the borrowing rate as captured by the sum of a 10-year government bond rate and the GZ corporate bond spread.[11] As we shall explain in the next section, the addition of the level of the borrowing rate is crucial for the identification of a financial shock. The model is estimated with 12 lags and a constant using data that cover the period from 1979:M7 to 2016:M12.

For the identification of monetary policy and central bank information shocks, we follow Jarocinski and Karadi (2020), who decompose high frequency surprises in Fed Funds futures (*FF4* contracts) around FOMC announcements into a monetary and an information component. This decomposition is motivated by the fact that, when information frictions are present, a 'signalling channel' of monetary policy can arise: a central bank's announcement can simultaneously convey information about monetary policy and its assessment of the economic outlook (see Romer and Romer, 2000; Melosi, 2017). Recent studies have shown that such a signalling component can be sizable in high-frequency market-based surprises around policy announcements by the Federal Reserve. In turn,

[10]It would of course be possible to also recover the Home structural shocks by identifying the remaining block of the identification scheme. This is, however, beyond the scope of this paper.

[11]The median maturity at issue across all bonds in GZ is 10 years.

this can lead to a non-negligible bias in the estimated impact of monetary policy on macroeconomic and financial variables.

We then estimate a UK VAR with monthly data over the same sample. In the vector of endogenous variables we include: the nominal yield on 1-year gilts as the monetary policy indicator, in a similar vein to the US model; a (log) index of monthly real GDP; a log index of consumer prices; the nominal exchange rate vis-à-vis the US Dollar; and a measure of corporate bond spreads. A detailed description of the data is provided in the Appendix. We chose 12 lags for the endogenous variables as in the US VAR. Moreover, we include as exogenous regressors 3 lags of US variables and a constant.

For the computation of credible intervals, we follow Mertens and Ravn (2013) and use a wild bootstrap. As discussed in section 2.1, we adapt the algorithm proposed by Rubio-Ramirez et al. (2010) and draw a fixed number of rotation matrices for each bootstrap draw of the reduced-form parameters, and then store all those that satisfy the sign restrictions for each bootstrap draw. For all results, we report 90% credible intervals as well as the mean of impulse response functions. As pointed out by Fry and Pagan (2011), in a classical setting this does not correspond to any 'model', that is, any single rotation that satisfies the sign restrictions.[12] With that proviso, we nevertheless find it useful for the discussion of our results, especially in order to compare monetary and financial shocks.

3 Set Identification of Financial Shocks

The aim of this section is to derive a set of sign restrictions that are consistent with a broad class of financial shocks, drawing from theoretical models with financial frictions. Our ultimate goal is to use these restrictions to identify a financial shock within the SVAR

[12] This of course only applies to the financial shock we identify, but not to the monetary policy and central bank information shocks identified with external instruments.

framework described above.

The identification of financial shocks within an SVAR framework is a challenging task. First and foremost, the presence of 'fast-moving' financial variables poses a serious challenge to the plausibility of any of the contemporaneous zero restrictions that are typically used to identify structural shocks in VARs. The literature has therefore moved to set identification, e.g. by imposing a number of sign restrictions on the impulse response functions of the VAR.[13]

However, even with sign restrictions, the task of achieving an economically plausible identification is not trivial. There are two major challenges. First, in the vast majority of theoretical models, financial shocks typically lead to dynamics of output, consumer prices, and policy rates that are similar to those of aggregate demand shocks, such as consumers' preference shocks, government spending shocks, etc.[14] Second, while the theoretical literature has analyzed different types of financial shocks, these tend to have very similar qualitative effects on the aggregate economy. For example, in sticky price models with financial frictions, various types of adverse financial shocks all generate a fall in activity and prices, an increase in credit spreads, and a monetary policy loosening by an inflation-targeting monetary authority. To separately identify these different financial shocks one would need to increase the dimensionality of the VAR model, which would quickly lead to a curse of dimensionality problem. In this paper we show that it is possible to find a *minimum* set of restrictions that allows us to distinguish a financial shock from a 'classical' aggregate demand shock. The identification of different types of financial shocks,

[13] The following papers, among many others, identify financial shocks with zero contemporaneous restrictions, sign restrictions or a combination of both: Musso et al. (2011), Meeks (2012), Fornari and Stracca (2012), Gilchrist et al. (2014), Furlanetto et al. (2014), and Abbate et al. (2016). Alternatively, some papers in the literature use the penalty function approach (initially proposed by Faust (1998) and Uhlig (2005)) to disentangle between financial or uncertainty shocks. See Pinter et al. (2013) and Caldara et al. (2016).

[14] While in the vast majority of theoretical models financial shocks tend to behave as aggregate demand shocks, there are examples in the literature where financial shocks imply dynamics typical of supply shocks (e.g., most notably, Gilchrist et al., 2017). Our identification strategy can be modified to take this into account.

however, represents an empirical challenge that goes beyond the scope of this paper. In what follows, we therefore use the term financial shock in a broad sense.

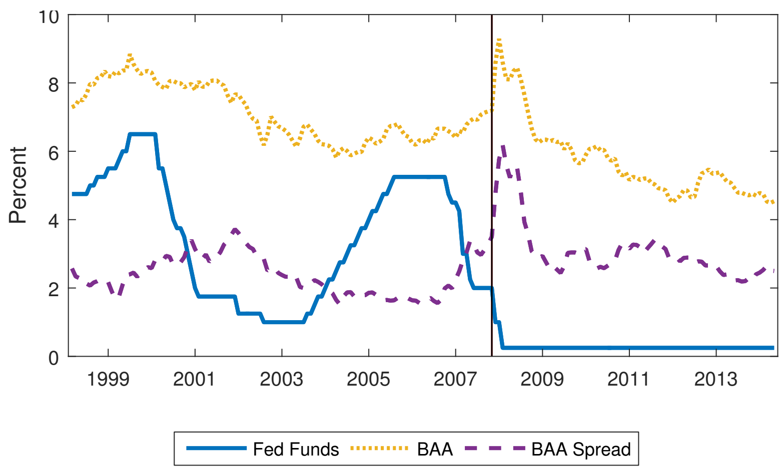
To derive a set of sign restrictions that allows us to disentangle financial shocks from aggregate demand shocks, we draw from theoretical models with sticky prices and a financial accelerator mechanism (Bernanke et al., 1999, Christiano et al., 2014). In these models, the borrowing rate on a loan with m-periods-ahead maturity (i_B^m) is typically given by the sum of two components: the rate on a government bond of similar maturity (i^m) plus a spread that arises because of imperfect information in credit markets (x^m). That is:

