Crisis? What Crisis?
Currency vs. Banking in the Financial Crisis of 1931*

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December 2, 2010

Abstract

This paper examines the role of currency and banking in the German financial crisis of 1931 for both Germany and the U.S. We specify a structural dynamic factor model to identify financial and monetary factors separately for each of the two economies. In contrast to conventional wisdom, we find only a minor role for monetary policy transmission, while financial distress was important. Monetary or financial crisis propagation from the U.S. to Germany was weak. Instead there is evidence of substantial crisis transmission from Germany to the U.S. via the banking channel. We also find major real effects of the 1931 crisis on both economies, again transmitted via the banking channel. Financial distress itself responded more strongly to real than to monetary factors. Results confirm Bernanke's (1983) conjecture that a non-monetary financial channel of crisis propagation was operative in the Great Depression.

JEL: N12, N13, E37, E47, C53
Keywords: Great Depression, banking channel, 1931 financial crisis, international business cycle transmission, factor analysis

*This research was funded by Deutsche Forschungsgemeinschaft under Collaborative Research Project SFB 649. Samad Sarferaz acknowledges financial support by the European Science Foundation via the Globalizing Europe Economic History Network and the Marie Curie Research Training Networks, and thanks the University of Zurich and the European University Institute in Florence for their hospitality. A previous version of this paper was circulated as CEPR Discussion Paper No. 7610.

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1 Introduction

Between 1929 and 1932, national output in the U.S. and Germany declined in unison, earlier and more strongly than in most other industrialized nations (see the data in Barro and Ursúa, 2008). The two economies were heavily exposed to each other, both through financial markets and the Gold Standard. German debt owed directly and indirectly to the U.S. exceeded 20% of U.S. GDP in 1931 (Schuker, 1988). This debt was lost almost entirely between 1931 and 1933. The trigger event for this was the Austro-German financial crisis of July 1931. In a matter of days, it led to the nationalization of Germany's five largest banks, the suspension of gold convertibility, the introduction of capital controls, a moratorium on reparations, and a standstill on short term debts that evolved into a full-blown debt default (see the account of events in James, 1986).

There is general agreement that the 1931 financial crisis was a key event in deepening the Great Depression internationally. The channels and the direction of crisis propagation and transmission seem less clear. Building on research by Born (1967) and James (1986), Schnabel (2004) highlighted the vulnerability of German banks as a key factor in the 1931 crisis, identifying lack of equity and high exposure to short-term foreign credit since the stabilization from the 1923 hyperinflation as deeper causes.

The 1931 financial crisis was also a crisis of the Gold Standard, and marked the beginning of its breakdown. Doubts about the credibility of Germany's commitment to the Gold Standard, as well as its ability to defend its currency, have been emphasized by Eichengreen (1992) and Temin (1989).

Moreover, the financial crisis of 1931 was a foreign debt and reparation crisis. Foreign borrowing under the favorable terms of the Dawes Plan between 1924 and 1929 had diluted the value of reparation claims. Tighter terms for reparation payments under the Young Plan put an end to further German borrowing and triggered a policy of fiscal austerity (Ritschl, 2002). Doubts about this policy and Germany's willingness and capacity to pay further reparations contributed to the outbreak of the crisis (Ferguson and Temin, 2003). When Germany's position finally unraveled, foreign debt including reparations under the Young Plan amounted to roughly 100% of German GDP (Ritschl, 2002).

Scholars have long emphasized the fact that Germany's foreign debt was mainly underwritten by the U.S., see Kindleberger (1973) and in particular, Schuker (1988).[1] James (2001) argued explicitly for financial crisis transmission of the 1931 crisis to the U.S. The financial crisis of 1931 also figures prominently in recent comparisons between the interwar depression and the Great Recession after 2007 (see Bordo and James, 2009).

The present paper is about assessing the role of these financial factors in aggravating the Great Depression in 1931. We exploit a balanced panel of financial, monetary, and real time series from both the U.S. and Germany. Germany was unique among the major European economies in collecting and producing high quality time series data between 1925 and 1933, replicating the Burns and Mitchell business cycle project in the U.S. That such an effort was made is itself a consequence of the stringent statistical reporting criteria of the 1924 Dawes Plan (Tooze, 2001). Our choice of the U.S./Germany comparison is motivated by the role of the U.S. as the anchor of the interwar gold standard and the high mutual financial exposure of the U.S. and Germany. To analyze the issue econometrically, we choose an approach that allows for sufficiently rich dynamics while capturing information from a large number of time series. Vector autoregression (VAR) analysis alone would not be adequate because of its limitation to a few time series. To exploit the information embedded in many disaggregate time series and avoid the curse of dimensionality, we rely on a dynamic version of factor analysis as e.g. in Forni, Hallin, Lippi, and Reichlin (2000) or Stock and Watson (2002a,b).

We combine the dynamic factor model with vector autoregressions to analyze the interdependencies between the estimated latent factors, following the factor augmented vector autoregression (FAVAR) approach by Bernanke, Boivin, and Eliasz (2005). Our version of the FAVAR model identifies the factors by exclusion restrictions, thus giving them a structural interpretation (as in Kose, Otrok, and Whiteman, 2003). For each of the two countries, we specify a currency component, a banking factor, and a real component separately. The

[1] This included inter-allied credits from the U.S. to Britain and France, for which German reparations served as collateral. These loans were defaulted on in 1932.

first is designed to capture monetary transmission channels under the Gold Standard, which would be in line with more traditional interpretations of the 1931 crisis as first- or second-generation currency crisis (as in Eichengreen, 1992 or Temin, 2008). The banking component is designed to be a measure of financial distress, reflecting views of the German 1931 crisis as a banking crisis (as in Reinhart and Rogoff, 2009). The identification of distinct nominal components in both countries allows us to examine their dynamic relationships both domestically and internationally.

We approach this question in a twofold manner. First, we obtain impulse response functions from shocks to the factors under weak identifying restrictions. To identify the influence of the 1931 financial crisis on the macroeconomic responses to shocks, we estimate the FAVAR model both for the whole observation period to late 1932 and a truncated sample that ends before the 1931 crisis. Second, we assess the information content of the individual factors by measuring their contribution to the forecasting power of the factor model. We do this at several critical junctures before and during the financial crisis of 1931, obtaining conditional forecasts with and without the respective factor in the information set.

Our results indicate that both monetary and financial transmission mechanisms were active during the slump. However, financial factors constitute by far the dominant channel of international crisis propagation, while monetary forces played only a moderate role (using a DSGE model, Cole, Ohanian, and Leung, 2005, obtain related results). This also holds domestically for both economies and is hardly influenced by the choice of subperiods. The overall limited role for monetary factors is consistent with evidence from a FAVAR model for the U.S. in Amir Ahmadi and Ritschl (2009). We also find that contrary to expectation, crisis transmission from the U.S. to Germany was comparatively minor. In contrast, we obtain evidence of marked crisis propagation from Germany on the U.S., transmitted mainly through the financial stress components.

These feedback effects became pronounced around the German crisis of July 1931. We find strong predictive power of Germany's financial factor for the U.S. economy, indicating a strong systemic component of the July 1931 crisis. We also find evidence that financial shock transmission to the U.S. after the crisis was stronger than before.

Our research is closely related to the debate about the causes of banking distress in the

U.S. economy during the Great Depression. Friedman and Schwartz (1963) argued that financial crises during the Great Depression were mainly the results of panics, as links to macroeconomic aggregates seemed difficult to find. By contrast, economic historians have argued for fundamental reasons of banking distress during the Depression, see e.g. Temin (1976), Wicker (1980), and White (1984). Calomiris and Mason (2003) used microdata to argue for strong links between bank failures and market fundamentals. Our results, based on the common components of disaggregate series, support this view: we find a substantial role for fundamentals in causing financial distress. On the other hand, Friedman and Schwartz (1963) emphasized also the importance of international financial shocks for U.S. banking. We find abundant support for this view as well, both for the period under study as a whole and the 1931 financial crisis in particular.

Our research is also related to the debate about U.S. monetary policy during the Great Depression. While we do not aim to identify monetary policy instruments, our strategy does allow us to identify shocks to the money market and to bank lending separately. Friedman and Schwartz (1963) famously claimed that the failure of monetary policy to provide banks with liquidity contributed to the severity of the Great Depression. In their view, the banking sector faced substantial shocks to liquidity preference, and hence a problem of illiquidity rather than insolvency (a detailed discussion appears in Calomiris, 2010). Research on the bank lending channel of monetary policy transmission in the wake of Bernanke and Blinder (1992) has provided underpinnnings to this perspective, see e.g. Bernanke and Gertler (1995) or Kashyap and Stein (1995, 2000). Under normal conditions, effects of monetary policy on credit demand and supply might be difficult to identify and would partly offset each other. In a credit crunch or close to the zero bound, however, the quantity effects on credit supply become dominant, providing ample scope for open-market and unconventional monetary policy (see Gertler and Karadi, 2009).[2]

We find the evidence on banking as a transmission channel of monetary shocks to be mixed, with real and international factors taking center stage instead. We do, however, find

[2] As noted by Friedman and Schwartz (1963) and many others, the Fed experimented with open market operations in Treasury bonds in the interwar period but largely refrained from trade in private sector assets, except for its traditional discount window facilities. See the discussions in Wheelock (1991) and Meltzer (2002).

real effects of financial shocks. This is particularly true during and after the 1931 financial crisis. Early research of Bernanke (1983) conjectured that financial distress during the Great Depression was non-monetary in nature, and that its real effects were important. Our results concur with that. We also find evidence of these effects amplifying over time, consistent with the financial accelerator mechanism described in Bernanke and Gertler (1996).

Last, our research links to a discussion among economic historians about the fallout of the 1931 financial crisis. Transmission to the U.S. has been emphasized by James (2001, 2009). For July 1931, coincident with the German banking crisis, Richardson and van Horn (2008) find a strong increase in financial distress at New York banks. Accominotti (2009) examined balance sheets of London banks and found that the German banking crisis was instrumental in weakening the Sterling and pushing Britain off the Gold Standard. Mouré (2002) argued that France's default on her inter-allied World War I debt in the wake of the end of German reparations seriously worsened the credit crunch in the U.S. (see also Eichengreen and Flandreau, 2008). More generally, our results relate to research about foreign debt crises and their international spillovers. Calvo, Leiderman, and Reinhart (1996) have identified large output effects of such crises in the defaulting countries as well as marked spillover effects. Calvo, Izquierdo, and Talvi (2006) have argued that the U.S. depression of 1929 to 1933 and the subsequent recovery to 1937 bear a lot of resemblance to foreign-debt-related recessions. With due caution, our results on the transatlantic spillover of Germany's financial crisis can be viewed as complementary to and consistent with this interpretation.

We estimate the dynamic factor model with Bayesian methods, employing Monte Carlo Markov chain (MCMC) techniques to infer the posterior distributions. Our choice of a Bayesian framework is motivated by two considerations. First, our observation period is both preceded and followed by fundamentally different macroeconomic regimes, the German hyperinflation of 1923 and foreign exchange control in the 1930s. As we are not interested in hypothesis testing through data sampling, but rather in optimally characterizing data from a given time period, the Bayesian approach follows naturally. Second, Bayesian numerical techniques are particularly robust in the presence of identifying exclusion restrictions, see Otrok and Whiteman (1998) and Kim and Nelson (1998).

Business cycle transmission with recent international data has been analyzed by structural VARs e.g. in Stock and Watson (2005) and by dynamic factor models in Eickmeier (2007). To our knowledge, the present paper is the first study applying modern time series methodology to the international transmission of the interwar Great Depression. Due to the limitations that existed so far in extending VARs to panel data, existing econometric work on the international Great Depression, as in Bernanke and James (1991) and Bernanke and Carey (1996), was confined to cross section methods.

We structure the evidence by grouping the national time series into nominal and real series and extracting identified factors specific to these groups under exclusion restrictions. We find that the real factors we construct from the data coincide well with traditional business cycle dating schemes and historical national accounts for the respective countries. This is well in line with the results of Stock and Watson (1998) on a factor approach towards business cycle dating. We group the nominal series further by subdividing them into general monetary indicators on the one hand and bank specific indicators on the other. The factors we extract from these series again seem to replicate the historical evidence quite well.

To obtain impulse responses, we try both Cholesky orderings and sign restrictions, drawing on Uhlig (2005) for the identification of traditional monetary policy shocks and on Ciccarelli, Maddaloni, and Peydró (2010) for the identification of shocks propagating via the bank lending channel.

The rest of this paper is structured as follows. The next section characterizes the dynamic factor model we employ. Section 3 provides the data. Section 4 obtains the factors and evaluates the relative importance of currency and banking in the 1931 crisis. Section 5 concludes.

2 A Structural DFA Model

The dynamic factor approach aims to assemble more information than could be processed by standard VAR analysis. We follow recent developments in dynamic factor analysis that have augmented VARs with information gathered from a large cross section of time series. The idea is to aggregate the common components of large time series panels into synthetic series or factors, which are then used as inputs into a standard VAR. For each of the two economies in our dataset, we restrict the factor loadings to specific subsets of the series, monetary, financial, and real.

