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Abstract

We evaluate the role played by loan supply shocks in the decline of investment and industrial production during the Great Depression in Germany from 1927 to 1932. We identify loan supply shocks in the context of a time varying parameter vector autoregression with stochastic volatility. Our results indicate that credit constraints were a significant driver of industrial production between 1927 and 1932, supporting the view that a structurally weak banking sector was an important contributor to the German Great Depression. We find further that loan supply shocks were an important driver of investment in the early phase of the depression, between 1927 and 1929, but not between 1930 and 1932. We suggest possible explanations for this puzzle and directions for future research.

Keywords: Bayesian; Credit supply; Great Depression; Germany

JEL Classification: C11; E32; N14; N24

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1 Introduction

If to understand the Great Depression is the holy grail of macroeconomics, then Germany may be the place to start the quest.[1] Germany's depression has received particular scholarly attention, because of the nation's position in the nexus of war debts, reparations and US foreign lending. The collapse of this triangular system of capital flows, which linked the largest industrial economies, transmitted deflationary shocks through the Gold Standard. Thus, understanding the causes of Germany's depression is crucial for identifying the culprits of the world-wide depression.[2] Moreover, the German slump was not only particularly early, but also extremely deep with a collapse in GDP and unemployment figures exceeding those of most advanced countries, thereby effectively contributing to the rise of National Socialism. Indeed, recent research provides evidence that both the austerity policies of the Brüning administration between 1930 and 1932, as well as the banking crisis of 1931, were direct contributors to the rise of Nazism (Galofré-Vilà et al., 2017; Doerr et al., 2019).

This paper analyzes one particular mechanism that we demonstrate contributed to the depth of the German Depression: the *bank lending channel*. In his seminal work on the U.S. Great Depression, Bernanke (1983) emphasizes the role of disruptions in financial intermediation and supply of bank loans. This non-monetary channel was able to explain declines in U.S. GDP over and above the effect of monetary shocks, the primary cause in the story of Friedman and Schwartz (1963). Previous studies on the interwar German economy have stressed the structural weakness of the German credit banks after the hyperinflation (Balderston, 1991), the possibility of constraints on bank lending after the stock market crash of May 1927 (Voth, 2003), and the persistence of a banking crisis even after a general bank holiday and the introduction of capital controls in July 1931 (Balderston, 1993). Yet, there exists, to the best of our knowledge, no empirical evidence on the existence and impact of loan supply shocks.

We estimate a Bayesian time-varying parameter vector autoregressive (TVP-VAR) model with monthly German data ranging from 1925:1 to 1934:12. This approach is well-suited for our purposes, as it allows us to identify loan supply shocks in addition to standard macroeconomic shocks. The extreme macroeconomic volatility during the late 1920's and early 1930's would make inferences from a simpler VAR model highly inaccurate. The TVP-VAR is able to lessen issues associated with changes in the prevailing macroeconomic regime, and has been successfully applied to studying changing macro-financial linkages in the context of recent financial crises (Bijsterbosch and Falagiarda, 2015; Gambetti and Musso, 2017). Perhaps most importantly, the model allows for stochastic

[1] Romer (1993) argues that the epicenter of the Great Depression lies in the US, which should make it the focal point of research. Bernanke (1995) argues for a comparative approach across countries to study forces of the depression. We believe that Germany, for its economic size and the reasons outlined in this paragraph, deserves as much attention from researchers as the US.

[2] The treaty of Versailles in the aftermath of WWI imposed reparations on Germany to be paid to Britain and France. In turn, France and Britain owed large sums of war debts to the US. After German hyperinflation had eliminated German savings in the early 1920s, US credits stabilized the German economy and indirectly financed the transfer of reparations to France and Britain. When capital flows reversed in 1930/31, deflationary shocks were transmitted to other nations via the Gold Standard. The literature has not settled on which party in the triangle is most to blame. Kindleberger (1986) and more recently Tooze (2014) point at the U.S., Irwin (2010) and Eichengreen (1992) emphasize the role of France, and Ferguson and Temin's (2003) contribution puts much responsibility on Germany.

volatility in the shocks, whereby it does not confound time-varying macroeconomic or financial instability with structural change in the relationship between credit and economic conditions.

Our results shed light to four key issues in the literature on the German Great Depression. First, as the German Hyperinflation had deteriorated the financial sector's balance sheets, our results empirically support the hypothesis that the rebuilding process itself contributed to the credit banks sluggish performance and constrained lending to the real economy (Balderston, 1991). Second, we lend indirect support to Voth (2003) who argued that the stock market crash initiated Germany's slide into depression, but provides no evidence on the bank lending channel, which he hypothesizes was the crucial channel of how the shock was transmitted to the economy as a whole. Third, the austerity policies of the Brüning administration between 1930 and 1932 and the twin crisis of 1931 were aggravated by the debt-deflation effects of a credit constrained economy. Finally, while the German Great Depression had many causes, it resembled the depression in other countries in terms of having the banking sector as an exacerbating factor (Bernanke, 1995; Grossman, 1994).

The remainder of the paper is structured as follows. After an overview of the debate on the economic history of post-inflation Weimar Germany, we provide details on the structural weakness of the banking sector and elaborate why we should expect the bank lending channel to be operative. The subsequent sections discuss the econometric approach and the results. Finally, we discuss the limitations and contributions of our study and explore areas for future research.