$$i_B^m = i^m + x^m. \tag{11}$$

In this class of models, the credit spread (x^m) endogenously responds to shocks in a countercyclical fashion, while the interest rate (i^m) is typically a moving average of short-term risk-free rates set by the central bank via a Taylor rule. Hence, a key feature of these models is that the equilibrium response of the borrowing rate (i_B^m) to demand and financial shocks is theoretically ambiguous. To see that, assume that a negative demand or financial shock hits the economy, putting downward pressure on both economic activity and prices. In response to the shock, monetary policy becomes accommodative ($i^m \downarrow$), while the credit spread increases ($x^m \uparrow$). It is therefore clear that, depending on (i) the monetary policy reaction function and (ii) the semi-elasticity of the credit spread to the shock, the borrowing rate prevailing in the economy might either increase or decrease.

In this paper we exploit this ambiguous response of the borrowing rate (i_B^m) to shocks to achieve identification. Our conjecture is that, in the face of financial shocks, movements in the credit spread dominate over movements in (current and future expected) policy rates, so that a negative financial shock leads to an *increase* in the borrowing rate. On the other hand, in the face of demand shocks, movements in the policy rate dominate over movements in the credit spread, so that a negative demand shock leads to a *fall* in the borrowing rate. Under such assumption, we can impose different sign restrictions on the borrowing rate to disentangle between demand and financial shocks.

Figure 1 Fed Funds, BAA Interest Rate, And BAA Spread



Note. The chart reports the Fed Funds rate (solid line), the yield on BAA-rated corporate debt (dotted line), and its spread over a safe interest rate of the same maturity (a 10-year government bond) over the period 1999:M1 to 2015:M3. The vertical line shows 2008:M9, when Lehman Brothers collapsed.

This conjecture originates from arguably the most spectacular financial shock in our sample: the Global Financial Crisis. Figure 1 reports the behavior of the Fed Funds rate (solid line), the yield on BAA-rated corporate debt (dotted line), and its spread over a safe interest rate of the same maturity (dashed line) over the period 1999:M1 to 2015:M3. A vertical line shows 2008:M9, when Lehman Brothers collapsed. The figure shows that, during the 2007-08 period, a mechanism as the one described above might have been at work. This is particularly evident in the last months of 2008: while the Fed sharply cut the Fed Funds rate, trying to accommodate the shock, credit spreads quickly spiked, putting upward pressure on borrowing costs. From the chart it is clear that the spread component dominated over the policy rate component, leading to an overall increase in the borrowing rate. It is important to stress here that the dynamics of interest rates and credit spreads reported in Figure 1 could be the result of a central bank information shock, i.e. a surprise Fed loosening that signals a bad state of the world, and in turn generates a spike in credit spreads. This observational equivalence leads to an identification problem that can, however, be addressed using our proposed approach. As discussed above, in our empirical application we explicitly control for central bank information shocks following the approach developed by Jarocinski and Karadi (2020), before imposing the sign restrictions. This implies that the sign restrictions will extract the financial shock only once the data have been cleaned for central bank information shocks.

In what follows, we formalize this conjecture using a well-known and widely used financial accelerator model, the 'modern' variant of Bernanke et al. (1999) developed and estimated by Christiano et al. (2014). Specifically, we show that the mechanism described above (i.e., that movements in the credit spread dominate over movements in the policy rate) is true for a broad set of financial shocks. Moreover, we show that this is not the case in the face of other aggregate demand shocks. We also show that our result is robust to different specifications of the monetary policy reaction function.

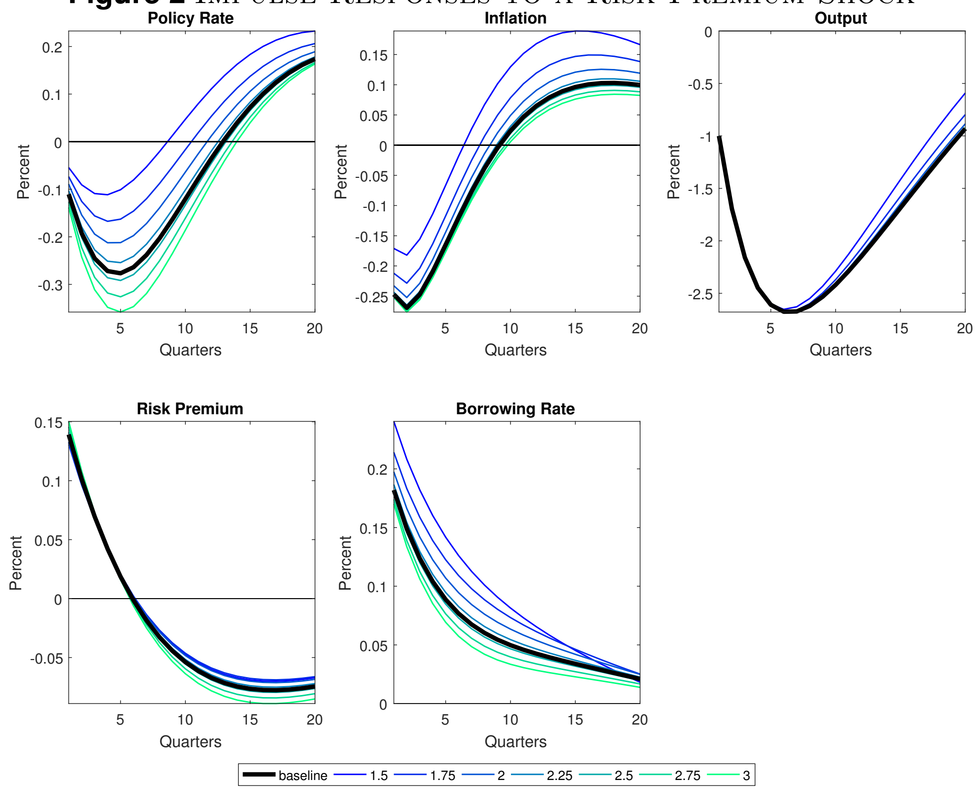
We start with financial shocks. Figure 2 plots the responses of output, inflation, the policy rate, the credit spread, and the borrowing rate in response to a shock to the external finance premium.[15] Our approach captures, in a reduced form way, a variety of financial shocks that raise the effective cost of financial intermediation, such as reduction in the net worth of financially constrained agents (e.g Bernanke et al., 1999, Gertler and Kiyotaki, 2010, Adrian and Shin, 2009), a reduction in the risk-taking behaviour of the financial sector (Coimbra and Rey, 2017), or a reduction in financial intermediaries' sentiment (Fostel and Geanakoplos, 2012, Gennaioli et al., 2012).[16] The dark thick lines display the impulse responses we obtain using the baseline estimated parameters in Christiano et al.