The data panel Y_t , spanning a cross section of N series and an observation period of length T, is described by an observation equation:

$$Y_t = C + \Lambda f_t + U_t \tag{1}$$

where f_t is a $K \times 1$ vector containing the latent factors, U_t is a $N \times 1$ vector of variable-specific idiosyncratic components, C is an $N \times 1$ vector of constant terms and Λ is the $N \times K$ coefficient matrix linking the K common factors to the i-th variable. More precisely, the Λ matrix controls for the structural interpretation of the factors, where each factor can be loaded on a subset of the data by imposing zero restrictions. In this context, we define

$$\Lambda = \begin{bmatrix} \Lambda^{US} & 0 \\ 0 & \Lambda^{D} \end{bmatrix}$$

where

$$\Lambda^{US} = \begin{bmatrix} \Lambda^{real} & 0 & 0 \\ 0 & \Lambda^{monetary} & 0 \\ 0 & 0 & \Lambda^{financial} \end{bmatrix}$$

and

$$\Lambda^{D} = \begin{bmatrix} \Lambda^{real} & 0 & 0 \\ 0 & \Lambda^{monetary} & 0 \\ 0 & 0 & \Lambda^{financial} \end{bmatrix}$$

The law of motion for the factors, which is in VAR form, is defined as:

$$f_t = \phi_1 f_{t-1} + \cdots + \phi_q f_{t-q} + v_t, \tag{2}$$

with $v_t \sim \mathcal{N}(0, \Sigma)$. The idiosyncratic components U_t are assumed to follow an AR(p) process:

$$U_t = \Theta_1 U_{t-1} + \ldots + \Theta_p U_{t-p} + \chi_t \tag{3}$$

where $\Theta_1, \ldots, \Theta_p$ are $N \times N$ diagonal matrices and $\chi_t \sim \mathcal{N}(0_{N\times 1}, \Omega_\chi)$ with

$$\Omega_\chi = \begin{bmatrix} \sigma^2_{1,\chi} & 0 & \cdots & 0 \\ 0 & \sigma^2_{2,\chi} & \vdots & \vdots \\ \vdots & \cdots & \ddots & 0 \\ 0 & \cdots & 0 & \sigma^2_{N,\chi} \end{bmatrix}$$

To ease the computational burden we *quasi difference* equation (1). Accordingly we multiply equation (1) by $(\mathcal{I} - \Theta(L))$, where $\Theta(L) = \Theta_1 + \cdots + \Theta_p$ and $\mathcal{I}$ is the identity matrix, which leads to the following expression:

$$Y_t^* = C^* + \Lambda^* f_t + \chi_t, \tag{4}$$

where $Y_t^* = (\mathcal{I} - \Theta(L))Y_t$, $\Lambda^* = (\mathcal{I} - \Theta(L))\Lambda$ and $C^* = (\mathcal{I} - \Theta(L))C$.

Prior Specification

For the AR-Parameters of the idiosyncratic components $\Theta_1, \Theta_2, \ldots, \Theta_p$ we specified the following prior:

$$\theta^{prior} \sim \mathcal{N}(\underline{\theta}, \underline{V}_\theta)$$

where $\underline{\theta} = 0_{p\times 1}$ and where

$$\left[\underline{V}_\theta\right] = \tau_1 \begin{bmatrix} 1 & 0 & \cdots & 0 \\ 0 & \frac{1}{2} & \vdots & \vdots \\ \vdots & \cdots & \ddots & 0 \\ 0 & \cdots & 0 & \frac{1}{p} \end{bmatrix}$$

We choose $\tau_1 = 0.2$. The shrinkage prior we specified implies that we punish more distant lags. This is applied by subsequently decreasing the uncertainty about the mean prior belief that the parameters are zero for increasing lag values.

For each of the factor loadings we specified the following prior:

$$\lambda^{prior} \sim \mathcal{N}(\underline{\lambda}, \underline{V}_\lambda)$$

where $\underline{\lambda} = 0$ and $\underline{V}_{\lambda} = 100$. For each of the variances of the disturbances in χ_t we specified the following prior:

$$\sigma_{\chi}^{prior} \sim \mathcal{IG}\left(\frac{\alpha_{\chi}}{2}, \frac{\delta_{\chi}}{2}\right)$$

where we choose $\alpha_{\chi} = 6$ and $\delta_{\chi} = 0.001$, which implies a fairly loose prior. $\mathcal{IG}$ denotes the inverted gamma distribution.

For the parameters of the VAR equation (2) we follow Bernanke, Boivin, and Eliasz (2005) and impose the Kadiyala and Karlsson (1997) Minnesota-type prior on the VAR parameters. Then, the prior distribution of the covariance matrix Σ and the VAR parameters Φ can be expressed by:

$$\Sigma_{prior} \sim \mathcal{IW}(\underline{\Sigma}, K+2),$$

with $\mathcal{IW}$ representing the inverse Wishart distribution and

$$vec(\Phi_{prior}) \sim \mathcal{N}(0, \Sigma_{prior} \otimes \underline{G}),$$

where $\underline{G}$ imposes less weight on more distant lags .

2.1 Estimation

Estimation of the model is via the Gibbs sampler. The principal idea of this algorithm is to break the joint distribution of the model parameters into the conditional distributions and to proceed by iterating over the conditional distributions. As a first step, we start by drawing the parameter block $\Xi = [\Lambda, \Theta_1, \ldots, \Theta_p, \Phi, \Omega_{\chi}\Sigma]$ and take values for the factors as given. In the next step we use the obtained draws and calculate the factors conditional on the realizations of the previous block. These values of the first Gibbs Sampling step are now used to compute the next step by iterating through the blocks just mentioned. Iterating over sufficiently many steps, the simulated frequency distribution converges to the joint distribution at an exponential rate.[3]. To ensure that the dynamic factor model is uniquely identified, the upper $K \times K$ block of the factor loadings matrix is set to the identity matrix[4] where each diagonal element corresponds to one of the structural factors.

[3]See Geman and Geman (1984) A more detailed description of the estimation procedure is provided in Appendix C.1.

[4]This is again similar to Bernanke, Boivin, and Eliasz (2005).

3 Data

Data are at a monthly frequency from September 1925 to November 1932. The U.S. series are taken from the NBER's macroeconomic history database, while the German data we take from Wagemann (1935). The U.S. data include, among others, bank debits, deposits, discount rates, steel production, machinery prices, orders of machinery, as well as an index of industrial production and trade. The German series are, among others, short term deposits, wholesale and consumer price indices, currency in circulation, discount rates, domestic orders of machinery, steel production, industrial production, and employment in the metal trades. All data except for the interest rates were standardized and transformed into first differences. For a more detailed description of the dataset see Appendix A.

4 Results

For the empirical results we choose the lag lengths $p = 1, q = 7$. We cycled through 30,000 Gibbs iterations. To avoid that our results are driven by the starting values we discard the first 10,000 draws of the chain as burn-in. All convergence diagnostics conducted were satisfactory.

4.1 Real and Nominal Factors

To add structure to the factor approach, we restrict the data space on which factors are allowed to load. For both the U.S. and Germany, we identify three factors, one of them real, the other two nominal. The first factor is designed to capture real activity in the respective national economies. The two nominal factors load on a number of currency and banking series, respectively.

(Figure 1 about here)

The real factor for the U.S. loads on output data for investment goods, as well as a contemporary index of output in manufacturing and trade (see Appendix A, Series 1-5). The result is shown in Figure 1(a). This factor is essentially a reflection of traditional business cycle chronologies, and is highly correlated with the most commonly used indices of industrial production. We found the result to be very robust to changes in the specification of the time series included. We also notice a very good fit with a broadly based factor of economic activity calculated in Ritschl, Sarferaz, and Uebele (2008). Our results confirm the observation by Stock and Watson (1998) that one-factor models describe the real state of the economy quite well.

The monetary factor for the U.S. in Figure 1(c) loads on different short-term market interest rates (see Appendix A, Series 11-13). This factor closely tracks the increase in short term interest rates through late 1929, followed by a sharp decline to early 1931. A pronounced upward shock becomes visible in mid-1931, right around the time of Germany's 1931 crisis.[5]

The U.S. banking factor in Figure 1(e) is based on the commonly used banking statistics from the NBER database (see Appendix A, Series 6-10). It shows continuing expansion through the 1920s, and reaches its peak with the October 1929 crash. The banking panic of December 1930 is also visible. Again, there is an additional downward shock in mid-1931, right after the German crisis.

Figure 1(b) shows the German factor of real activity (see Appendix A, Series 14-17). Fast recovery from a recession in 1925/6 is followed by a marked slowdown in 1927. Real activity peaks in the summer of 1929, and is already in decline at the time of the New York stock market crash. A beginning recovery in the first half of 1931 is suddenly chocked off by a strong downward shock at the time of the German crisis. After a double dip in summer 1932, recovery set in and was well under way before early 1933, when the Nazis got to power. All this is in line with conventional wisdom (see James, 1986).

The German currency factor in Figure 1(d) is again largely composed of interest rates (see Appendix A, Series 23-25). It peaks in mid-1929 and then falls rapidly to reach its trough in mid-1930. An upward jump is visible in September 1930, after a national election that sharply increased the Nazi and communist votes. There is some slight improvement before the German crisis of mid-1931 and a huge shock afterwards. Interest rates came down markedly during 1932, leveling out towards the end of 1932.

[5] We experimented extensively with alternative monetary factors that loaded on monetary aggregates or on both money and interest rates. None of these alternatives affected the qualitative results of our analysis.

The banking factor in Figure 1(f), loading on the banking series in our dataset (see Appendix A, Series 18-22), is quite similar to series generated by Schnabel (2004) and Adalet (2005). It shows almost continuous improvement to March 1929, when a first setback occurred, coincident with the first Young Plan crisis (see James, 1985). Recovery to early 1930 was followed by a second setback, coincident with the adoption of the Young Plan, Schacht's resignation from the Reichsbank presidency, and the downfall of the last parliamentary government. After that, the banking factor begins a precipitous decline, which develops into a collapse at the time of the mid-1931 crisis. There is no recovery until early 1933. Germany's two nominal factors thus both show a major, sudden decline in mid-1931. Eyeballing the evidence from the factors, one may conclude that both a currency and a banking crisis were at work.

Drawing the evidence from this section together, a common salient feature of the factors, and thus of the common underlying dynamics of our time series, is the marked deterioration in mid-1931, at the time of the financial crisis. This effect is not limited to the German data, and is indeed visible also in the factors we extracted from the U.S. series. The next section will trace the phenomenon further, employing impulse-response analysis of a structural FAVAR.

4.2 Currency vs. Banking: the Transmission of Shocks

This section relates the above factors to each other in a VAR analysis. As the factors are identified, their dynamic relationships have a structural interpretation as well. We analyze the transmission of surprise shocks within and across the two economies using impulse response functions. Our interest focuses on the relative importance of monetary shocks, transmitted through the Gold Standard mechanism, and of shocks to the banking system, transmitted through the mutual exposure of the two countries' banking systems to each other.

We orthogonalize the shocks using mostly the temporal Cholesky decomposition. Our principal identification strategy is to assume that the U.S. factors do not react simultaneously to international conditions, while the German ones do: U.S. real activity is assumed endogenous to U.S. monetary and banking conditions only. German currency conditions are assumed endogenous to U.S. factors but exogenous to German banking conditions. We furthermore assume that German real were endogenous to all other factors.

We choose this ordering with a working hypothesis in mind. Reflecting conventional wisdom on the interwar Gold Standard as in Eichengreen (1992). This prior hypothesis is that major shocks to the international economy originated from the U.S. and that monetary transmission took precedence over financial or real channels. As a consequence, evidence pointing to other transmission mechanisms will not just result from a prior implicit in the identification scheme, but instead from overturning that prior.[6]

For the propagation of shocks to the U.S. interest and banking factors, we adopt a sign restriction approach in the spirit of Uhlig (2005). The idea is to focus only on plausible draws for the impulse responses, thus avoiding sign puzzles in the response of nominal series to a monetary shock. Uhlig restricts the responses of nominal series and remains agnostic about the response of real activity, leaving it unrestricted. In contrast, we restrict the response of U.S. real activity while leaving the responses of the other nominal factors unrestricted.[7]

The motivation for our choice is a potential ambiguity of responses in bank lending to a monetary shock. Bernanke and Gertler (1995) and Kashyap and Stein (1995) have pointed to asymmetries in the response of firms' credit demand to monetary shocks, depending on the degree to which firms are rationed in credit markets. Only under a credit crunch or near the zero bound for interest rates would observed bank lending identify credit supply. Although this condition was probably given for much of our observation period, we do not want to impose it. In the same vein, the response of money demand to an adverse shock in banking conditions is ambiguous and would depend on the ability of banks to respond by issuing debt or equity, which motivates us to leave its sign unrestricted.

We also run the FAVAR analysis of this section separately for a truncated observation period from 1925 to May 1931, cutting off just before the onset of the financial crisis. Comparison of the impulse response functions from the full and truncated sample allows us to draw additional conclusions about the possible impact of the 1931 crisis.

[6]Permutations of the Cholesky orderings left the qualitative results largely unaffected.

[7]We also experimented with Uhlig's agnostic sign restrictions, but found the response of the U.S. real factor to be close to zero. [see Referee Appendix C.2, Figure 14]

4.2.1 Full Observation Period

Figure 2 shows the impulse response functions and the error bands for adverse shocks to U.S. real activity, obtained under the Cholesky ordering described above. Real shocks were highly persistent. They were transmitted to the U.S. monetary factor, which exhibits a marked downward response of interest rates. Adverse effects on U.S. banking conditions were strong as well, and are remarkably persistent. On average, around 40% of the forecast error variance in the U.S. banking factor is explained by real shocks, albeit with substantial variation. This appears to support the finding by Calomiris and Mason (2003) and others that banking distress in the depression had fundamental causes and was not just a consequence of panics, as claimed by Friedman and Schwartz (1963). Real shocks to the U.S. economy also had adverse effects on the German economy, although with remarkably less persistence.