2 The Great Depression in Germany: An Overview

Much ink has been spilled on the causes of the German Great Depression. Until the seminal work by Borchardt (1979) the consensus of economic historians was that deflationary and budget-balancing policies of Heinrich Brüning, chancellor from 1930 to 1932, caused the depression.[3] According to the Keynesian paradigm, alternatives to austerity were available and feasible. Within the classic Keynesian framework there are several possibilities to explain the crisis. One interpretation is that restrictive monetary policy between 1925 and 1929 raised Germany's interest rate above the world rate of interest. The balance of payments equilibrium was restored after 1929 when the government reacted by cutting expenditure and increasing taxes.[4] A second possibility, famously advanced by Kindleberger (1986), is that an autonomous movement of capital, caused by a decline in US lending, shifted the balance of payments equilibrium to a higher interest rate. This line of reasoning, which sees the causes outside Germany, has been dismantled by the seminal work of Peter Temin (1971), who showed that the downturn in Germany began already in 1927, too early to have been caused by an autonomous decline in US foreign lending. The alternative Keynesian explanation would thus be that output began to decline either because of a shock to German exports or through a reduction in autonomous investment. The traditional Keynesian interpretation became the subject of heavy critique with the work of Knut Borchardt (1979, 1980). Borchardt's revisionist argumentation is based on distributional conflict and inept attempts for their resolution, especially excessive wage increases during the 1920s. This depressed profits and created a very unfavorable

[3] c.f. the early and influential work by Haberler (1937)

[4] For a graphical illustration of this line of argumentation ork the reader is referred to Ritschl (1998).

position of the German economy during the World Depression. During the Great Depression the German government was cut off from access to credits because of the burden caused in the 1920s. The deflationary policies were thus a predicament and not intentional policies. It follows that economic expansion from 1933 onwards was only made possible by the removal of the restrictions that caused the compelling deflationary policies of Brüning.

Ritschl (1998) offers a solution that reconciles the Borchardt hypotheses within a Keynesian analytic framework. Introducing the reparations problem in a sovereign debt model he argues that at a certain debt threshold further credits to Germany were denied. The connection between reparations and the German economy is found in the missing incentive structure of the different reparation regimes. Because the Dawes-regime, from 1924 to 1929, gave Germany no incentive for a real-resource transfer of reparations, she subverted paying reparations by accumulating massive foreign debts. This strain on the balance of payments is ultimately responsible for the depth of the German crisis.

Crucially, the Young plan 1929/1930 represents a regime change as the seniority of commercial credits over reparations reverses. Because the Young plan effectively increased the public debt overhang by the amount of reparations and above the amount deemed acceptable by private creditors, credit constrains became binding. This forced Germany into deflation.

A challenge for this interpretation is that the German Depression had already been underway by 1928 and seems to have started in late 1927 as several indicators of investment show (Temin, 1971; Ritschl, 1999). In 1928 net investment fell by 15 percent, most of it driven by lower inventory investment. From 1927 to 1929, the fall in investment was 55 percent, enough to explain the fall in national production. It needs to be stressed, however, that investment did not see a very sharp downturn. Instead the German economy gradually slid into Depression from 1927 onwards. If the origin of the German Depression was internal, it might very well be that foreign creditors started to withdraw capital once investment deficiencies became obvious and the viability of the German economy was put into question. Priority only became pressing once capital inflows ceased (Ferguson and Temin, 2003).

The tests that such a hypothesis must pass are multidimensional. Was the beginning of the German Depression caused internally? Are there feedback mechanisms that can cause an initially relatively minor event to have a negative effect that grows over time? Is this enough to cause an outflow of capital?

Voth (2003) gives an answer to the first question that goes beyond Temin's claim of an autonomous fall in investment. He provides qualitative evidence that Hjalmar Schacht, president of the Reichsbank, perceived the stock market boom of 1926/27 as a bubble and his econometric evidence suggests that pricking the non-existing bubble, by threatening the big banks to restrict credit, had significant adverse effects on investment. To answer the second question Voth suggests three possible transmission mechanism. First, the stock market crash had a negative effect on business sentiment. Second, the collapse in trading volume made German shares less liquid causing transaction costs to rise significantly. Consequently, the stock markets role in allocating capital became more difficult. Third, the destruction of equity values lowered the value of collateral and affected investment via the bank lending channel. Specifically, Voth argues that the stock market crash may

have been instrumental for the reduction in credit and the curtailment of business investment.

Our emphasis on Voth's third transmission mechanism, the bank lending channel, is supported by research which has shown the close relationship between asset price changes and financial intermediation (Adrian and Shin, 2010; Gan, 2007). Yet, evidence for the bank lending channel seems to be nonexistent for the German depression. But as the next section will show, the structural weakness of the German credit banks during the period suggests that the bank lending channel could be a powerful mechanism to explain the collapse of investment.

Lastly, the bank lending channel may have been a key contributor to the rise of the Nazi Party towards the end of the Weimar Republic. In a recent paper Doerr et al. (2019) show how the failure of Jewish-led Danatbank in 1931 induced a strong reduction in the wage bill for connected firms. This led to increasing city-level unemployment in cities with more Danat-connected firms. These cities saw increased anti-Semitism and increased Nazi Party support. While Doerr et al. (2019) do not investigate the specific mechanism through which Danat-connected firms reduced their wage bill, an increase in the real costs of credit intermediation because of the bank-failure as in Bernanke (1983) is the obvious candidate.

3 The German credit banks and the development of the short term foreign credit market

Although Balderston stresses the weak structure of the German credit banks, this story has little to no place in his narrative about the collapse of investment (Balderston, 1993, chpt. 5). Moreover, Balderston (1983, 1993) has argued against a collapse in business confidence as a cause for the fall of investment because the downturn, he contends, started not in inventories but in infrastructure fixed investment and housebuilding. Instead, Balderson stresses the importance of the German bond market, which had been severely impaired by hyperinflation and received further blows because of Reichsbank President Schacht's hostility to foreign borrowing and Parker Gilbert's, the Agent General for Reparations, critic of German public finances.[5] This increased the long term interest rate and thereby exerted a negative effect on investment.