[15] Specifically, and with reference to Christiano et al. (2014) original code, we plot the following variables: output is `gdp_obs`; inflation is `inflation_obs`; the policy rate is `Re`; the risk premium is `premium_obs`; the borrowing rate is defined as the long term rate `RL` plus the risk premium.

[16] Anderson and Cesa-Bianchi (2020) show that shocks to the net worth of financial intermediaries have observationally equivalent effects on corporate credit spreads as shocks to the net worth of firms.

(2014). The impulse responses clearly show that the policy rate and the credit spread move in different directions, but the latter dominates. As a result, the borrowing rate increases.

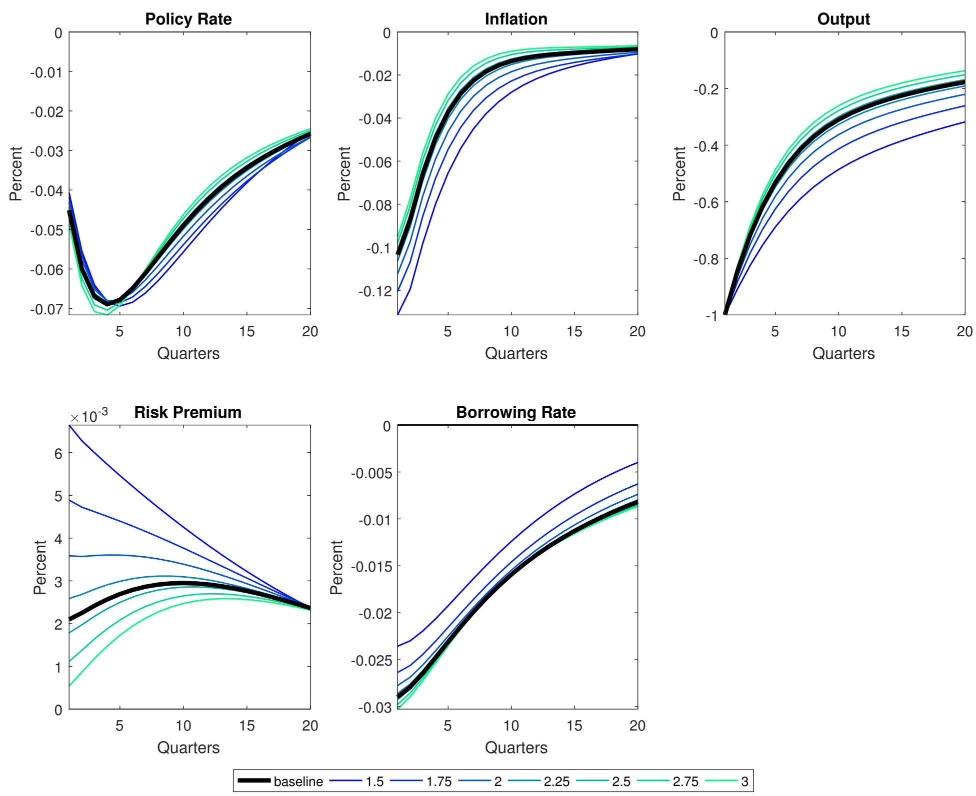
Figure 2 Impulse Responses to a Risk Premium Shock



Note. The thick dark line is computed using the parametrization in the baseline estimated model of Christiano et al. (2014). The thin colored lines are obtained by varying the coefficient on inflation in the Taylor Rule. We consider values from 1.5 to 3. The size of the shock is normalized so that it generates a fall in output of 1 percent.

The response of the borrowing rate crucially depends on the reaction function of the central bank. For example, a more 'aggressive' monetary policy rule (i.e., a Taylor rule with a higher coefficient on deviations of inflation from target) would generate a larger fall in the policy rate, which would also decrease the lending rate. If this effect is strong enough, the response of the lending rate could turn negative, thus invalidating our identification assumption. To address this issue, we assess the robustness of the above theoretical predictions to different monetary policy reaction functions. The thin lines in Figure 2 display how the impulse responses change when changing the parameter governing the response of the policy rate to deviations of inflation from target in the Taylor rule (ϕ^π). We consider a wide set of parameter values that covers the range typically considered in the literature, i.e. we consider values from $\phi^\pi = 1.5$ to $\phi^\pi = 3$. The impulse responses under these alternative Taylor rules show that the borrowing rate increases irrespective of the strength of the monetary policy response to inflation. In the Online Appendix we also show that this result holds true for other financial shocks.

Figure 3 Impulse Responses to a Government Spending Shock



Note. The thick dark line is computed using the parametrization in the baseline estimated model of Christiano et al. (2014). The thin colored lines are obtained by varying the coefficient on inflation in the Taylor Rule. We consider values from 1.5 to 3. The size of the shock is normalized so that it generates a fall in output of 1 percent.

We now turn to aggregate demand shocks. Figure 3 reports the IRFs of the same variables considered in Figure 2 to a negative shock to government consumption.[17] The

[17]Results are similar when we consider other type of demand shocks, such as preference shocks or

shock is contractionary, so that output and inflation fall and the central bank responds by lowering the policy rate. Since the credit spread is countercyclical, similar to what we observed for the financial shock, the policy rate and the credit spread move in different directions. However, in the face of an aggregate demand shock, the movement in the policy rate now dominates over the credit spread. As a result, the borrowing rate falls. Again, we check that our finding is robust to the strength of the central bank response to deviations of inflation from target, as shown by the thin lines in Figure 3, and to other types of demand shocks, such as consumers' preference shocks (reported in the Online Appendix).