(Figures 2 about here)

Figure 3 shows the responses to tightening conditions in the U.S. money market (although not necessarily to monetary policy itself). By construction, the responses of the U.S. monetary and real activity factors are negative for six months. On average, U.S. banking responds negatively for most horizons, although considerable parts of the probability mass indicate positive responses. Confirming a hypothesis of Bernanke (1983), monetary factors had only limited explanatory power for financial conditions in the Depression: about 10% of the forecast error variation in the U.S. banking factor are explained by the U.S. interest factor. This result was very robust under a variety of different specifications of both the monetary and the banking factors. The sign restriction on the monetary factor itself is again binding: at the six months horizon, as the constraint is lifted, the response turns into negative territory. The responses of the German factors are broadly similar to their U.S. counterparts but on the whole more diffuse.

(Figure 3 about here)

The forecast error decompositions in Figure 3 suggest a share of 10-20% for nominal tightening in explaining the variance of U.S. real activity. This confirms results of Sims (1999) in a longitudinal study of U.S. monetary policy in the 20th century, as well as of Amir Ahmadi and Ritschl (2009) from a non-structural FAVAR model for U.S. monetary policy during the Great Depression.

Figure 4 shows the responses to tightening financial conditions. A sign restriction operates on the response of banking and of real activity for six months after the shock. As explained above, the response of money market conditions remains unrestricted. Shocks to banking are quite persistent and also translate into persistent real effects. However, the response of real activity in the U.S. is negative for the first six months by construction. After that, it remains negative on average, but draws with positive responses do occur, indicating that the restriction is binding. As before, the German responses are structurally similar but more diffuse.

(Figure 4 about here)

The forecast error decompositions in Figure 4 suggest that about 15 % of the variation in the real factor can be explained by shocks to financial conditions, which is slightly higher than for monetary shocks.

On the whole, the evidence gathered above suggests less than pervasive effects of adverse shocks to U.S. monetary and financial conditions. The real effects of monetary and financial tightening on the U.S. economy are roughly similar to those obtained in factor models for the postwar period, e.g. by Bernanke, Boivin, and Eliasz (2005) and Amir Ahmadi and Uhlig (2009). The results also appear to suggest that transmission of U.S. business cycle shocks to Germany was mainly through real channels, while the transmission of U.S. monetary and financial shocks to Germany played only a limited role.

Next we look at the effects of shocks to the German factors. As would be expected, a shock to real activity in Germany (see Figure 5) is persistent domestically but has no discernible effect on the U.S. economy. Shocks to German money market conditions, shown in Figure 6, propagate through the German economy without sign puzzles and have real effects.

However, their contribution to the forecast error variance of the German real factor is low (see Figure 6).

(Figures 5 and 6 about here)

Monetary market tightening in Germany has near-significant impact effects on real conditions in the U.S., which however peter out quickly. The effect of nominal tightening in Germany on the U.S. interest factor is initially negative and significant but quickly turns into positive, however without remaining significant. This effect would be consistent with the classical gold standard mechanism, however in a slightly non-standard way: the U.S. acted as a short-term monetary shock absorber for the international gold standard, much like the Bank of England's policy of leaning against foreign monetary shocks in the pre-World War I years.

Spillovers from the periphery to the center become much more pronounced for adverse shocks to the German banking factor. The impulse responses to a German banking shock in Figure 7 reveal persistent and significant effects on U.S. real activity and U.S. banking, while the effect on the U.S. interest factor is hump-shaped and changes signs. We found this transmission of German financial shocks on U.S. banking to be robust under a wide variety of alternative specifications. The variance decompositions in Figure 7 show a high contribution to the forecast error variance of German real activity. With some delay, considerable explanatory power also builds up for real and banking activity in the U.S.

(Figures 7 about here)

This result would lend support to the hypothesis of James (2001) that the deepening of the U.S. recession in 1931 was at least partly triggered by the international repercussions of the 1931 crisis in Austria and Germany. The variance decompositions in Figure 7 also show that explanatory power of these international financial shocks for U.S. real activity is much higher than that of U.S. monetary and financial shocks (in Fig. 3 and 4 above).

4.2.2 Truncated Observation Period, 1925 to May 1931

To identify the contribution of the 1931 crisis to this surprising result, we truncate the observation period to end in May 1931. Figure 8 shows the responses to German currency shocks for this subperiod. During this first phase of the international depression, adverse monetary shocks in Germany had adverse effects on German real activity and banking, but significant, favorable effects on real conditions in the U.S. In contrast, all responses to an adverse shock to German banking (in Figure 9) are now less pronounced than for the full observation period including the 1931 crisis (in Figure 7 above). Evidently, the crisis of 1931 sharpens the results. The financial transmission effects of the Germany's financial meltdown on the U.S. economy must have been considerable.

(Figures 8 about here)

Drawing the results of this section together, our application of a dynamic factor model finds only limited evidence for the traditional view that U.S. monetary or banking shocks were key in explaining the depression in either country. We also notice that nominal shocks to the U.S. economy do not play a dominant role in explaining the variation of real activity.

Conversely, we do find substantial effects of Germany's nominal shocks on real activity in the U.S. economy. Again the monetary channel is of relatively minor importance. Transmission through the banking channel, however, seems quantitatively important and highly persistent. The effects have not fully built up after 20 months, and would explain 30% in the variance of both U.S. real activity and the U.S. banking factor.

Apparently, most of these effects did not materialize before the 1931 crisis. Truncating the observation period to end in May 1931, we find the responses to Germany's nominal conditions to be less pronounced and less significant. Financial transmission from Germany to the U.S. must have been strongest after June 1931. This suggests that international spillovers from the German crisis of 1931 were a significant force in deepening the U.S. recession.

We also find that while nominal factors seem to have played a rather minor role in the U.S. recession, the overall role of nominal factors in the German recession seems stronger.

Responses of German real activity to adverse shocks in German monetary and banking conditions are estimated precisely and without having to resort to sign restrictions. In the case of financial shocks, they are also quantitatively important, accounting for a third of the forecast error variance in German real activity. Again, the explanatory power of monetary shocks is much lower: the explained variation in German real activity is only about 10%.

The results so far imply that banking conditions played a dominant role in the German crisis of 1931. As a corollary, if there was a financial frictions channel of transatlantic business cycle transmission in the Great Depression, it originated in Germany rather than in the U.S., and affected both economies significantly. This is consistent with the claim by Harold James (2001) that the German banking crisis had major spillover effects on the international economy. It is also consistent with the claim of James (1986) and Schnabel (2004) that Germany's 1931 crisis was causally a banking crisis, while monetary transmission under the Gold Standard played only a secondary role.

4.3 Currency vs. Banking: the Systematic Effects

Thus far, attention has focused on the transmission of surprise shocks. In the following section, we examine possible systematic effects that may have been factored into expectations. Systematic components included in the agents' information set at time t would be reflected in the accuracy of forecasts made on the basis of that information set. In this section we obtain forecasts of real activity in Germany and the U.S., conditional on the information at critical junctures before and during the 1931 crisis. To evaluate the information content of the banking factor at any of these points in time, we obtain each forecast twice, once from a bivariate VAR including the banking factor, once from a univariate AR of the same lag length in the real activity factor alone.

4.3.1 Conditional forecasts of activity in Germany

Univariate forecasts for the German real factor from March and May 1931 would predict recovery, extrapolating from the green shoots that had become visible in early 1931. Only after the crisis, by July 1931, would univariate forecasts predict a further downturn in real activity. (FOR REFEREES: see Referee Appendix C.3, Figure 15.)

To evaluate the gain in forecasting power over the univariate forecast, in Figure 10 we add the German interest factor (LHS) and the German banking factor (RHS), respectively, and perform bivariate conditional forecasts for the same three truncated samples.

(Figure 10 about here)

For all three subsamples, forecasting performance is substantially better when banking instead of interest is included in the information set. Already in March 1931, the bivariate forecast including the banking factor predicts further decline in real activity, albeit with wide error margins. An even more pronounced drop in output is visible in the forecast from May 1931, the month before the actual crisis started. This forecast is also notably more precise than the previous one. The median forecast from July correctly predicts the further downturn into mid-1932.

By contrast, the forecasts including the monetary factor are rather uninformative about output before the crisis starts, and pick up the slump in activity only after the crisis is factored in. Essentially, including interest rate information yields little improvement over an univariate forecast of real activity.

These results confirm the evidence from the impulse response analysis in the previous section: the domestic driving force behind Germany's 1931 crisis was the weakness of its banking system. The deterioration in banking conditions foreshadowed the July 1931 crisis, and indeed has considerably predictive power. By comparison, domestic monetary conditions play only a secondary role.

To assess the contribution of U.S. factors to activity in Germany, we included U.S. rather than German monetary and banking data in the forecasts.

(Figure 11 about here)

As the results show, predictive power of the U.S. data for German activity is low: before July 1931, the forecasts in Figure 11 essentially reproduce the failed forecasts of real activity including German monetary information in Figure 10 above. It is noteworthy that the inclusion of the U.S. monetary factor tends to buttress the prediction of a continuing upswing in Spring 1931. Even after the beginning of crisis in July, the forecasts conditional on U.S. monetary data continue to be optimistic. Incorporating U.S. banking data leads to slight forecast improvements, but overall performance falls short of the forecasts with German banking data in Figure 10. According to these results, U.S. data are not very informative about the German financial crisis; they provide no evidence that the 1931 crisis was triggered by conditions in the U.S.

4.3.2 Conditional forecasts of activity in the U.S.

As in Germany, any systematic effects of nominal factors on real activity operated through the banking system, not through conventional channels of monetary transmission. Figure 12 shows bivariate conditional forecasts of U.S. real activity at the same critical junctures as before, including, respectively, the U.S. interest factor (LHS) and the U.S banking factor (RHS).

(Figure 12 about here)

As can be seen, the forecasts on the LHS are upbeat about an imminent end to the recession. For all three subsamples, including monetary information in the forecast of U.S. real activity would firmly suggest that recovery was just around the corner[8] By contrast, including the U.S. banking factor (on the RHS of Figure 12) generates rather more pessimistic forecasts of real activity, and is indeed a substantial improvement over the univariate forecasts. Clearly, conditions captured by the banking factor were highly informative about future real activity, while monetary information was not.

The prediction exercise in Figure 12 is the closest we get to testing Bernanke's (1983) hypothesis of non-monetary factors in the Great Depression that operated through the financial sector. The strong, systematic effects we find for the U.S. banking factor suggest that during 1931, financial frictions did indeed play a major role in deepening the U.S. recession,

[8]Indeed, these forecasts are more optimistic about real activity than the univariate forecasts would be. (FOR REFEREES: univariate forecasts of U.S. real activity are reported in Figure 17 in the Referee Appendix.)

and that these financial factors were indeed independent of monetary forces.

The results of Figure 12 also permit conclusions about the timing of these financial frictions. While the financial factor is highly informative in the forecasts of May and July, it does not add much precision to a univariate forecast of economic activity as of March, 1931. This would imply that the fallout of the collapse of the bank of the United States in late 1930 (described in Friedman and Schwartz, 1963) was either short-lived or not very important quantitatively.

To test James' (2001) hypothesis of a major fallout of the European financial crisis of mid-1931, in Figure 13 we replace the currency and banking factors in the bivariate forecasts of U.S. real activity of 12 above with their respective German equivalents. As before, monetary factors are not informative about future activity, but the banking factor is. Indeed the forecasts of U.S. real activity including the German banking factor in Figure 13 are as good as or even marginally better than their counterparts including the U.S. banking factor in Figure 12 above.

(Figure 13 about here)

This implies that German banking conditions on the eve of the 1931 financial crisis were informative about U.S. real activity, while the German currency factor adds no predictive power. For July 1931, immediately after the financial crisis, we obtain a very similar result.

In sum, we find that banking conditions in both the U.S. and Germany have considerable predictive content for real activity in mid-1931, while monetary factors do not. However, U.S. banking conditions have very little forecasting power for German real activity, while the German banking factor is highly informative about real activity in the U.S.. This evidence would be difficult to reconcile with an interpretation of the 1931 financial crisis as a primarily monetary phenomenon, or as contagion of distress originating in the U.S. banking system. It is consistent, however, with the interpretation that the financial crisis of mid-1931 was primarily rooted in Germany's national banking system and had strong adverse effects on the U.S. economy as well.

5 Conclusion

This paper assessed the relative importance, both domestic and international, of Gold Standard transmission vs. banking channels in the origins and the propagation of the German financial crisis of 1931. To identify channels of crisis causation and propagation, we employed a structural dynamic factor model of the interactions between the U.S. and the German economy between 1925 and 1932. To this end we restricted the model to yield structural factors representing banking and monetary conditions in the U.S. and the German separately. We also included one real factor for each of the two economies. Our real factors appear to trace established business cycle chronologies very well. Our nominal factors for Germany suggest that both monetary and banking conditions in Germany deteriorated severely and persistently in the 1931 crisis.

The main finding of this paper is that banking conditions constituted a major channel of domestic propagation of the Great Depression, confirming the central claim of Bernanke (1983). This financial propagation mechanism had marked real effects but appears to have been largely independent of monetary forces. The domestic financial channel comes out stronger in Germany but is also present in the U.S. By contrast, we found only limited effects of monetary conditions, be it on real activity or on the financial factor. This result proved robust under a large variety of different specifications we experimented with.