Yet, we claim that the banking sector played an important part in supplying loans to German businesses and that it needs to be connected to the decline in output. Moreover, to the extent that market-based and bank-based finance are substitutes, the latter cannot be excluded from a narrative of financial constraints. We will hence briefly describe the structural weakness of the banking sector between 1927 and 1931, which can make for a large bank lending channel.

Table 1 shows advances, which are tantamount to loans, and equity plus reserves of the Berlin great branch banks. The Berlin great branch banks in 1929 consisted of *Deutsche Bank und Disconto-Gesellschaft*, *Darmstädter und Nationalbank*, *Dresdener Bank* and *Commerz- u. Privatbank*. Together they accounted for more than 20 percent of the banking sector's total assets at the end of 1920s. More importantly for our analysis, they accounted for about half of all *advances* (Debitoren) in the banking system. We observe that advances increased every year until 1929, with the largest absolute increases in 1926/27 and 1928/29. The equity base of these banks had been eroded during the hyperinflation and equity plus reserves (column 4) could not keep up with the increases in advances, but was actually decreasing between 1927 and 1929. The banks accepted lower liquidity ratios in the 1920s than they did before the war, because of more severe competition from foreign banks, smaller savings banks and from other joint-stock banks. Competition for deposits decreased the credit banks' profitability. On the one hand, lower profits prevented the banks from issuing new securities because this would have impaired dividends. On the other hand, banks were forced to undertake more adventurous balance sheet expeditions by increasing their advances (Balderston, 1991).

A caveat of the series in table (1) is that it excludes the large provincial banks, who often maintained regional branch networks similar to the structure of the great branch banks. The large provincial banks, of which *Bayerische Hypotheken- und Wechselbank* (BHW), *Allgemeine Deutsche Credit-Anstalt* (ADAC), *Bayerische Vereinsbank* and *Barmer Bankverein* were the most important, stood in direct competition with the great branch banks, not the least because their loan portfolios were dominated by industrial loans for which they competed with the great branch banks (Schnabel, 2004). However, the data series we use in our econometric analysis in section (4) includes the BHW

[5]Schacht was responsible for the withdrawal of the exemption from the capital yield tax in December 1926 that foreigners hitherto enjoyed. Although the exemption was reintroduced in June 1927, Schacht then started to pressure the Advisory Council for Foreign Credits to enforce stricter criteria of eligibility for foreign loans.

and ADAC. For the descriptive purpose of this section about the structural weakness of the banking sector which can explain the presence of the bank lending channel, the series in table (1) is regarded as sufficient.

Both, the series in table (1) and the series used in section (4) exclude the two great non-branch banks *Berliner Handels-Gesellschaft* (BHG) and *Reichs-Kredit-Gesellschaft*. Yet, we don't think these two institutions are important for our analysis since these banks worked mostly with a small number of wealthy and homogeneous clients (Schnabel, 2004).[6] For the remainder of the paper we will use the term *great banks* (Grossbanken) for the set of banks which we analyze, which excludes the great non-branch banks but includes the two large provincial banks BHW and ADAC.

Table 1: Advances and Equity + Reserves of 4 Credit banks* (Mio. RM)

Balance at end Year	Advances (Debitoren)			Equity + Reserves
	Total	a) secured	b) unsecured	
1913	2948.7	2208	740.6	1490.8
1924	1478.4	780.1	692.3	621.3
1925	2300.7	1462	838.7	629.7
1926	2848.5	2113.7	734.8	720.4
1927	3795.7	2767.5	1028.2	769.8
1928	4287.6	2643.8	1362.8	757.1
1929	5311.4	3957.1	1354.3	714.5
1930	5286.4	4026.1	1260.3	779,5
1931	4381.3	3198	1183.3	529.2
1932	4053.9	3097.3	956.6	444.2

*Deutsche Bank und Disc.-Ges., Dresdener Bank, Commerz- u. Privatbank including their absorbed institutions
Source: (Bank, 1927-1933, 1928, p.514)

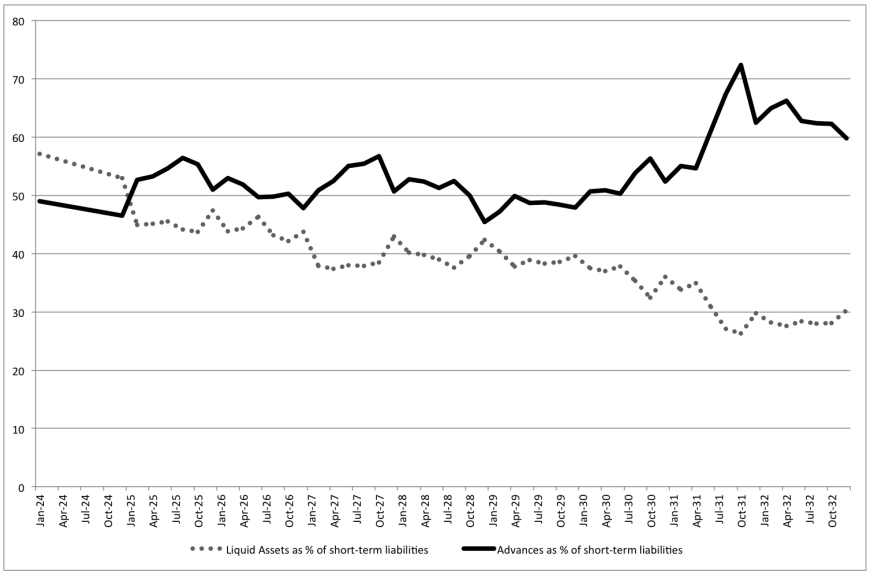
One way to look at the liquidity of the great banks is by considering advances as a percentage of short-term liabilities (i.e. mainly deposits) or liquid assets as a percentage of short-term liabilities. Liquid assets include till cash, deposits at note-issuing and other banks, and bills of exchange. These ratios are plotted in figure (1), which also demonstrates their inverse relationship. The solid line represents the advances to short-term liabilities ratio.