These results therefore suggest that there exists a minimum set of sign restrictions that allows us to distinguish between financial and demand shocks based on the response of the borrowing rate. Specifically, a (contractionary) financial shock is defined as a shock that decreases output, prices and the policy rate, and increases the credit spread and the borrowing rate. In the next section we identify a financial shock using these sign restrictions in a structural VAR of the type described in section 2, which allows us to track the impact of the shock on the macroeconomy and its international transmission. We also compare the effects and spillovers of the financial shock with monetary policy and central bank information shocks.

Before moving to the description of our empirical results, it is worth noting that, in principle, one could use additional restrictions to separately identify demand shocks from financial shocks. In the class of models considered in this Section, adverse financial shocks — which are transmitted to the rest of the economy via their effect on either the demand or supply of capital — may generate a fall in investment, but an increase in consumption. The opposite is true for demand shocks that directly reduce consumption (e.g. preference shocks) and lead to a countercyclical increase in investment. Thus, in principle one could exploit the opposite co-movement between consumption and investment to separately

investment specific shocks. See the Online Appendix.

identify demand shocks and financial shocks. We find, however, that predictions are sensitive to the parametrization of the Taylor rule and, most importantly, do not hold for *all* types of financial shocks. For example, as explained in Christiano et al. (2014), risk shocks lead to a positive co-movement between investment and consumption. As our objective is to identify a broad class of financial shocks, we do not exploit these restrictions in our application. We think, however, that these restrictions could be very useful to identify particular subsets of such shocks.

4 Empirical Results

In this section we present the main results of the paper. We first discuss the domestic and international transmission of a US financial shock. We then compare the financial shock to a monetary policy shock and a central bank information shock. Finally, we report a number of exercises to check the robustness of our baseline empirical findings.

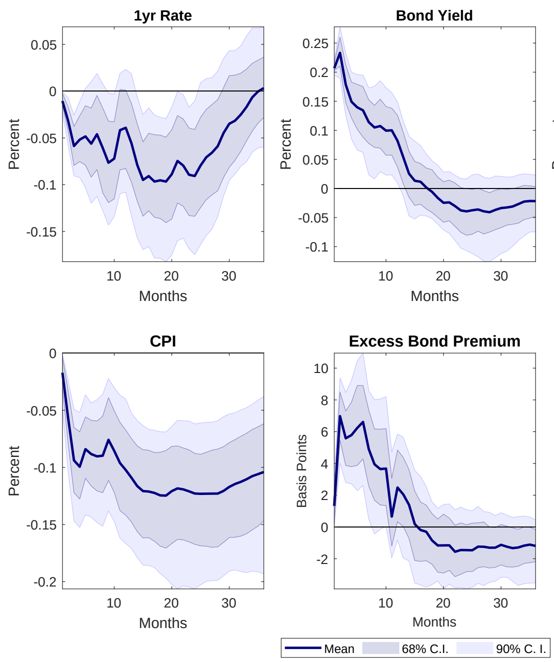
4.1 The International Transmission of US Financial Shocks

We start by analyzing the domestic transmission of a 1 standard deviation US financial shock (Figure 4). We interpret this shock as an increase in the effective cost of financial intermediation, which therefore raises the cost of external finance.[18]

Consistent with the sign restrictions derived in section 3, the (contractionary) financial shock increases spreads and bond yields, and lowers activity and prices. The impact of the shock is quantitatively sizable: real GDP contracts by almost 0.1% at the trough, and prices fall by almost 0.15%. This is despite a loosening of monetary policy, with the 1-year interest rate declining persistently and troughing at about −0.1%. The shock also

[18] As discussed above, this could be driven, for example, by a reduction in the net worth of financially constrained agents, a reduction in the risk-taking behaviour of the financial sector, or a reduction in financial intermediaries' sentiment.

Figure 4 US Financial Shock: Transmission Within the US

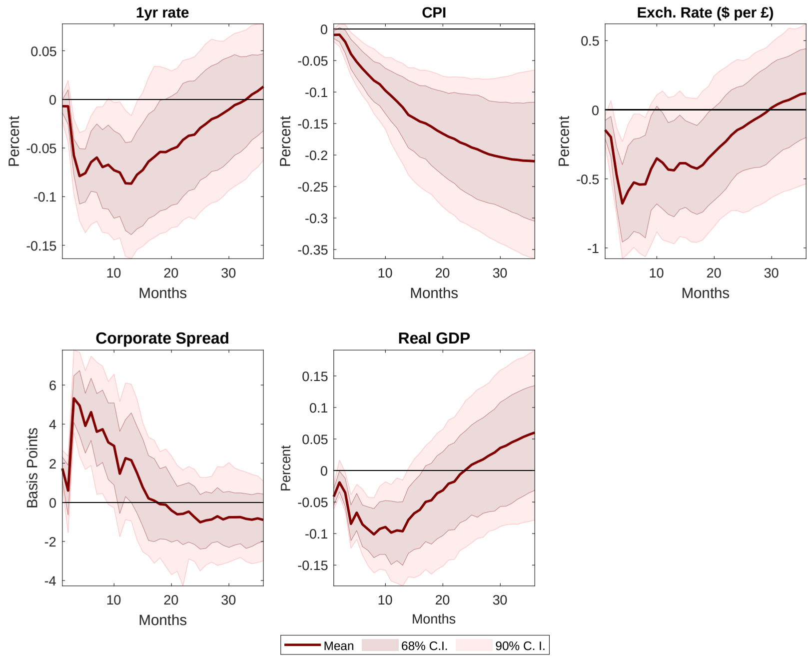


Note. The solid line and shaded areas report the mean, 68% and 90% confidence intervals computed using wild bootstrap with $2 * 10^6$ replications and 10^4 rotations per bootstrap draw.

has persistent effects on the Excess Bond Premium, which peaks at around 7 basis points and remains elevated for several months before reverting to its long-run value. The bond yield, which initially also increases, gradually falls as the effect of looser monetary policy and lower bond spreads feed through.

How do financial shocks transmit internationally? Figure 5 plots the responses of UK variables to the US financial shock. If an international credit channel exists, the increase in US credit spreads should be quickly transmitted internationally, leading to an increase in UK credit spreads. Figure 5 shows that this is indeed the case. While the initial increase is somewhat small, credit spreads rapidly increase to about 5 basis points, a magnitude that is similar to the one observed in the US. In turn, the increase in UK credit spreads acts as an amplifier of the contractionary effects of the US financial shock: UK consumer prices fall and so does UK real GDP, with magnitudes that are slightly larger than their

Figure 5 US Financial Shock: Transmission to the UK



Note. The solid line and shaded areas report the mean, 68% and 90% confidence intervals computed using wild bootstrap with $2 * 10^6$ replications and 10^4 rotations per bootstrap draw.