The second main result is strong international transmission of the Great Depression through the financial channel. This transmission went from Germany to the U.S., from the periphery to the core. This effect comes out stronger after the 1931 crisis. By contrast, transmission of nominal shocks from the U.S. to the German economy was less pronounced than expected.

The results of this paper suggest that international financial exposure played a major role in propagating the Great Depression, and confirm that banking distress in the financial meltdown of 1931 was a major event that deepened the recession, more so than U.S. monetary policy.

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Appendix

A Data

	Series	Mnemonic
1	U.S. Steel Production	m01135a
2	U.S. Index of Industrial Production and Trade, Seasonally Adjusted	m12004c
3	U.S. Index of Orders for Machinery Tools and Forging Machinery	m06029
4	U.S. Index of Production Of Machinery, Seasonally Adjusted	m01277b
5	U.S. Index of Consumer Goods	m01056
6	U.S. Loans On Securities, Reporting Member Banks, Federal Reserve System	m14074
7	U.S. All Other Loans, Reporting Member Banks, Federal Reserve System	m14075a
8	U.S. Index of Deposit Activity	m12008b
9	U.S. Bank Debits	m12030
10	U.S. Clearings Index of Business	m12020b
11	U.S. Commercial Paper Rate	m13002
12	U.S. Discount Rates	m13009
13	U.S. Ninety Day Time-Money Rates On Stock Exchange Loans	m13003
14	German Orders of Machines	–
15	German Steel Production	–
16	German Industrial Production	–
17	German Employment in Metal Trade Sector	–
18	German Savings Deposits	–
19	German Demand Deposits	–
20	German Creditors	–
21	German Stocks of Bills of Exchange	–
22	German Debtors	–
23	German Discount Rates	–
24	German Private Discount Rates	–
25	German Warenwechsel	–

Source: German data are taken from Wagemann (1935). U.S. data are taken from the NBER macro history database, www.nber.org/databases/macrohistory/contents/.

B Figures

B.1 Latent Common Components

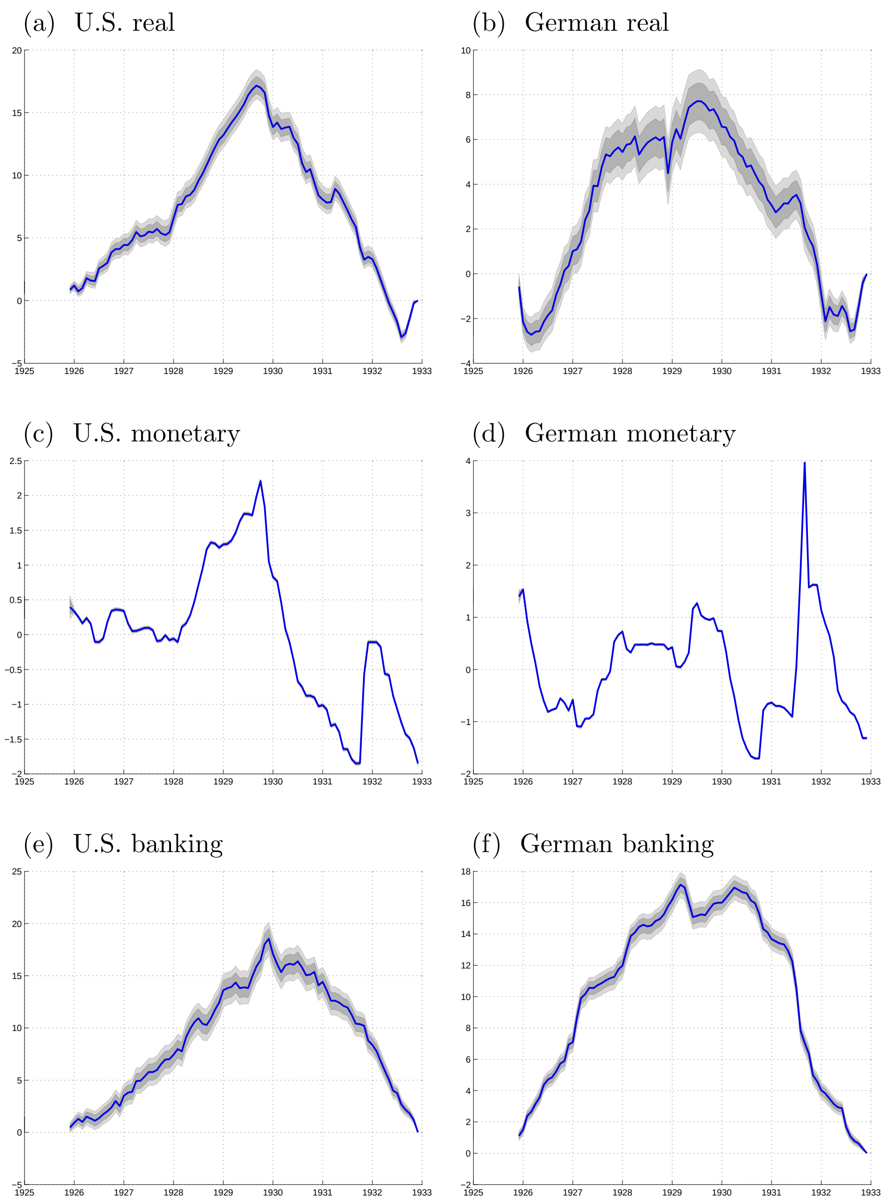
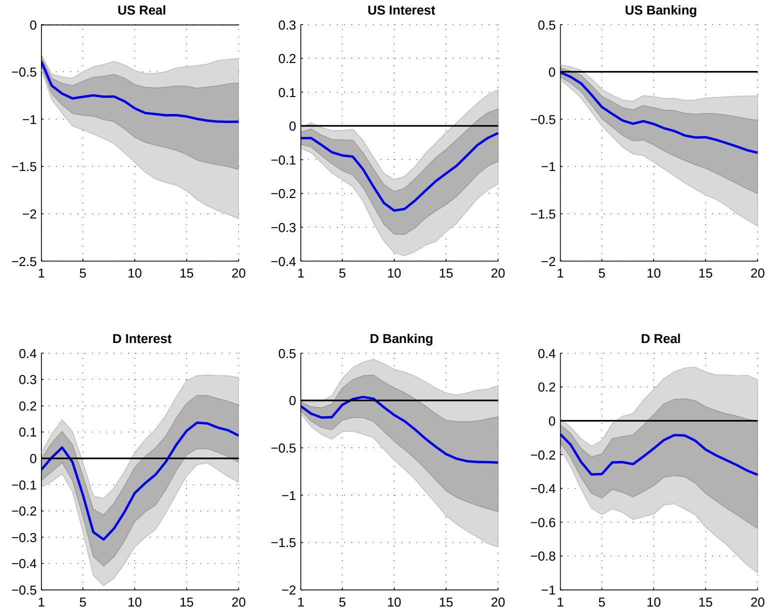


Figure 1: Latent common components for the U.S. and German real, monetary and financial variables. The dark gray shaded area represents 68% and the light shaded area 90% of the posterior probability mass.

B.2 Impulse Response Analysis (1925:9–1932:11)

(a) Impulse Responses (U.S. Real Shock)



(b) Variance Decomposition

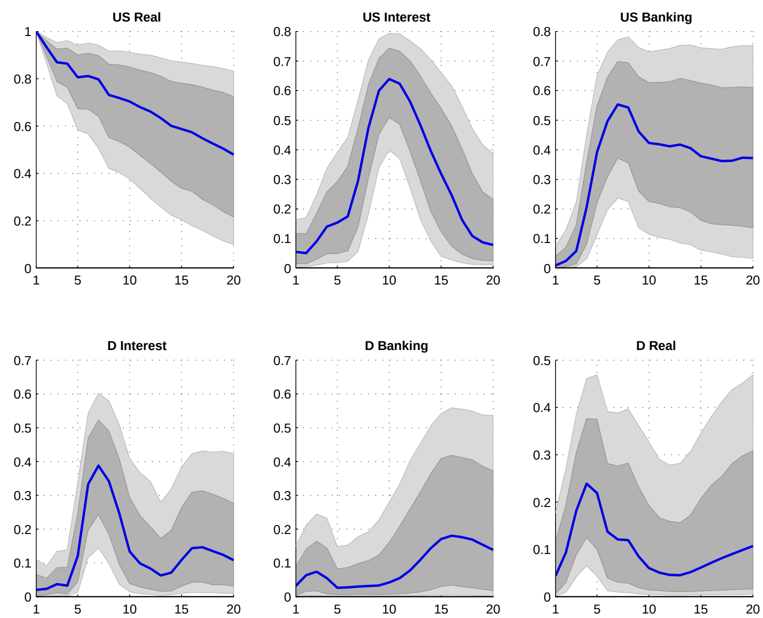
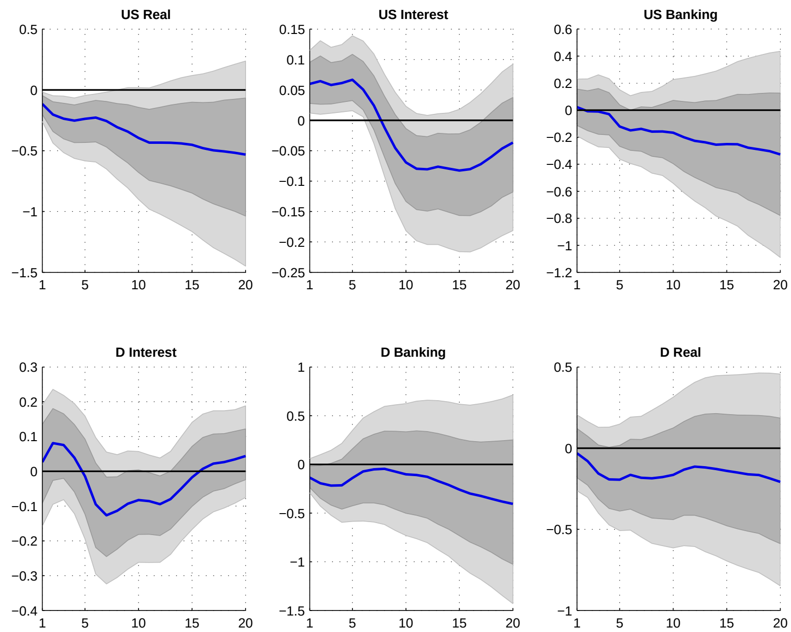


Figure 2: Responses of all variables (upper panel) to and fraction of the variance explained (lower panel) by a contractionary shock of one standard deviation in size in the U.S. real factor. The dark gray shaded area represents 68% and the light shaded area 90% of the posterior probability mass.

(a) Impulse Responses (U.S. Monetary Shock)



(b) Variance Decomposition

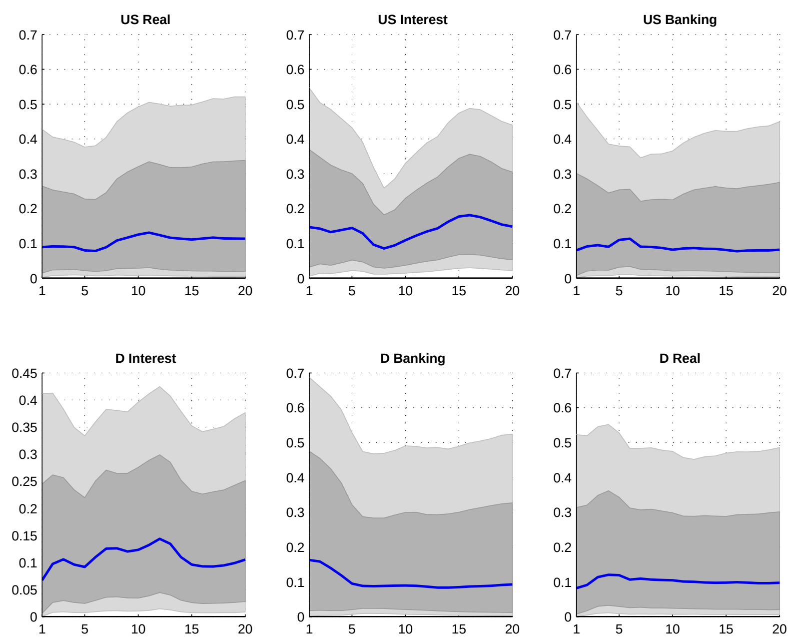
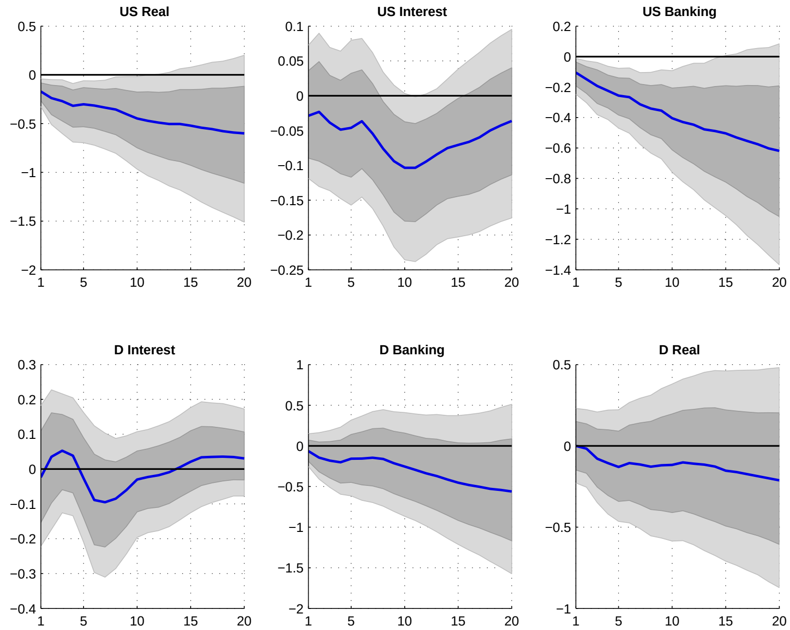


Figure 3: Responses of all variables (upper panel) to and fraction of the variance explained (lower panel) by a contractionary shock of one standard deviation in size in the U.S. monetary factor. The dark gray shaded area represents 68% and the light shaded area 90% of the posterior probability mass. A sign restriction operates on the responses of the U.S. real and the U.S. monetary factors for the first six months after the shock.