Five months after the stock market crash of May 1927 this ratio stood at 56.7 percent, which is the highest value for the period between 1924 and April 1931. The fact that this ratio increased constantly between the stock market crash and October 1927 can imply that banks were trying to accommodate clients by allowing longer repayment periods for loans.[7] But from October onwards, the advances ratio reached a level higher than what bankers felt comfortable with (Habedank, 1981). The banks increasingly referred customers to foreign banks for advances on their goods, which can be seen in the steep increase of reimbursement credits (i.e. *Warenvorschüsse* (Statistisches Reichsamt, 1936, No. 132)). But because German banks acted as intermediaries on these advances a contingent risk remained on the banks' balance sheets. The German banks were willing to take this risk. As table (2) shows, German banks' and non-banks' foreign short-term debt increased at least until 1929.

[6] Average loans and deposits where higher for these two banks. This implies lower verification costs when granting these loans and we would expect the bank lending channel not to be as significant.

[7] This is consistent with evidence from mid-1927 of increased delays in the settlement of trade debts. See footnote 25 in Balderston (1983).

Figure 1: Liquidity Ratios of the Great Banks



The series are taken from Table 5.12 in Balderston (1993).

Especially, "liabilities for clients", the balance sheet counterpart to reimbursement credits, show a disproportional increase from 1927 onwards. If borrowers had the opportunity to switch to foreign banks for funding, this poses a potential problem for the bank lending channel. Yet, we think this effect is negligible. Reimbursement credits were only granted to companies that were generating enough foreign exchange to service their debt and thereby the substitution towards foreign credit should have happened only in the export sector. In any case, if there was a substitutability between domestic and foreign credits, our empirical estimates below are biased against the bank lending channel hypothesis. In this light, our findings provide even stronger support for credit constraints being a meaningful driver of the economy.

Together, the increase in advances and short-term foreign financing indicates that the German economy in 1927 moved from financing itself in the bond market towards bank based finance. An economy, such as Germany in the period from 1927 to 1932, so reliant on bank loans should be particularly vulnerable to loan supply shocks.

We are not in a position to judge whether this increased dependence on bank loans was caused by Schacht's and Gilbert's critique of foreign borrowing and the impairment of the German bond market as argued by Balderston.[8] Nor are we able to judge whether the initial shock that caused the downturn in investment is to be found in the collapse of the bond market, a change in business sentiments or the stock market crash. Yet, neither of these would by itself have had the power to drive the German economy into depression. Whatever the initial shock, without a severely credit constrained economy, it could have been absorbed by the banking system.

The motor of recession had started in mid to late 1927 and the narrowing trade deficit in 1928

[8]Note for example that a collapse in business sentiment could cause borrowers to switch towards bank loans. In periods with low future profitability when reputation effects are important borrowers will choose monitored debt (bank loans) over non-monitored debt (bond issues) (Diamond, 1991).

Table 2: Short-term liabilities of 92 Credit banks and estimated total short-term debt owed to foreigners incl. non-banks (Mio. RM)

State at end of June	Total short-term debts (w/o German interbank deposits)	of which		Estimated total foreign short-term debt (incl. non-banks)
		a) Foreign deposits	b) "Liabilities for clients"	
1925	4588	837	391	4000
1926	5658	1312	300	5100
1927	7632	2485	521	8600
1928	9825	3768	1136	12000
1929	11866	4020	1769	15700
1930	13382	3880	2062	15300
1931	10580	1530	2068	13100
1932	7869	615	1324	9700
1933	7157	527	1116	8000

Notes: The second column of this table states the total amount of short-term debts of 92 credit banks without interbank deposits. Together columns 3 and 4 then state the total amount of short-term debt of these 92 credit banks owed to foreigners. Column 4 is an estimate of the total foreign short-term debt including non-banks. *Source*: (Bank, 1927-1933, 1928, p.514) and (Untersuchungsausschuss für das Bankenwesen, 1933, p.512)

reveals that the boom in Germany was coming to an end. Falling interest rates went alongside an increase in deposits that was faster than the increase in bills. Both the falling interest rate and the slackening demand for bills are signs that the IS curve was shifting to the left between 1928 and 1929.

Because of the low capital of banks and the impaired balance sheets we suspect that the credit banks exerted significant pressure on the German economy not only in late 1927 but also at other times during the period 1927 to 1932. Specifically, it is likely that the bank lending channel operated during the fiscal crisis between October and December 1929, when the great credit banks lost deposits to Switzerland and the Netherlands. Contrary to the usual seasonal decrease in advances, they did not fall this time. Neither did liquid assets show their usual seasonal upswing.

Finally, we expect the bank lending channel to be operating when Germany was hit by a twin crisis in June/July 1931. Although both the currency and banking crisis persisted into 1932, we think that the banking crisis was more damaging than the currency crisis after capital controls were introduced in July 1931 because of the bank lending channel. While the decision to hold Reichsmarks against foreign currency was marginal, the decision to hold Reichsmarks rather than real assets was no longer marginal in an era of continuously falling prices, i.e. the steady appreciation in the value of money. A debt deflation occurred and led to heavy disinvestments in stocks of inventory and massive bankruptcies.