US counterparts. The contraction in the UK economy happens despite a depreciation of sterling vis-à-vis the US dollar (likely reflecting a flight to the 'safe haven' US dollar) and a loosening of the UK monetary policy stance, with the 1-year rate falling by almost 10 basis points.

Overall, we interpret these impulse responses as being consistent with an international credit channel for US financial shocks. The tightening in US financial conditions quickly spills over internationally. Despite the loosening in UK monetary policy, credit costs in the UK increase, making it harder for UK policy-makers to cushion the contractionary effects of the US financial shock. As we shall show in the next sections, the comovement of credit spreads across countries in response to financial shocks is similar not only to the one we obtain conditional on monetary policy shocks (as extensively shown by the existing literature), but also to the one we obtain conditional on central bank information shocks.

4.2 A Comparison with Monetary and Central Bank Information Shocks

In this section, we explore how the impact of financial shocks compares to monetary policy and central bank information shocks.

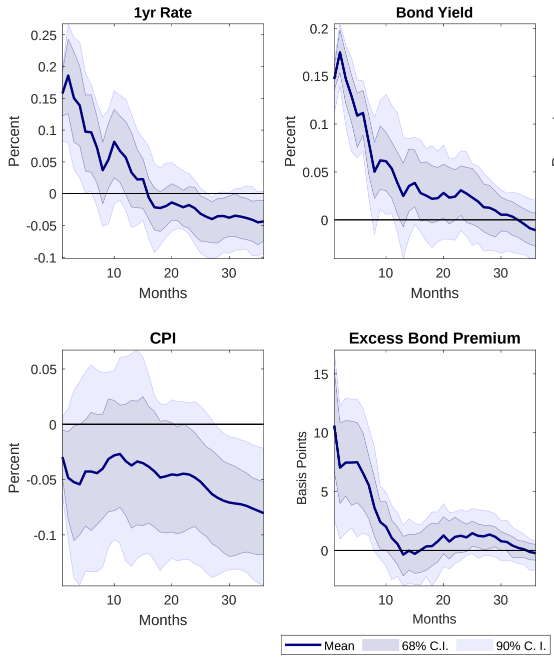
A US Monetary Policy Shock We start by describing the impulse responses of US variables to a 1 standard deviation US monetary policy shock (Figure 6). Not surprisingly — given the similar specification and methodology — our results are very similar to those in Gertler and Karadi (2015) and Jarocinski and Karadi (2020). A surprise increase in the 1-year rate (instrumented with exogenous monetary policy surprises) leads to a significant fall in real GDP, a small contraction in CPI, and an increase in the excess bond premium, which Gertler and Karadi (2015) interpret as being consistent with a *domestic* credit channel of monetary policy.[19] As monetary policy affects corporate bond yields through both an expectations channel (which affects the path of future expected short rates) and the aforementioned domestic credit channel (which affects corporate bond spreads), the corporate bond yield also increases in response to the monetary policy shock.

We now turn to the international transmission of monetary policy shocks. This question has been extensively studied in the existing literature.[20] In line with previous findings, the responses of UK variables to a US monetary policy shock (Figure 7) corroborate the existence of an international credit channel of monetary policy. The UK corporate credit spread increases slightly on impact and rapidly jumps to 7 basis points. The impulse responses also show that sterling depreciates vis-à-vis the US dollar, at first by about

[19]Following Mertens and Ravn (2013), we report two reliability statistics for the validity of the two instruments we employ to identify monetary policy and central bank information shocks: the mean R^2s of the first-stage regressions across bootstrap draws are 0.05 and 0.03, respectively, while the means of the sorted eigenvalues of the reliability matrix are 0.07 and 0.04, respectively. Both statistics indicate that the instruments do provide useful information for the identification of our structural shocks, albeit with a fair amount of noise.

[20]See Rey (2016), Dedola et al. (2017), and Kalemli-Ozcan (2019) among many others.

Figure 6 US Monetary Policy Shock: Transmission Within the US



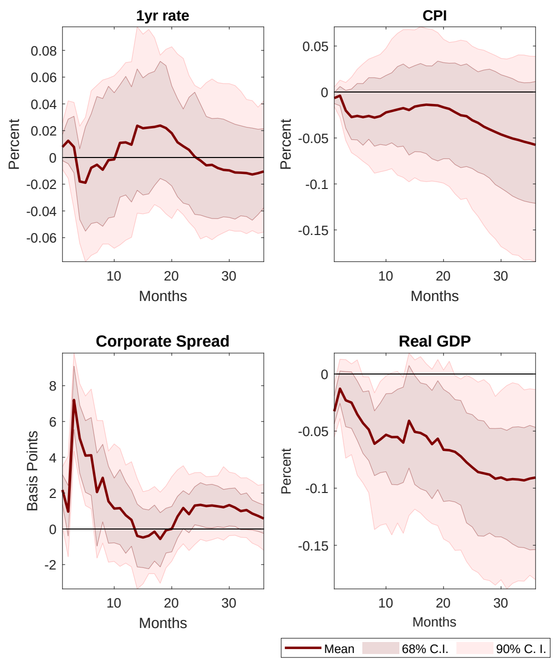
Note. The solid line and shaded areas report the mean, 68% and 90% confidence intervals computed using wild bootstrap with $2 * 10^6$ replications and 10^4 rotations per bootstrap draw.

0.2%, and then gradually reaching 0.6%. Real GDP gradually falls, suggesting that the foreign demand and credit channels dominate over the expenditure-switching channel. CPI slightly falls but in a non-significant fashion, suggesting that downward pressures from lower demand are countered by the pass-through to domestic prices of a depreciated exchange rate. The UK monetary policy response is correspondingly muted.