(a) Impulse Responses (U.S. Financial Shock)



(b) Variance Decomposition

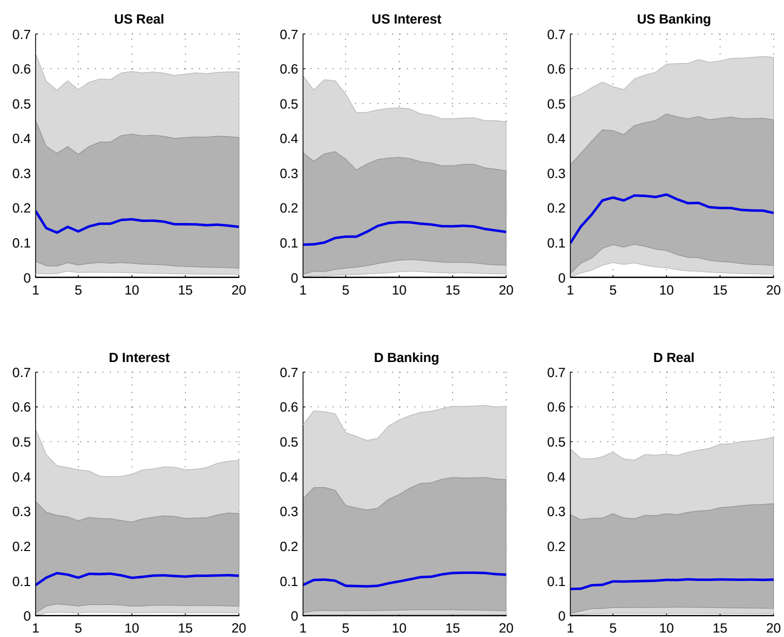
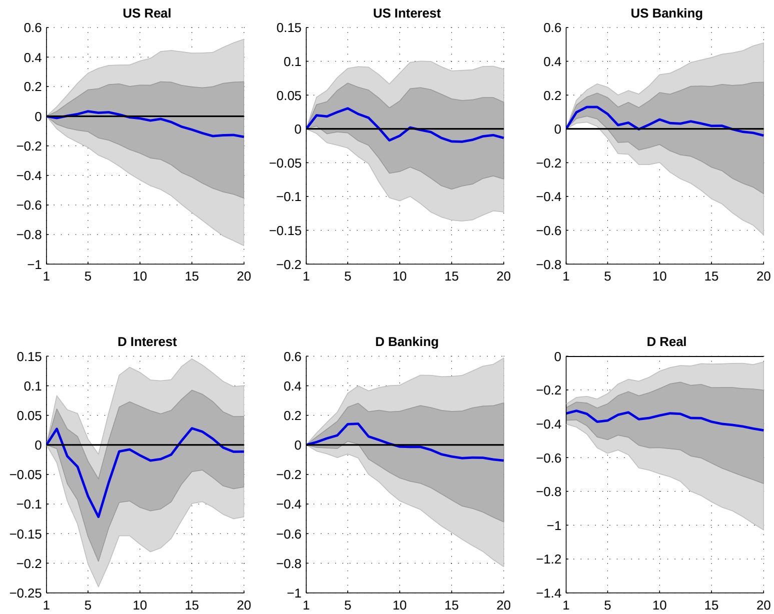


Figure 4: Responses of all variables (upper panel) to and fraction of the variance explained (lower panel) by a contractionary shock of one standard deviation in size in the U.S. financial factor. The dark gray shaded area represents 68% and the light shaded area 90% of the posterior probability mass. A sign restriction operates on the responses of the U.S. real and the U.S. banking factors for the first six months after the shock.

(a) Impulse Responses (German Real Shock)



(b) Variance Decomposition

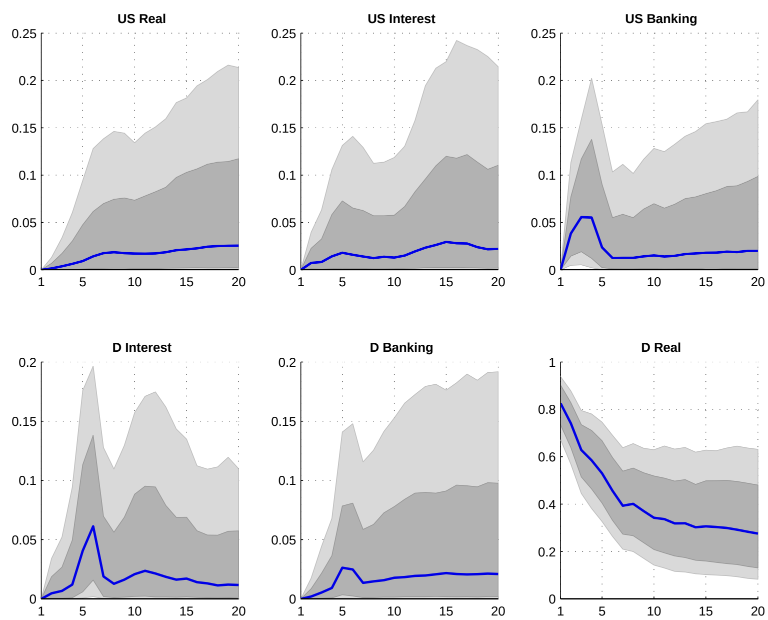
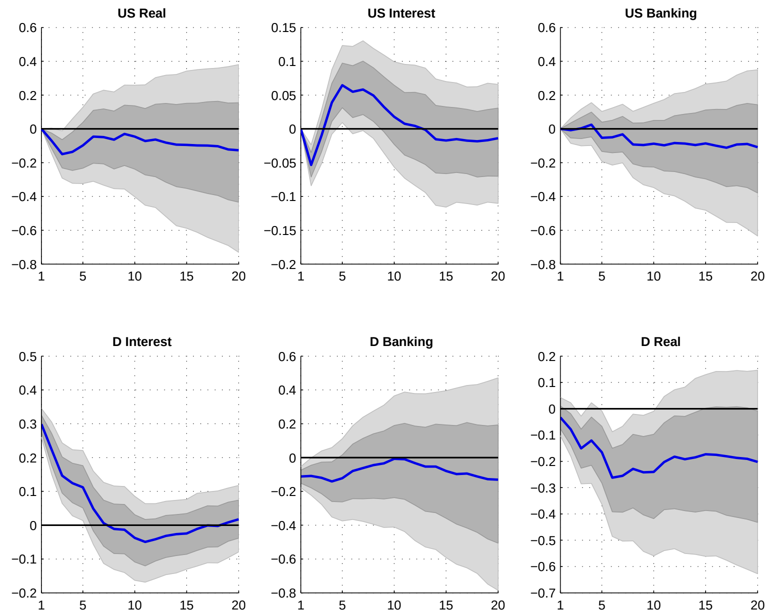


Figure 5: Responses of all variables (upper panel) to and fraction of the variance explained (lower panel) by a contractionary shock of one standard deviation in size in the German real factor. The dark gray shaded area represents 68% and the light shaded area 90% of the posterior probability mass.

(a) Impulse Responses (German Monetary Shock)



(b) Variance Decomposition

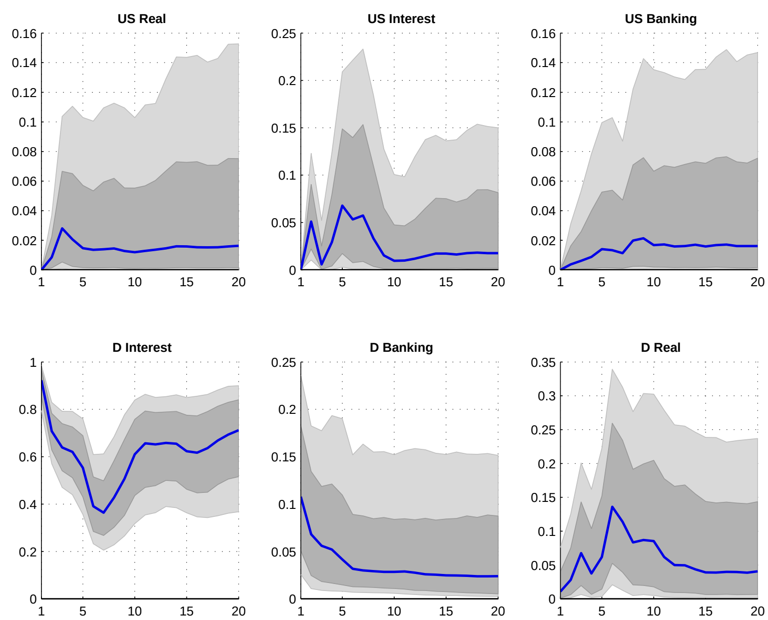
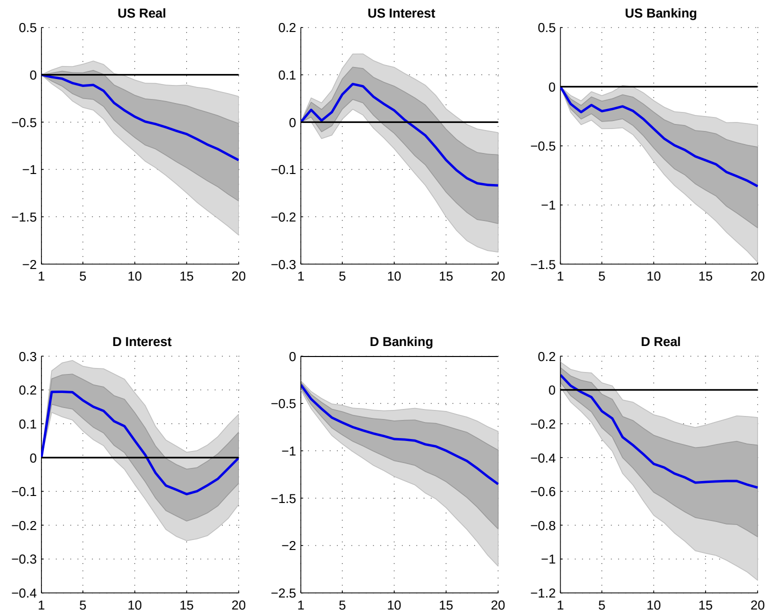


Figure 6: Responses of all variables (upper panel) to and fraction of the variance explained (lower panel) by a contractionary shock of one standard deviation in size in the German monetary factor. The dark gray shaded area represents 68% and the light shaded area 90% of the posterior probability mass.

(a) Impulse Responses (German Financial Shock)



(b) Variance Decomposition

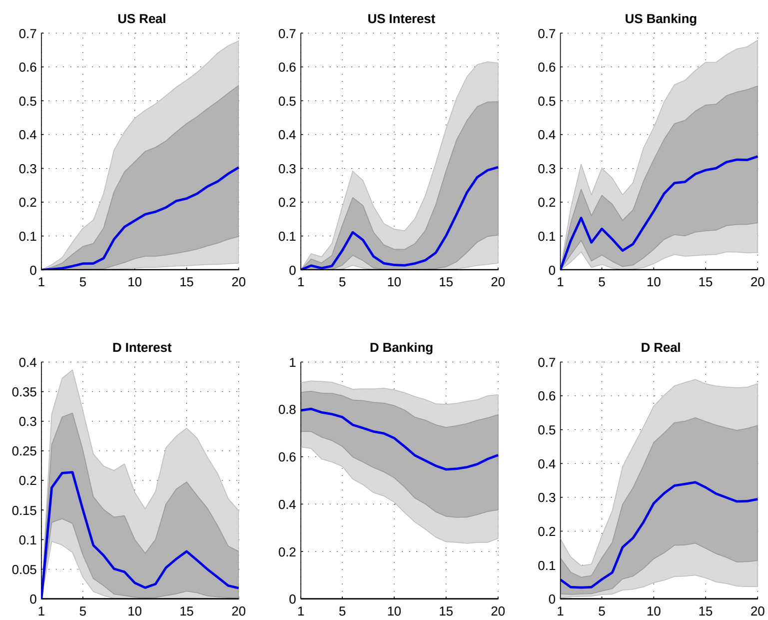
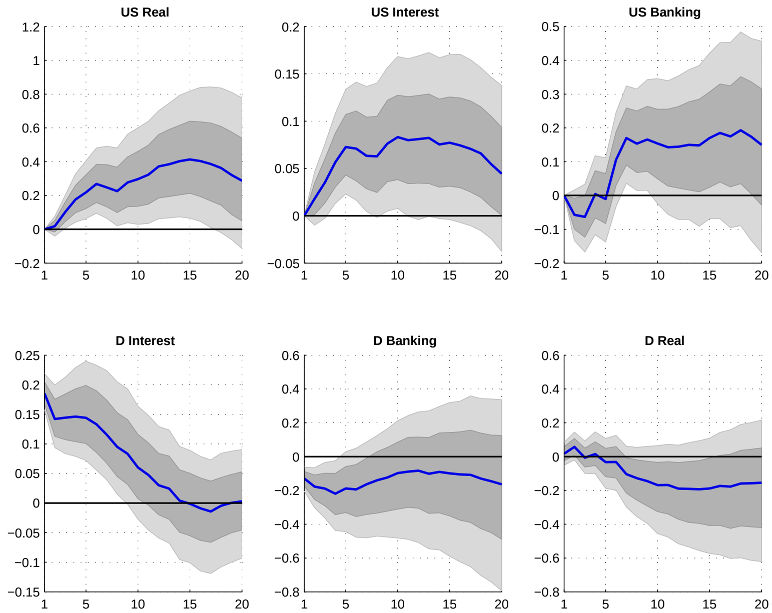


Figure 7: Responses of all variables (upper panel) to and fraction of the variance explained (lower panel) by a contractionary shock of one standard deviation in size in the German financial factor. The dark gray shaded area represents 68% and the light shaded area 90% of the posterior probability mass.