Summing up, we expect the German economy to be susceptible to loan supply shocks for the whole period between May 1927 and January 1933, because of its low equity base, the high level of illiquid advances and the competition for short-term deposits.

4 Empirical Approach

We estimate a time-varying parameter vector autoregression (TVP-VAR) to study how changes in credit impacted the economy.[9] The motivation for doing this arises from the high degree of economic and financial instability observed during the interwar years, which could make results from static VARs misleading. The TVP-VAR is sufficiently flexible to allow for regime changes between financial and real economic variables, while also being able to deal with changing macroeconomic volatility. This flexibility is necessary when studying periods of financial instability. Indeed, the TVP-VAR has recently been used to study the impact of credit supply shocks in the context of the Great Recession.[10] More broadly, it has been shown to display good forecasting performance, even when applied to data incorporating different economic regimes (D'Agostino et al., 2013).

The TVP-VAR with ρ lags and N endogenous variables is specified as follows:

$$\boldsymbol{y_t} = \boldsymbol{\mu_t} + \sum_{i=1}^{\rho} \boldsymbol{B_{i,t}} \boldsymbol{y_{t-i}} + \boldsymbol{\nu_t} \ ; \ var(\boldsymbol{\nu_t}) = \boldsymbol{\Omega_t} \tag{1}$$

Where $\boldsymbol{\mu_t}$ are time-varying constants, $\boldsymbol{B_{i,t}}$ is an $N \times N$ coefficient matrix corresponding the ith lags of the N endogenous variables $\boldsymbol{y}$. $\boldsymbol{\nu_t}$ are error terms and $\boldsymbol{\Omega_t}$ contain the variances of the errors.

The covariance matrix is decomposed as follows:

$$\boldsymbol{A_t \Omega_t A_t'} = \boldsymbol{\Sigma \Sigma'} \tag{2}$$

Where $\boldsymbol{A_t}$ is a lower triangular matrix with ones on the diagonal, governing the contemporaneous covariances between the coefficients:

$$\boldsymbol{A_t} = \begin{bmatrix} 1 & 0 & \cdots & 0 \\ a_{21,t} & 1 & \cdots & 0 \\ a_{31,t} & a_{32,t} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1,t} & \cdots & a_{nn-1,t} & 1 \end{bmatrix} \tag{3}$$

$\boldsymbol{\Sigma_t}$, meanwhile holds the diagonal terms of the covariance matrix:

$$\Sigma_t = \begin{bmatrix} \sigma_{1,t} & 0 & \cdots & 0 \\ 0 & \sigma_{2,t} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & \cdots & 0 & \sigma_{n,t} \end{bmatrix} \tag{4}$$

This decomposition allows us to write:

$$\boldsymbol{\nu_t} = \boldsymbol{A_t^{-1}} \boldsymbol{\Sigma_t} \boldsymbol{\epsilon_t} \tag{5}$$

With $\boldsymbol{\epsilon_t} \sim N(0, I_n)$

[9] The model is based on work by Primiceri (2005).

[10] Gambetti and Musso (2017); Bijsterbosch and Falagiarda (2015).

This decomposition is particularly helpful for modelling the dynamics of the parameters, which are assumed to follow random walks. In order to illustrate this, define an $(N\rho + 1) \times N$ matrix of all the coefficients as follows: $\boldsymbol{\beta_t} = vec([\boldsymbol{\mu}, \boldsymbol{B_{1,t}}, ...\boldsymbol{B_{\rho,t}}])$. Furthermore, define $h_{i,t} = ln\sigma_{i,t}$, i.e. the logarithm of diagonal elements of the covariance matrix.

We can then write the random walk processes governing the parameter evolution as follows:

$$\boldsymbol{\beta}_t = \boldsymbol{\beta}_{t-1} + \boldsymbol{e}_t; \quad var(\boldsymbol{e}_t) = \boldsymbol{Q} \tag{6}$$

$$ln(h_{i,t}) = ln(h_{i,t-1}) + z_{i,t}; \quad var(z_{i,t}) = w_i \tag{7}$$

$$a_{ij,t} = a_{ij,t-1} + v_{i,t}; \quad var(v_{i,t}) = s_i \tag{8}$$

The matrices Q, S and W (the latter two have diagonal elements s_i and w_i respectively) are the hyperparameters governing the variances of the model states.

Even in the TVP-VAR context, a significant problem in the present case is the high degree of instability in the economic variables. If the underlying Bayesian priors are left relatively unconstrained, draws of $\boldsymbol{Q}$ might not be positive definite, which causes draws of $\boldsymbol{\beta}_t$ to "explode", leading to serious problems with the numerical stability of the algorithm and difficulty replicating the results. It would be possible to select only draws that are stationary, but this approach has been shown to lead to biased results (Koop and Potter, 2011). This issue can nevertheless be mitigated by using priors that lead to some degree of shrinkage. We therefore modify the estimation algorithm by Primiceri (2005) to allow for the 'data-based priors' by Korobilis (2014), which extends approaches from the recent prior-selection literature for univariate regression to the VAR context (Belmonte et al., 2014). These priors allow the data to have a considerable degree of influence on the amount of shrinkage that a given set of parameters take, which leads to increased stability especially for parameters which would otherwise cause unstable draws. The attractiveness of this prior choice is further increased by the relatively short span of our sample. Moreover, no shrinkage is imposed on the prior for the variance of the shocks, which can be an especially important feature of the series examined in the context of the Great Depression.