Our result on the response of UK monetary policy policy is in line with the evidence provided by Kalemli-Ozcan (2019), who shows that a US monetary policy shock leads to a fall in the interest rate differential (measured as the domestic interest rate minus the US interest rate) in a panel of advanced economies (with the opposite finding for emerging market economies). Figure A.1 in the Appendix reports the impulse response to a US monetary policy shock of the interest rate differential on the 1-year government bond rate as implied by our VAR, and shows that such differential is negative and significant.[21]

[21] In Figure A.1, we also consider an extended specification of our VAR where we add the 10-year

Figure 7 US MONETARY POLICY SHOCK: TRANSMISSION TO THE UK



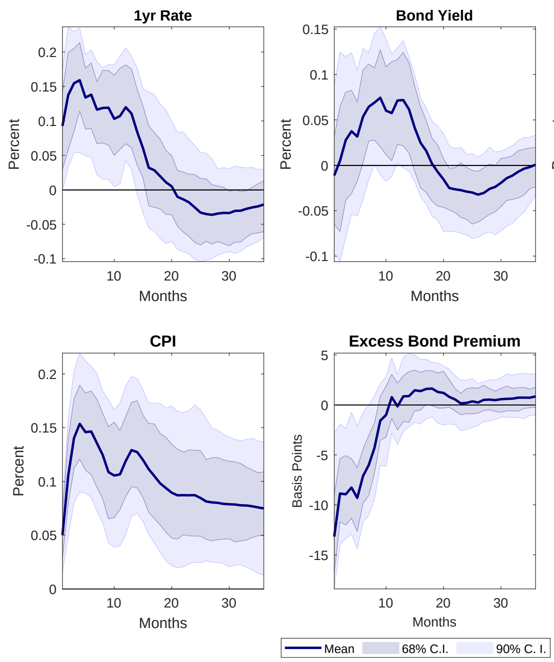
NOTE. The solid line and shaded areas report the mean, 68% and 90% confidence intervals computed using wild bootstrap with $2 * 10^6$ replications and 10^4 rotations per bootstrap draw.

A US Central Bank Information Shock We now explore the domestic and international transmission of Fed information shocks. We start by analyzing the response of the US economy to a 1 standard deviation central bank information shock (Figure 8). Not surprisingly — given the similar specification and approach — our results are similar to those in Jarocinski and Karadi (2020). An unexpected increase in the 1-year rate instrumented with exogenous central bank information surprises leads to a significant increase in real GDP, an increase in CPI, and a contraction in the excess bond premium.

How do central bank information shocks transmit internationally? Figure 9 reports the responses of UK variables to a Fed information shock. As for financial and monetary policy shocks, the central bank information shock leads to an international comovement of corporate credit spreads, with UK spreads decreasing slightly on impact, and rapidly

government bond yield differential. Also in line with Kalemli-Ozcan (2019), we find that this longer-maturity interest rate differential also becomes negative in response to a US monetary policy shock.

Figure 8 Fed Information Shock: Transmission Within the US



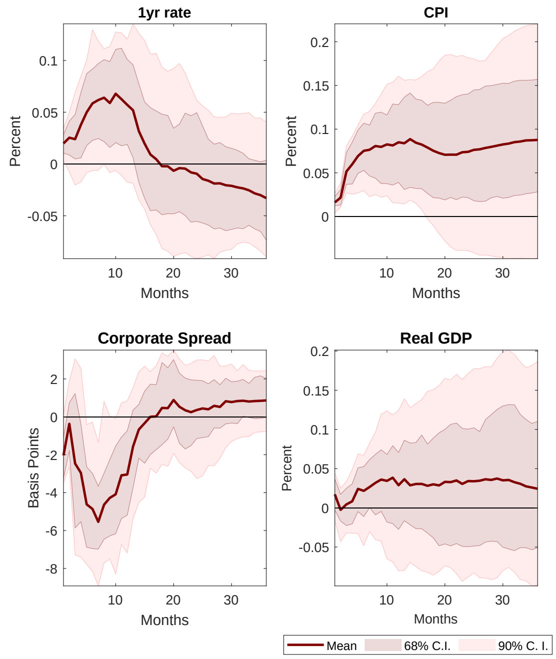
Note. The solid line and shaded areas report the mean, 68% and 90% confidence intervals computed using wild bootstrap with $2 * 10^6$ replications and 10^4 rotations per bootstrap draw.

falling by almost 6 basis points. The shock also leads to international comovement in output and prices. CPI rapidly increases above its long-run trend by almost 0.1%; and real GDP increases by about 0.05%, even though the effect is statistically significant only at the 68% confidence level. Consistent with the good news in the US economy, the US dollar appreciates vis-à-vis Sterling, even though the response is significant only at the 68% confidence level. Finally, monetary policy accommodates the shock by raising interest rates, consistent with what is implied by an inflation targeting regime.

4.3 Robustness

We describe here the results from a set of exercises showing the robustness of our results. All the charts associated with the robustness exercises are reported in the Online Appendix to the paper.

Figure 9 Fed Information Shock: Transmission to the UK



Note. The solid line and shaded areas report the mean, 68% and 90% confidence intervals computed using wild bootstrap with $2 * 10^6$ replications and 10^4 rotations per bootstrap draw.

Identification of additional shocks. We re-estimate our model imposing additional sign restrictions to identify (in addition to a monetary policy and a financial shock) an aggregate supply shock, to address the potential concern that with set identification, the identification of additional shocks might change the credible sets for the financial shock. However, the identification of the additional shock does not affect our baseline identification of a financial shock.

Inflation targeting sample. The UK adopted an inflation target as its nominal anchor following its exit from the Exchange Rate Mechanism in 1993. Given this important structural change in the UK economy, we check that our results are robust when considering a shorter sample starting in 1993:M1. Note that we do not need here to reduce the sample for the US model since (as noted above) the US and the UK models can be estimated separately.

Global financial crisis. A concern is that our results might be driven by the global financial crisis. When we estimate our model on a sample period that excludes the global financial crisis (i.e. from 1979:M7 to 2007:M12) we find qualitatively the same results, even though less precisely estimated.

Alternative measure of economic activity. Another concern might be the use of monthly GDP series as measures of real activity. We therefore also report results using instead the unemployment rate for both countries. For all three shocks, the responses are consistent with our baseline results using GDP, and corroborate the existence of an international credit channel.

5 Inspecting the Mechanism

The evidence in the previous section shows that US shocks significantly affect credit conditions both domestically and internationally. In particular, financial shocks, monetary policy shocks, and central bank information shocks all lead to a strong international comovement in corporate bond spreads. We interpret this evidence as suggesting that, in line with theoretical models with financial frictions and a high degree of financial integration, an international credit channel is at work.