B.3 Impulse Response Analysis (1925:9 to 1931:5)

(a) Impulse Responses (German Monetary Shock)



(b) Variance Decomposition

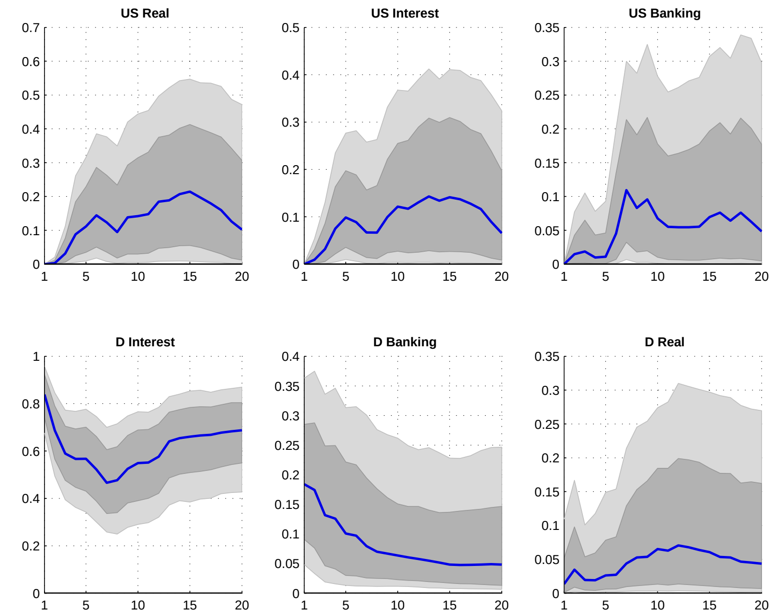
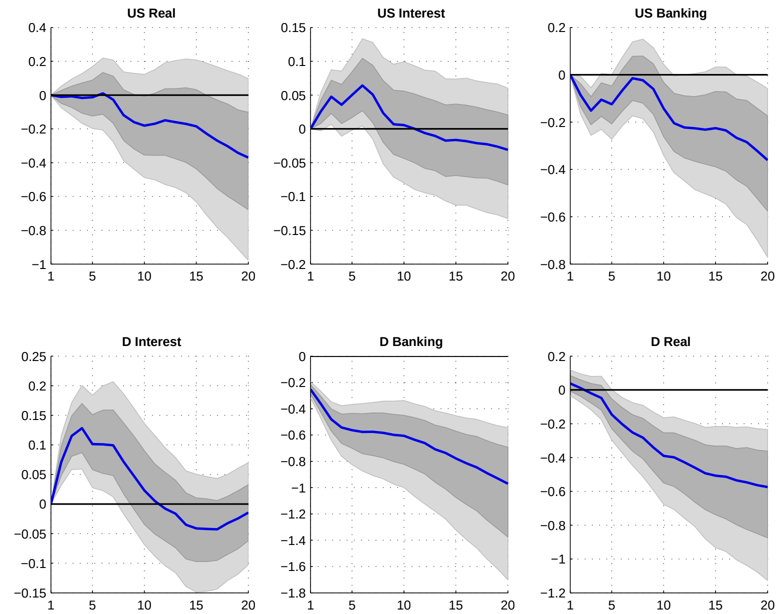


Figure 8: Responses of all variables (upper panel) to and fraction of the variance explained (lower panel) by a contractionary shock of one standard deviation in size in the German monetary factor when sample period is truncated to 1931:5. The dark gray shaded area represents 68% and the light shaded area 90% of the posterior probability mass.

(a) Impulse Responses (German Financial Shock)



(b) Variance Decomposition

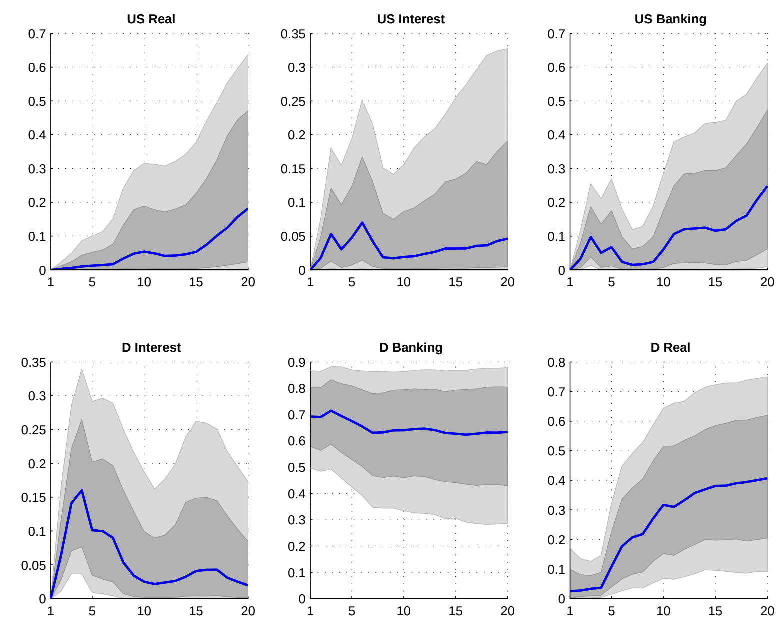
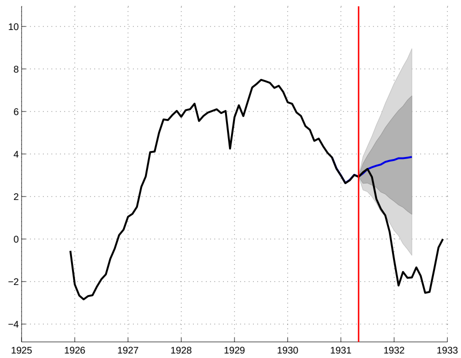


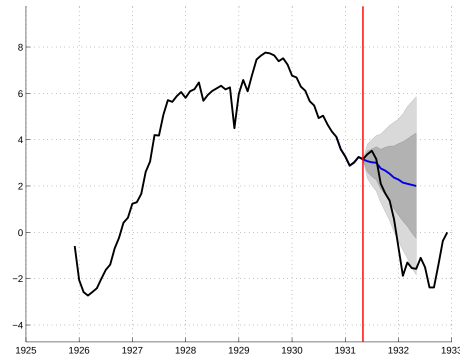
Figure 9: Responses of all variables (upper panel) to and fraction of the variance explained (lower panel) by a contractionary shock of one standard deviation in size in the German financial factor when sample period is truncated to 1931:5. The dark gray shaded area represents 68% and the light shaded area 90% of the posterior probability mass.

B.4 Systematic Effects: Forecasting the Depression

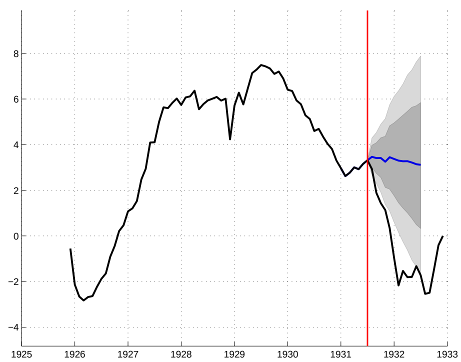
(a) March 1931 (German Interest)



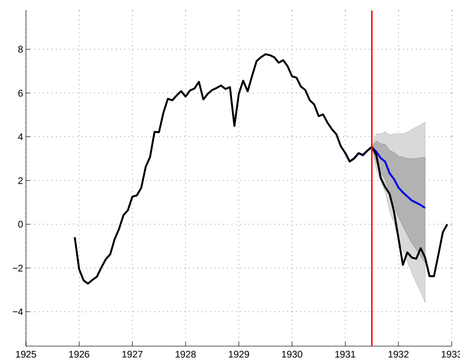
(b) March 1931 (German Banking)



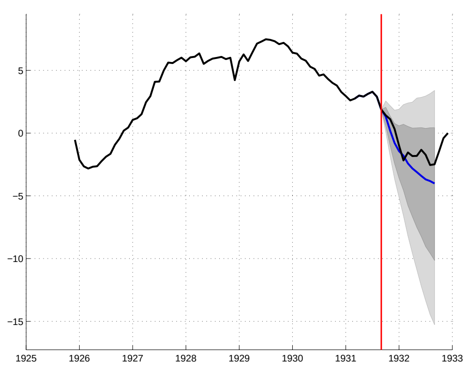
(c) May 1931 (German Interest)



(d) May 1931 (German Banking)



(e) July 1931 (German Interest)



(f) July 1931 (German Banking)

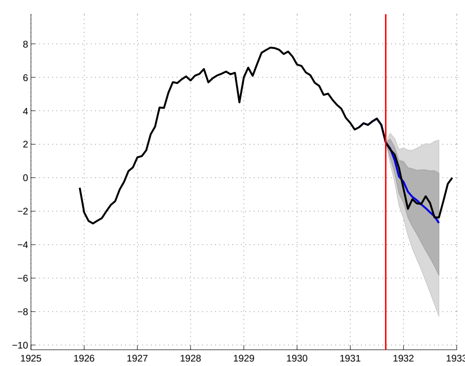
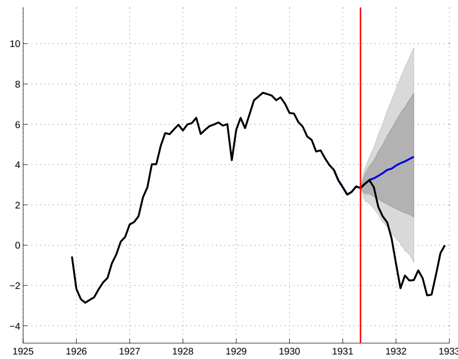
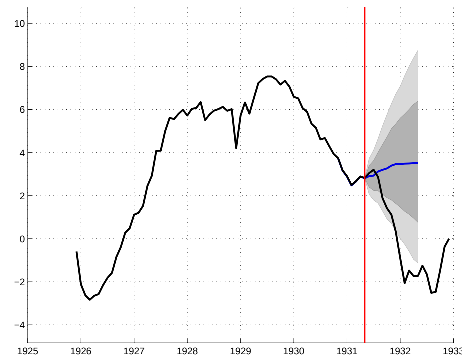


Figure 10: Forecasting the German real sector from March 1931, May 1931 and July 1931, using interest rates (left) and banking variables (right). The dark gray shaded area represents 68% and the light shaded area 90% of the posterior probability mass.

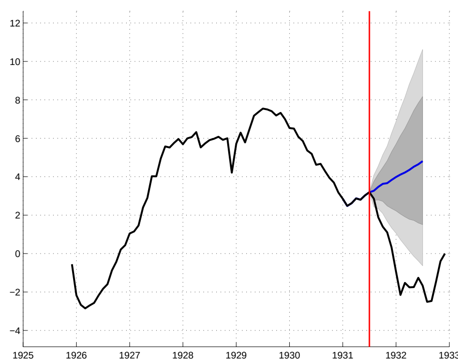
(a) March 1931 (U.S. Interest)



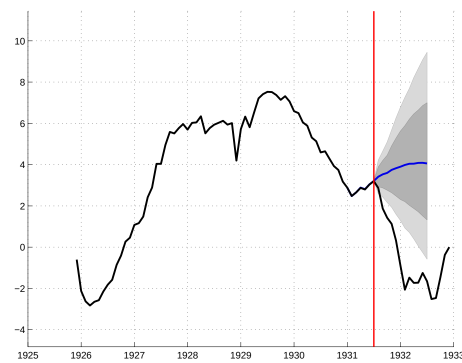
(b) March 1931 (U.S. Banking)



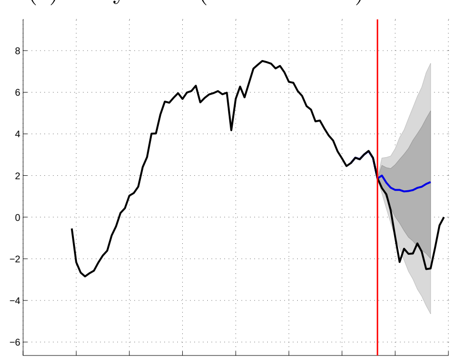
(c) May 1931 (U.S. Interest)



(d) May 1931 (U.S. Banking)



(e) July 1931 (U.S. Interest)



(f) July 1931 (U.S. Banking)

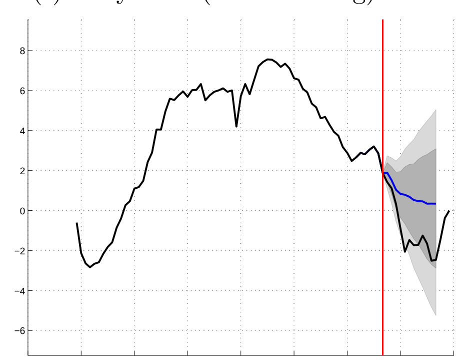


Figure 11: Forecasting the German real sector from March 1931, May 1931 and July 1931, using U.S. interest rates (left) and U.S. banking variables (right). The dark gray shaded area represents 68% and the light shaded area 90% of the posterior probability mass.