We estimate this TVP-VAR over the period from 1925:1 to 1934:12 using monthly German data. All variables are seasonally adjusted.[11] The VAR model has three lags, which has been selected based on the Deviance Information Criterion, outlined by Chan and Grant (2016). Estimating the model with four lags yields similar results.[12] Estimating the model with five or six lags leads to numerical instability.

The variables that we include in our specification are: investment (proxied by the production of investment goods); the index of industrial production (IP); the call money rate (r); and advances (credit). We chose the call money rate over the private discount rate because the latter shows no movement between October 1932 and May 1934 and therefore causes computational problems. Figure A.1 in the appendix plots both interest rates. The call money rate shows considerably more volatility and is usually above the private discount rate. Apart from that the two series exhibit strong co-movement. We achieve identification in the impulse responses by using Cholesky-decomposition

[11] Seasonal adjustment is done using the X-13 ARIMA method (Bureau, 2016).

[12] The impact of credit shocks on investment become weaker, but still positive in this specification.

with the following variable ordering: $\boldsymbol{y} = [Investment, IP, credit, r]'$.

Our credit series are advances of the great credit banks, which include Deutsche Bank, Dresdner Bank, Commerzbank, Bayerische Hypotheken- und Wechselbank, and Allgmeine Deutsche Credit-Anstalt including all institutions absorbed by these banks during the period. The series comprises about half of all advances granted by the banking system.[13] Advances are tantamount to loans, given that the majority of them were secured by some kind of asset. Moreover, these loans are almost exclusively loans to the non-bank private sector since business with government institutions was conducted mainly by the *Staats- und Landesbanken* and interbank loans were usually granted using bank bills or nostro accounts.[14] The series that we use is thus well suited to evaluate the effect of credit constraints on production.

Advances were reported only on a bimonthly basis between 1925 and 1927 and we log-linearly interpolate the series to fill the gaps. These years are not incorporated into our impulse responses. The data comes from official statistics published in Statistisches Reichsamt (1936, 1937), Wagemann (1936) and Institut für Konjunkturforschung (1928). Table (A.1) in the appendix lists the exact composition and description of the data.

5 Results

Figure 2 shows impulse response functions of industrial production (IP) and investment to a shock in loans over a horizon of 12 months. The solid line shows the impact of a credit shock on a given variable and horizon. More specifically, this line is the point-wise median response at each forecast horizon. The dashed lines indicate the 86th and 14th percentiles of the draws from the MCMC algorithm, commonly used in Bayesian statistics.[15]

The left-hand side figure shows the median impulse response of industrial production for the years 1927-1932, whereas the right-hand side one shows the response of investment. Both of these variables responded to positive credit shocks, with industrial production rising 0.25% and investment rising 0.05% after a 1% credit shock. These results clearly support the hypothesis that credit shocks were a meaningful driver of economic conditions amidst the German economic downturn. The structural weaknesses in the Germany banking system in the late 1920s meant that their ability to provide credit was significantly constrained, whereby the domestic economy responded substantially to changes in bank lending. Moreover, the significance of the results suggests that regardless of what financing alternatives existed for bank loans, they were clearly insufficient to overcome the impact of the domestic banks' weaknesses.[16]

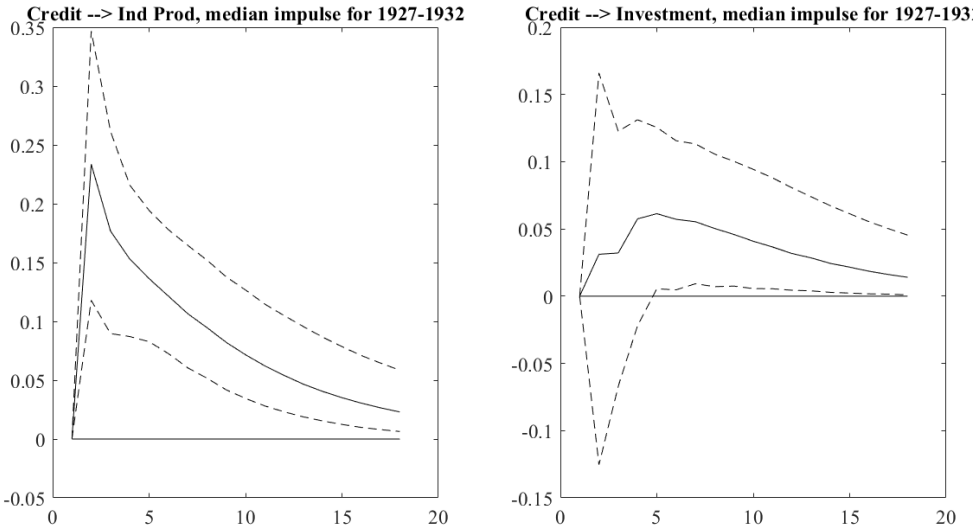
[13] The period that we study is marked by waves of amalgamations. Deutsche Bank merged with Disconto Gesellschaft in 1929, as did Commerzbank and Mitteldeutsche Credit bank. The second largest bank in 1931, Darmstädter und Nationalbank, was absorbed by Dresdner Bank following its bankcruptcy in 1931. In November 1929 advances from the banks in our series accounted for 54% of all advances in the banking system as reported in Die Bank (1927-1933). The monthly magazine Die Bank (1927-1933) reported aggregate balance sheet statistics of all credit banks, state-owned banks (Staats- und Landesbanken) and *Girozentralen* and thereby excludes mortgage banks, savings banks and the private bankers. These latter type of banks traditionally had a negligible share in granting direct loans to industry.

[14] Advances by credit banks to other banks made up only 5.9% of all advances in November 1929 as reported in Bank (1927-1933).

[15] This is because models typically express high degrees of dispersion at the extreme quantiles.