In this section we provide additional evidence to support our interpretation. We proceed in two steps. First, we show that the responses of credit spreads act to amplify the responses of real variables to US shocks. Second, we show that US shocks induce international comovement in credit spreads based on different asset classes (i.e., not only corporate bonds spreads).

5.1 Closing the International Credit Channel

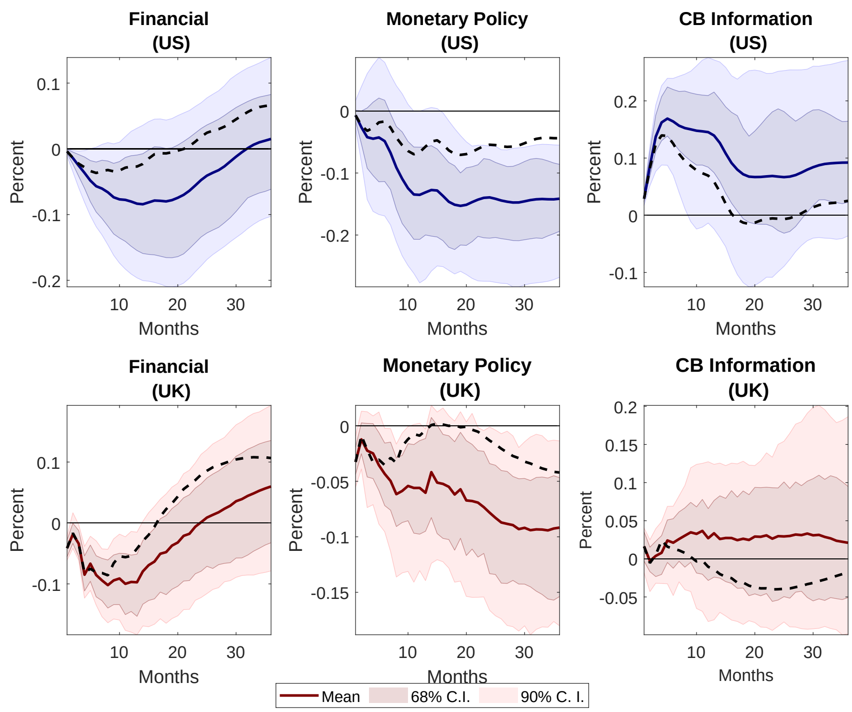
Adverse shocks that lower the net worth of financially constrained agents or lead to a reduction in financial intermediaries' risk aversion and sentiment lead to an increase in credit spreads. The increase in borrowing costs depresses agents' demand, which in turn lowers their net worth and raises credit spreads further. This is the feedback loop that gives rise to a domestic credit channel. When agents' balance sheets are denominated in both domestic and foreign currency, their net worth (and, therefore, the credit spreads they face) is also directly affected by foreign shocks through movements in the price of foreign assets and liabilities and/or the exchange rate. The no-arbitrage conditions imposed by international financial integration imply a strong pressure towards cross-border equalization of asset prices, leverage, and credit premia faced by financially constrained investors, thus creating tight linkages in macroeconomic dynamics across countries.

Thus, if an international credit channel is at work, domestic and foreign credit spreads should not only co-move, but also amplify the real effects of foreign shocks. A crude, yet intuitive way to investigate whether our model captures a similar mechanism involves closing the main channel of transmission associated with financial frictions. In our empirical model, we can compare our baseline impulse responses to US financial, monetary policy, and central bank information shocks to counterfactual ones in which the credit spread in both countries is held fixed at its steady state value. The difference between the two sets of responses can then provide some evidence on the amplification role played by credit spreads via the international credit channel.

Figure 10 reports the responses of real GDP to financial, monetary policy, and central bank information shocks in our baseline specification (solid lines) alongside the same responses obtained when closing the domestic and international credit channel (dashed lines).[22] The top panels report the response of US real GDP to the US financial shock (left panel), monetary policy shock (middle panel), and central bank information shock (right panel) analyzed in the previous section. Similarly, the bottom panels report the international spillovers of the US shocks on UK real GDP. All panels paint a similar

[22]The full set of impulse responses is reported in the online Appendix.

Figure 10 Closing the International Credit Channel: The Response of Real GDP



Note. The solid lines and shaded areas report the mean, 68% and 90% confidence intervals computed using wild bootstrap with $2 * 10^6$ replications and 10^4 rotations per bootstrap draw. The dashed lines reports the counterfactual impulse responses computed keeping credit spreads fixed.

picture: when the credit channel is not at work, real GDP in both the US and the UK is less susceptible to financial, monetary policy, and central bank information shocks. The effects of the shocks are not only smaller, but also less persistent.

The evidence reported in this section suggests that credit spreads can amplify the international transmission of shocks, with meaningful implications for the real side of the economy. This points to the existence of an international credit channel and is in line with theoretical models with financial frictions and a high degree of financial integration, where financially constrained agents holding foreign and domestic risky assets can act as a powerful propagation mechanism of shocks across countries.

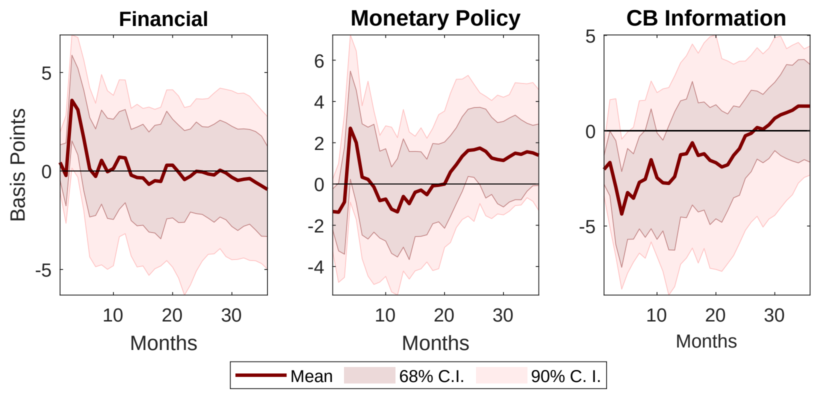
5.2 Alternative measures of credit spreads

In this section, we provide additional evidence, based on the mortgage and interbank markets, that reinforces our empirical findings and their interpretation. Figure 11 reports the responses of UK mortgage spreads (top panels) and 3-month Libor spreads (bottom panels) to the same US financial shock (first column), monetary policy shock (second column), and central bank information shock (third column). If an international credit channel is at work, we should observe a countercyclical behaviour of credit spreads irrespective of the shock considered.