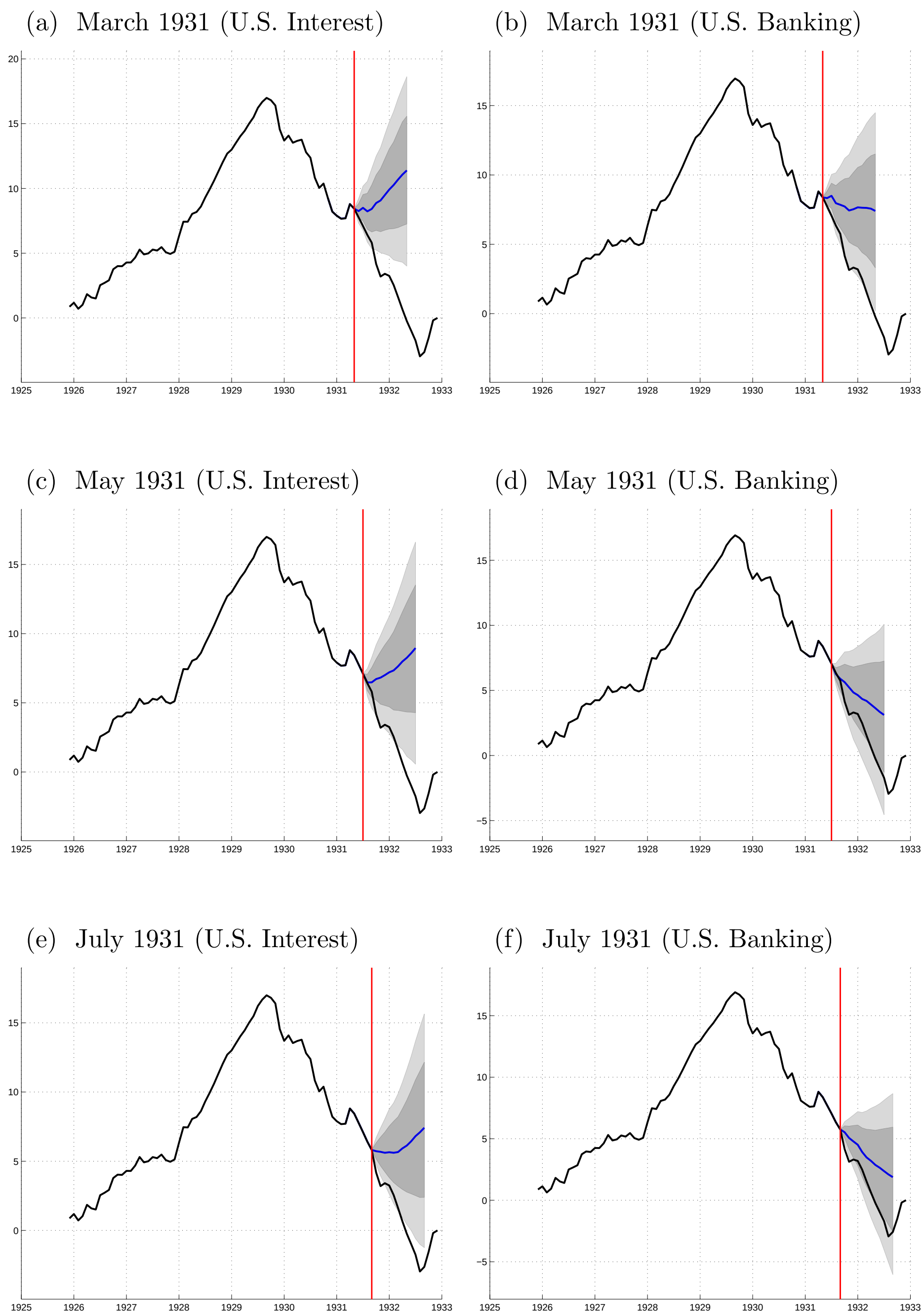


Figure 12: Forecasting the U.S. real sector from March 1931, May 1931 and July 1931, using U.S. interest rates (left) and U.S. banking variables (right). The dark gray shaded area represents 68% and the light shaded area 90% of the posterior probability mass.

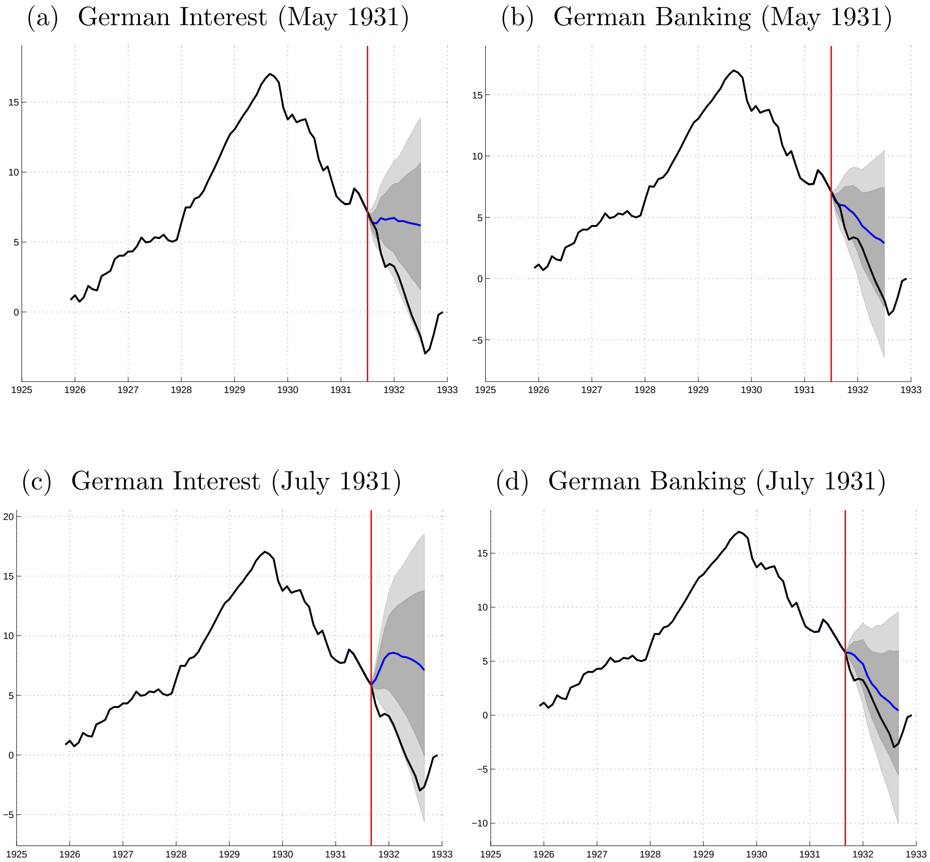


Figure 13: Forecasting the U.S. real sector from May 1931 and July 1931, using German interest rates (left) and German banking variables (right). The dark gray shaded area represents 68% and the light shaded area 90% of the posterior probability mass.

C Technical Appendix

C.1 Estimation

C.1.1 Estimating the Parameter Block

In this section we condition on the factors f_t. Because equation (1) is set of N independent regressions with autoregressive error terms it is possible to estimate Λ, $\Theta_1, \Theta_2, \ldots, \Theta_p$, Ω_χ and Ω_ϵ equation by equation.[9] We rewrite equation (3) as:

$$u_i = X_{i,u}\theta_i + \chi_i \tag{5}$$

where $u_i = [u_{i,p+1} \ u_{i,p+2} \ \ldots \ u_{i,T}]'$ is $T - p \times 1$, $\theta_i = [\theta_{i,1} \ \theta_{i,2} \ \ldots \ \theta_{i,p}]'$, is $p \times 1$ and $\chi_i = [\chi_{i,p+1} \ \chi_{i,p+2} \ \ldots \ \chi_{i,T}]'$ is $T - p \times 1$ and

$$X_{i,u} = \begin{bmatrix} u_{i,p} & u_{i,p-1} & \cdots & u_{i,1} \\ u_{i,p+1} & u_{i,p} & \cdots & u_{i,2} \\ \vdots & \vdots & \vdots & \vdots \\ u_{i,T-1} & u_{i,T-2} & \cdots & u_{i,T-p} \end{bmatrix}$$

which is a $T - p \times p$ for $i = 1, 2, \ldots, N$.

Combining the priors described in section 2 with the likelihood function we obtain the following posterior distributions.

The posterior of the AR-parameters of the idiosyncratic components is:

$$\theta_i \sim N(\overline{\theta_i}, \overline{V}_{i,\theta})I_{S_\theta} \tag{6}$$

where

$$\overline{\theta_i} = \left(\underline{V_\theta}^{-1} + (\sigma^2_{i,\chi})^{-1}X'_{i,u}X_{i,u}\right)^{-1}\left(\underline{V}_\theta^{-1}\underline{\theta} + (\sigma^2_{i,\chi})^{-1}X'_{i,u}u_i\right)$$

and

$$\overline{V}_{i,\theta} = \left(\underline{V}_\theta^{-1} + (\sigma^2_{i,\chi})^{-1}X'_{i,u}X_{i,u}\right)^{-1}.$$

[9] See also Chib (1993).

where I_{S_θ} is an indicator function enforcing stationarity.

The posterior of the variance of the idiosyncratic component $\sigma_{i,\chi}$ is:

$$\sigma_{i,\chi} \sim \mathcal{IG}\left(\frac{(T+\alpha_\chi)}{2}, \frac{((u_i - X_i\theta_i)'(u_i - X_i\theta_i) + \delta_\chi)}{2}\right) \tag{7}$$

To estimate the factor loadings we rewrite equation (1) as:

$$y_i^* = c_i^* + \lambda_i f^* + \chi \tag{8}$$

where $y_i^* = [(1-\theta(L)_i)y_{i,p+1}\ (1-\theta(L)_i)y_{i,p+2} \ldots\ (1-\theta(L)_i)y_{i,T}]'$ which is $T-p \times 1$, $c_i^* = c_i(1-\theta(L)_i)$ and $f^* = [(1-\theta(L)_i)f_{p+1}\ (1-\theta(L)_i)f_{p+2}\ \ldots\ (1-\theta(L)_i)f_T]'$, which $T-p\times 1$ with $\theta(L)_i = (\theta_{i,1} + \theta_{i,2} + \cdots + \theta_{i,p})$ for $i = 1, 2, \ldots, N$. Thus, the posterior for the factor loadings is:

$$\lambda_i \sim N(\overline{\lambda_i}, \overline{V}_{i,\lambda}) \tag{9}$$

where

$$\overline{\lambda_i} = \left(\underline{V}_\lambda^{-1} + (\sigma_{i,\chi}^2)^{-1} f^{*\prime} f^*\right)^{-1} \left(\underline{V}_\lambda^{-1}\underline{\lambda} + (\sigma_{i,\chi}^2)^{-1} f^{*\prime} y_i^*\right)$$

and

$$\overline{V}_{i,\lambda} = \left(\underline{V}_\lambda^{-1} + (\sigma_{i,\chi}^2)^{-1} f^{*\prime} f^*\right)^{-1}.$$

To estimate the VAR parameters of the factors $\phi_1, \phi_2, \ldots, \phi_q$ we find it useful to rewrite equation (2) as:

$$f = X_f \phi + \nu \tag{10}$$

where $f = [f_{q+1}\ f_{q+2}\ \ldots\ f_T]'$ is $T-q\times K$, $\phi = [\phi_1\ \phi_2\ \ldots\ \phi_q]'$ is $Kq\times K$, $\nu = [\nu_{q+1}\ \nu_{q+2}\ \ldots\ \nu_T]'$ is $T-q\times K$ and

$$X_f = \begin{bmatrix} f_q & f_{q-1} & \cdots & f_1 \\ f_{q+1} & f_q & \cdots & f_2 \\ \vdots & \vdots & \vdots & \vdots \\ f_{T-1} & f_{T-2} & \cdots & f_{T-q} \end{bmatrix}$$

which is $T-q\times Kq$. Thus, the posterior of the VAR parameters can be drawn from the following distribution:

$$vec(\Phi) \sim \mathcal{N}(vec(\bar{\Phi}), \Sigma \otimes \overline{G}) I_{S_\Phi},$$

where $\bar{\Phi} \equiv \overline{G}(X_f{}'X_f)\hat{\Phi}$ and $\overline{G} = (\underline{G}^{-1} + X_f{}'X_f)^{-1}$. where I_{S_Φ} is an indicator function enforcing stationarity.

C.1.2 Estimating the Latent Factors

To estimate the common latent factor we condition on the parameters of the model.[10] Our observation equation in the following state-space system is:

$$Y_t^* = C^* + HF_t + \chi_t \tag{11}$$

where

$$H = [\Lambda \ -\Theta_1\Lambda \ -\Theta_2\Lambda \ \ldots \ \Theta_p\Lambda \ 0_{N\times K(q-p-1)}]$$

Our state equation is:

$$F_t = \Phi F_{t-1} + \widetilde{\nu}_t \tag{12}$$

where $F_t = [f_t, f_{t-1}, \ldots, f_{t-q+1}]'$ is $Kq \times 1$, which is denoted as the state vector, $\widetilde{\nu}_t = [\nu_t \ 0 \ \ldots \ 0]'$ is $Kq \times 1$ and

$$\Phi = \begin{bmatrix} \phi_1 & \phi_2 & \cdots & \phi_q \\ & \mathcal{I}_{K(q-1)} & & 0_{K(q-1)\times K} \end{bmatrix}$$

which is $Kq \times Kq$. For all empirical results shown below we use $q > p$.