[16] If alternative forms of financing would have been readily available and easily substitutable for bank loans, we

Figure 2: Impulse responses of industrial production and investment from credit



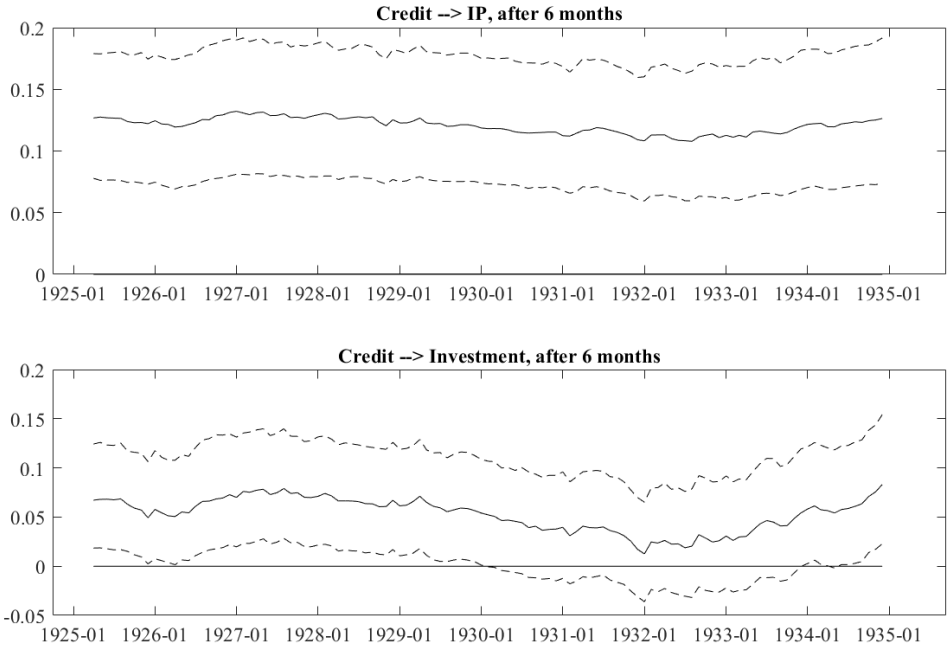
An alternative view of these results can be gained from figure 3, which shows that the impulse responses of IP and especially investment were time-varying. Credit was an important driver of industrial production throughout the period at issue, whereby credit shocks at any given moment could have influenced the economy. This supports our argument of a structurally weak banking sector in Germany. At the same time, note that the impact of credit on investment was most significant before 1930.

The time-varying impact of credit to investment and economic conditions comes to the fore more strongly in the forecast error variance decompositions shown in figure 4. These tell us that credit shocks could explain between 65% to 70% of fluctuations in industrial production itself in any given year between 1925-1935, and between 5% and 20% of changes in investment in these years. Therefore, the shocks in credit are likely to have been especially strong contributors to the growth and the subsequent decline in industrial production, which is likely to have been a key channel through which credit constraints transmitted to the economy more broadly.

Investment, as our literature review above suggests, may have been driven by factors pertaining to the financial markets more broadly as opposed to the banking system alone. In particular, we consider the reversal of international capital flows in 1930/31 and the decline in bond issuance and long-term financing abroad as a separate cause for the fall of investment. Hence, we add domestic and foreign bond issuance to our model in the appendix (A). Yet, our indicator for market-based finance has no impact on industrial production or investment and the effect of bank credit is unaffected by the inclusion of the new variable. This suggests that other factors pertaining to firms investment decisions, such as short-run ex ante real interest rates or expected profits, may have been more important drivers of investment between 1930 and 1933 and we acknowledge that this is a question

would expect the impulse response of economic conditions to loans to be less significant.

Figure 3: Time-varying impulse responses of industrial production and investment to credit shocks



ripe for further research.

The impulse responses of loans to shocks in industrial production and investment are plotted in figure 5. What this figure tells us is that banks did *not* increase their lending even as economic conditions improved. If they did, we would expect bank lending to respond positively to shocks to industrial production. Combined with the other results in this section, what emerges is a picture of a credit constrained economy. This is an important finding in so far as it provides an explanation for the relatively low level of investment of Weimar Germany's economy. Previous studies have sought an explanation for the low level of investment either in excessive wages (Ritschl, 1990) or excessive interest rates (Voth, 1995). While we don't deny that either one of these explanations may have had an effect on investment, our results indicate that new investment was also hampered by a credit constrained economy.

Indeed, as shown in figure 6, we find support for the argument that interest rate shocks influenced German investment especially during the depth of the depression in 1932. Together with our results in figure 3, this can be interpreted as saying that interest rate shocks were *more important* than credit shocks for investment in the German economy at the height of the crisis. In other years, however, interest rate shocks did not have as significant an impact on investment as credit did.