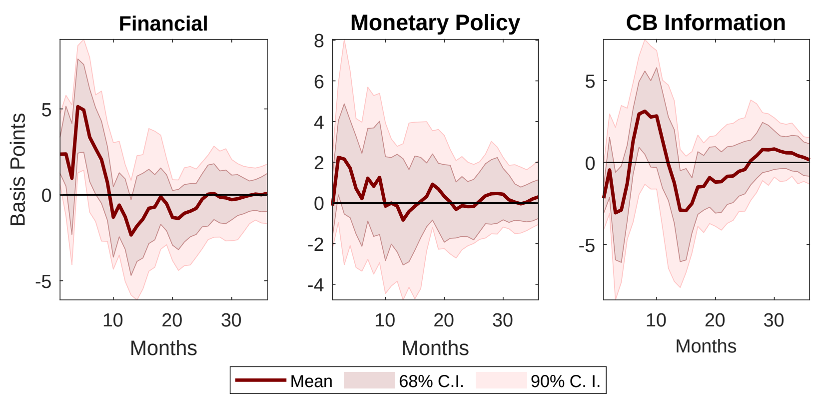
The impulse responses in Figure 11 show that this is the case. As documented by previous studies (e.g. Rey (2016)), mortgage spreads increase in response to a US monetary policy shock. But, fitting our narrative , mortgage spreads also increase in response to a US financial shock that tightens financial conditions, and decrease in response to a Fed information shock that loosens financial conditions. We obtain a similar pattern for the spread between the 3-month Libor and the yield on 3-month Treasury bills, which also responds countercyclically to the three shocks that we consider: the response is particularly evident for the financial and monetary policy shocks, while it is less well-estimated, but nevertheless suggestive, for the central bank information shock.

Figure 11 UK's Response to US Financial Shock: Alternative Credit Spreads Measures

(A) Mortgage spreads



(B) Libor spreads



Note. The solid line and shaded areas report the mean, 68% and 90% confidence intervals computed using wild bootstrap with $2 * 10^6$ replications and 10^4 rotations per bootstrap draw. The top panel reports mortgage spreads, computed as the difference between mortgage rates and the 10-year government bond yield; the bottom panel reports Libor spreads, computed as the difference between the 3-month Libor and the 3-month Treasury Bill.

6 Conclusion

We provide empirical evidence on the existence of an international credit channel for the transmission of US financial, monetary policy, and central bank information shocks across borders. To do so, we propose a new identification approach that combines external instruments and sign restrictions. We embed this identification approach in a two-country structural VAR for the analysis of the international transmission of US shocks to the UK economy.

Financial shocks lead to synchronized movements in credit spreads across countries and to economically meaningful real effects, as do monetary policy and central bank information shocks. Our results support the notion that frictions in domestic and international financial contracting can act as a powerful spillover amplifier. Understanding whether our findings also apply to other small open economies besides the UK is an interesting avenue for future research.

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Appendix

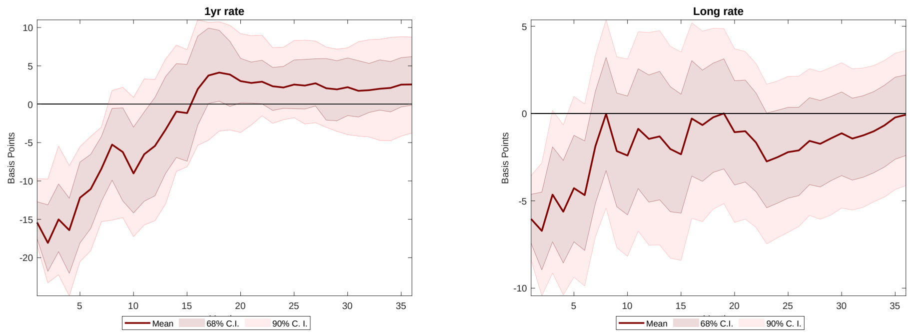
Data: US. We extend the original data set of Gertler and Karadi (2015) (1-year Treasury Yield, CPI, industrial production, Excess Bond Premium) to 2015:M3. All variables are from Datastream and seasonally adjusted. We use the series of monetary policy surprises purged of central bank information shocks from Jarocinski and Karadi (2020). An update of the Excess Bond Premium series (originally from Gilchrist and Zakrajsek (2012)) is available on Simon Gilchrist's web page.[23] Our measure of the corporate bond yield is obtained by adding to the Gilchrist-Zakrajsek (GZ) corporate bond spread (also available on the same web page) the 10-year government bond yield.[24] We obtain a monthly GDP series by interpolating quarterly real GDP (OECD Main Economic Indicators) using the methodology used in Miranda-Agrippino and Rey (2020b).

Data: UK. We use the following variables, with sources in parenthesis: 1-year Gilt yield as policy indicator (Bank of England), the CPI (OECD Main Economic Indicators), the nominal \$/£ exchange rate (Bank of England), and a monthly estimate of real GDP (provided by the National Institute of Social and Economic Research). All variables are monthly and seasonally adjusted. The corporate credit spread is taken from "*A millennium of macroeconomic data*"('Spliced interpolated series 1854-2015' from the tab '*M11. Mthly corp bond yields*' of the excel file available online)[25]

Additional results. We report here the impulse responses of the interest rate differential implied by our baseline VAR. We measure the differential as the UK interest rate minus the US interest rate. In line with the findings of Kalemli-Ozcan (2019) for advanced economies, we find that a US monetary policy shock leads to a fall in the interest rate differential (left panel of Figure A.1). We also estimated a version of our VAR with a 10-year government bond rate and found that the differential decreases at longer maturities (right panel).

[23] `http://people.bu.edu/sgilchri/Data/data.htm`.
[24] Note that the median maturity at issue across all bonds in GZ's sample is 10 years.
[25] `https://www.bankofengland.co.uk/statistics/research-dataset`.

Figure A.1 US's Response to US Monetary Policy Shock: Interest Rate Differentials



Note. The solid line and shaded areas report the mean, 68% and 90% confidence intervals computed using wild bootstrap with $2 * 10^6$ replications and 10^4 rotations per bootstrap draw.