To calculate the common factor we use the algorithm suggested by Carter and Kohn (1994) and Frühwirth-Schnatter (1994) . This procedure draws the vector $F = [F_1 \ F_2 \ \ldots \ F_T]$ from its joint distribution given by:

$$p(F|\Xi, Y) = p(F_T|\Xi, y_T) \prod_{t=1}^{T-1} p(F_t|F_{t+1}, \Xi, Y^t) \tag{13}$$

[10]See also Kim and Nelson (1999)

where $\Xi = [\Lambda, \Theta_1, \ldots, \Theta_p, \Phi, \Sigma, \Omega_c hi]$ and $Y^t = [Y_1 \ Y_2 \ \ldots \ Y_t]$. Because the error terms in equations (11) and (12) are Gaussian equation (13)can be rewritten as:

$$p(F|\Lambda, Y, \Xi) = \mathcal{N}(F_{T|T}, P_{T|T}) \prod_{t=1}^{T-1} \mathcal{N}(F_{t|t,F_{t+1}}, P_{t|t,F_{t+1}}) \tag{14}$$

with

$$F_{T|T} = E(F_T|\Lambda, \Xi, Y) \tag{15}$$

$$P_{T|T} = Cov(F_T|\Lambda, \Xi, Y) \tag{16}$$

and

$$F_{t|t,F_{t+1}} = E(F_t|F_{t+1}, \Lambda, \Xi, Y) \tag{17}$$

$$P_{t|t,F_{t+1}} = Cov(F_t|F_{t+1}, \Lambda, \Xi, Y) \tag{18}$$

We obtain $F_{T|T}$ and $P_{T|T}$ from the last step of the Kalman filter iteration and use them as the conditional mean and covariance matrix for the multivariate normal distribution $\mathcal{N}(F_{T|T}, P_{T|T})$ to draw F_T. To illustrate the Kalman Filter we work with the state-space system equations (11) and (12). We begin with the prediction steps:

$$F_{t|t-1} = \Phi F_{t-1|t-1} \tag{19}$$

$$P_{t|t-1} = \Phi P_{t-1|t-1}\Phi + Q \tag{20}$$

where

$$Q = \begin{bmatrix} \Sigma & 0 & \cdots & 0 \\ 0 & 0 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 0 \end{bmatrix}$$

which is $Kq \times Kq$. To update these predictions we first have to derive the forecast error:

$$\kappa_t = Y_t^* - C^* - HF_{t|t-1} \tag{21}$$

its variance:

$$\Sigma = HP_{t|t-1}H' + \Omega_\chi \tag{22}$$

and the Kalman gain:

$$K_t = P_{t|t-1}H'\Sigma^{-1}. \tag{23}$$

Thus, the updating equations are:

$$F_{t|t} = F_{t|t-1} + K_t\kappa_t, \tag{24}$$

$$P_{t|t} = P_{t|t-1} + K_tHP_{t|t-1}, \tag{25}$$

To obtain draws for $F_1, F_2, \ldots, F_{T-1}$ we sample from $\mathcal{N}(F_{t|t,F_{t+1}}, P_{t|t,F_{t+1}})$, using a backwards moving updating scheme, incorporating at time t information about F_t contained in period $t+1$. More precisely, we move backwards and generate F_t for $t = T-1, \ldots, p+1$ at each step while using information from the Kalman filter and F_{t+1} from the previous step. We do this until $p+1$ and calculate $f_1, f_2, \ldots, f_p$ in an one-step procedure.

The updating equations are:

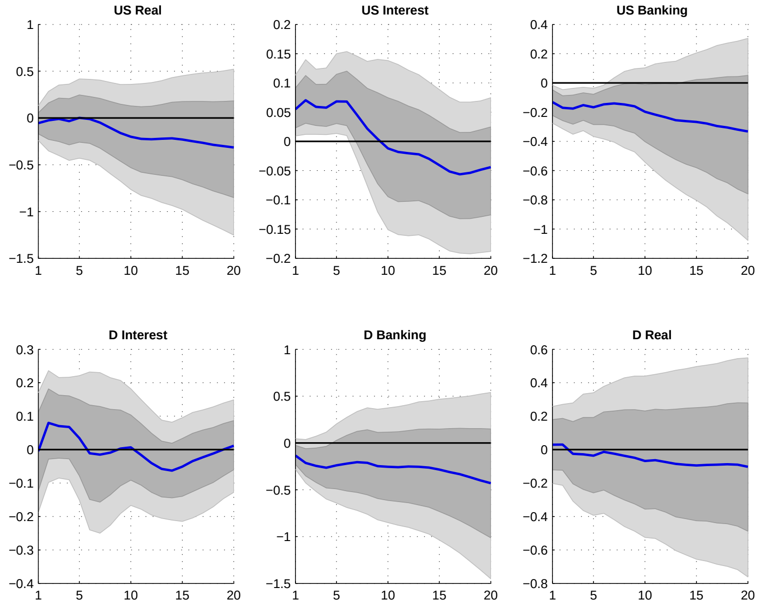
$$F_{t|t,F_{t+1}} = F_{t|t} + P_{t|t}\Phi' P_{t+1|t}^{-1}(F_{t+1} - F_{t+1|t}) \tag{26}$$

and

$$P_{t|t,F_{t+1}} = P_{t|t} - P_{t|t}\Phi' P_{t+1|t}^{-1}\Phi P_{t|t} \tag{27}$$

C.2 Responses to Nominal Shock, Weak Identifying Restrictions

(a) Impulse Responses (U.S. Nominal Shock, Weak Identifying Restrictions)



(b) Variance Decomposition

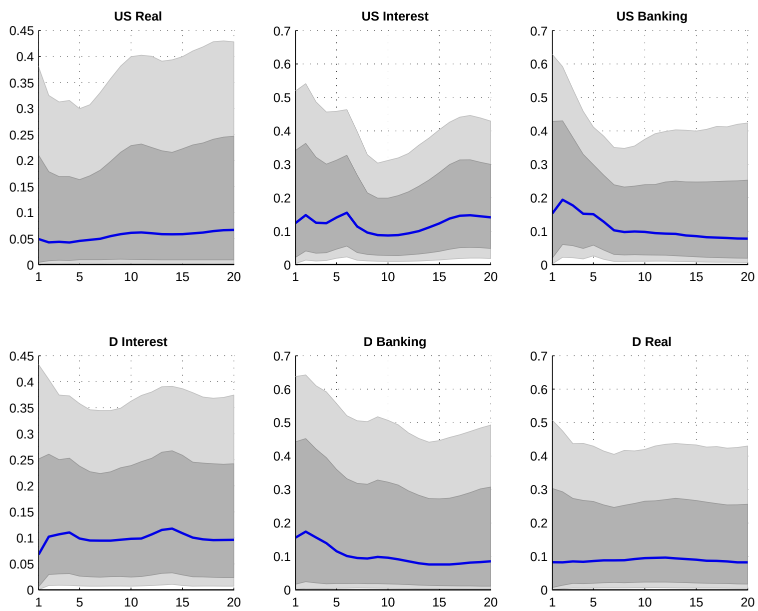
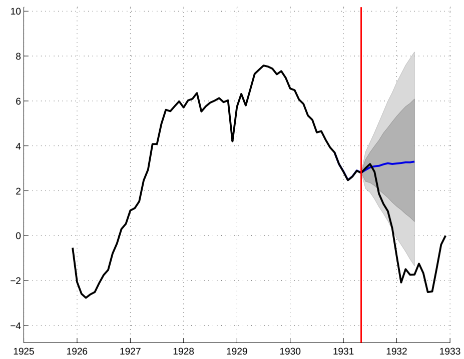


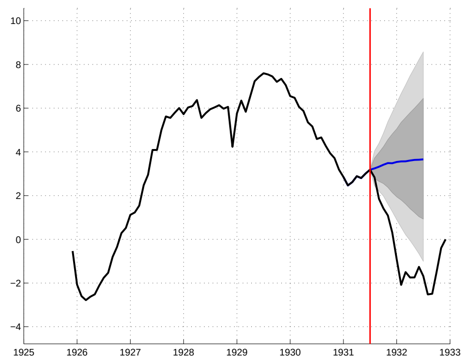
Figure 14: Responses of all variables (upper panel) to and fraction of the variance explained (lower panel) by a contractionary nominal shock. The dark gray shaded area represents 68% and the light shaded area 90% of the posterior probability mass. A sign restriction operates on the responses of the U.S. interest and banking factors for the first six months after the shock.

C.3 Univariate Conditional Forecasts

(a) March 1931



(b) May 1931



(c) July 1931

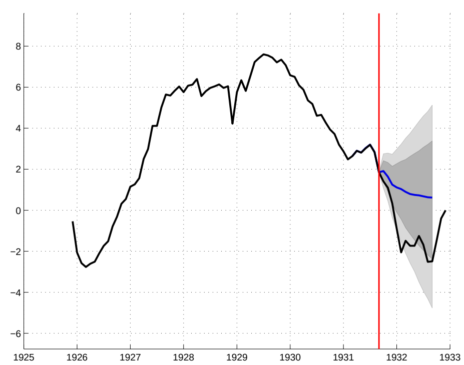
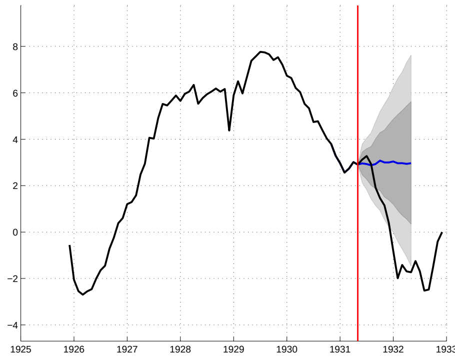
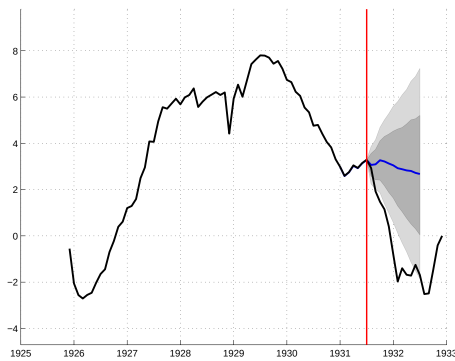


Figure 15: Forecasting the German real sector from March 1931, May 1931 and July 1931, using German real variables only. The dark gray shaded area represents 68% and the light shaded area 90% of the posterior probability mass.

(a) March 1931



(b) May 1931



(c) July 1931

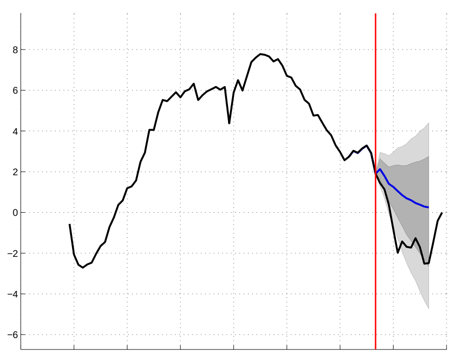
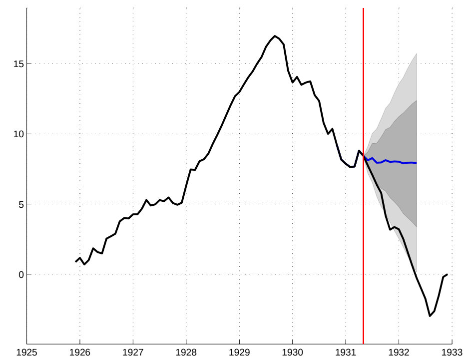
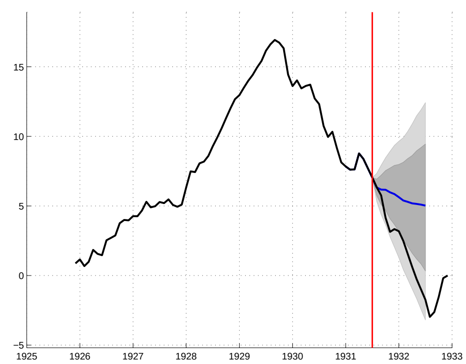


Figure 16: Forecasting the German real sector from March 1931, May 1931 and July 1931, using German and U.S. real variables. The dark gray shaded area represents 68% and the light shaded area 90% of the posterior probability mass.

(a) March 1931



(b) May 1931



(c) July 1931

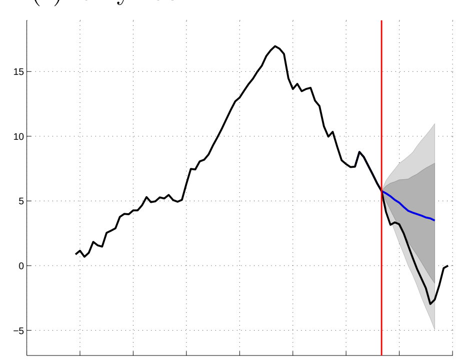


Figure 17: Forecasting the U.S. real sector from March 1931, May 1931 and July 1931, using U.S. real variables only. The dark gray shaded area represents 68% and the light shaded area 90% of the posterior probability mass.