Figure 4: Time-varying forecast error variance decomposition of shocks to credit after 12 months

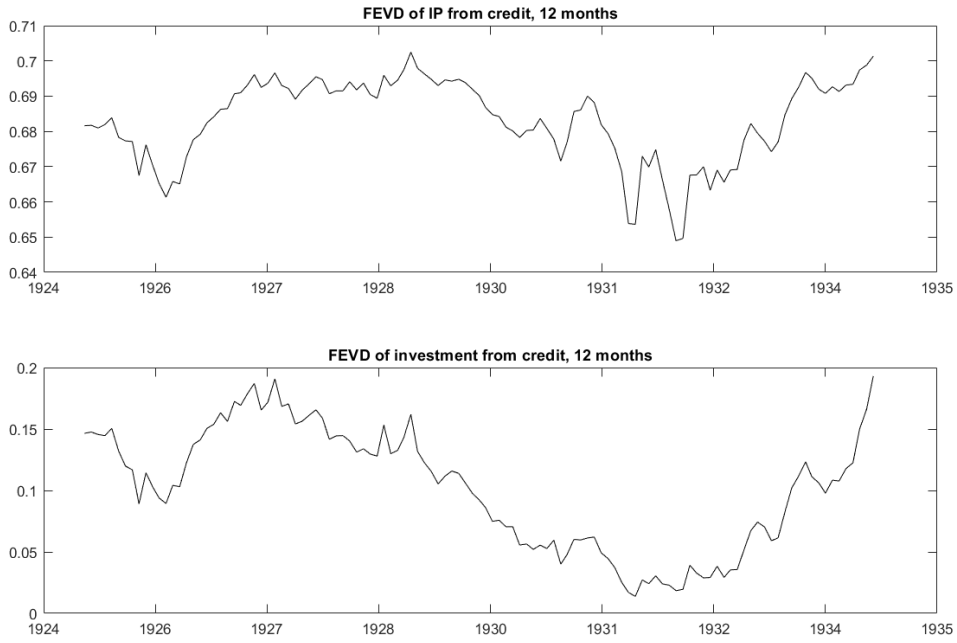


Figure 5: Impulse responses of credit from industrial production and investment shocks

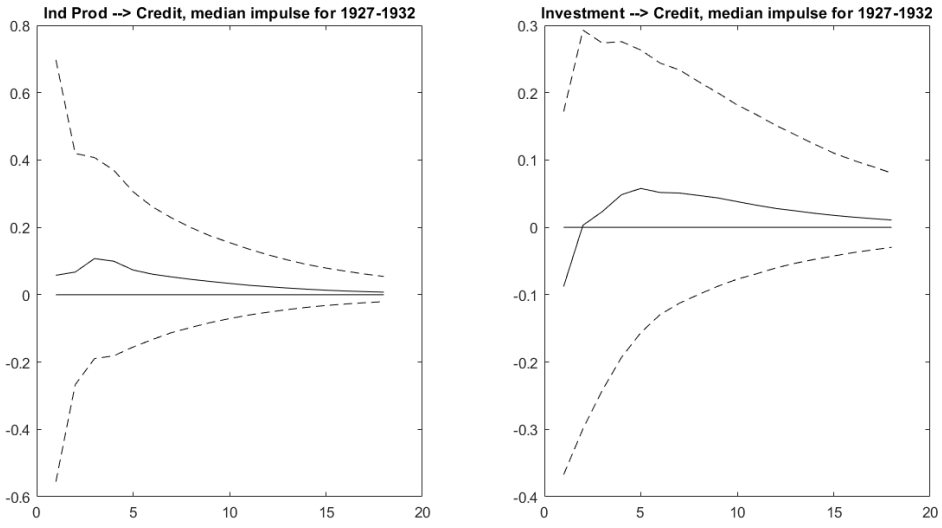
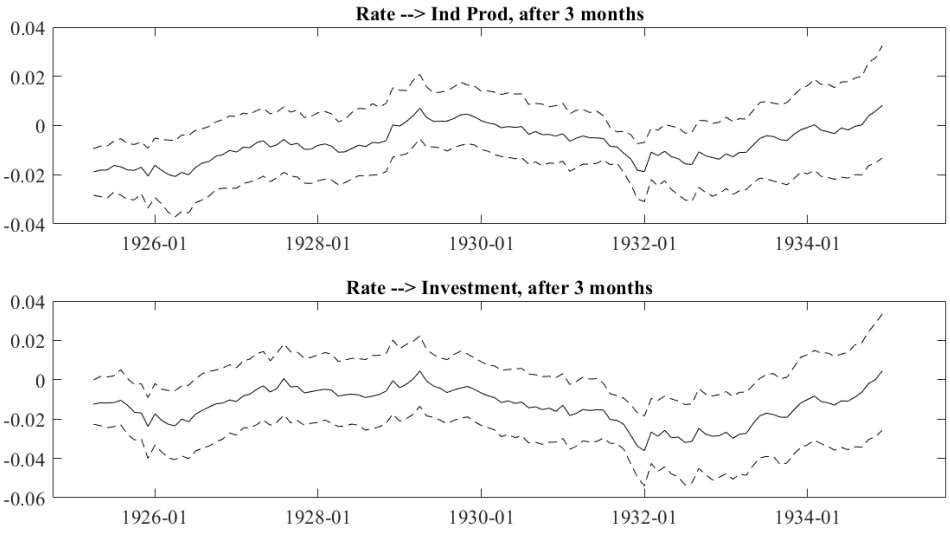


Figure 6: Impulse responses of industrial production and investment from interest rate shocks



6 Conclusion

This is the first study to test for the presence of the bank lending channel during one of the most dramatic periods in German and global economic history. We estimate time-varying parameter vector autoregressions to evaluate the importance of credit constraints between 1924 and 1934. These methods are able to accommodate the significant changes that occurred in the German financial system during the period, and therefore offer a new approach to contributing to the discussion on the causes of the Great Depression in Germany.

We demonstrate that bank lending was an important driver of economic fluctuations in 1924-1934. Credit constraints were a drag on output, as proxied by industrial production, for the entire period under study. The effect on investment, however, is most significant only in the early phase of the Depression from 1927 to 1929. This is an important finding, but one that needs to be contrasted with other transmission channels and evaluated in relative terms against competing hypotheses of the causes of the German slump. In subsequent research we aim to dive deeper into the determinants of investment spending and the causes of the investment downturn in 1927 and after 1929.

A Appendix

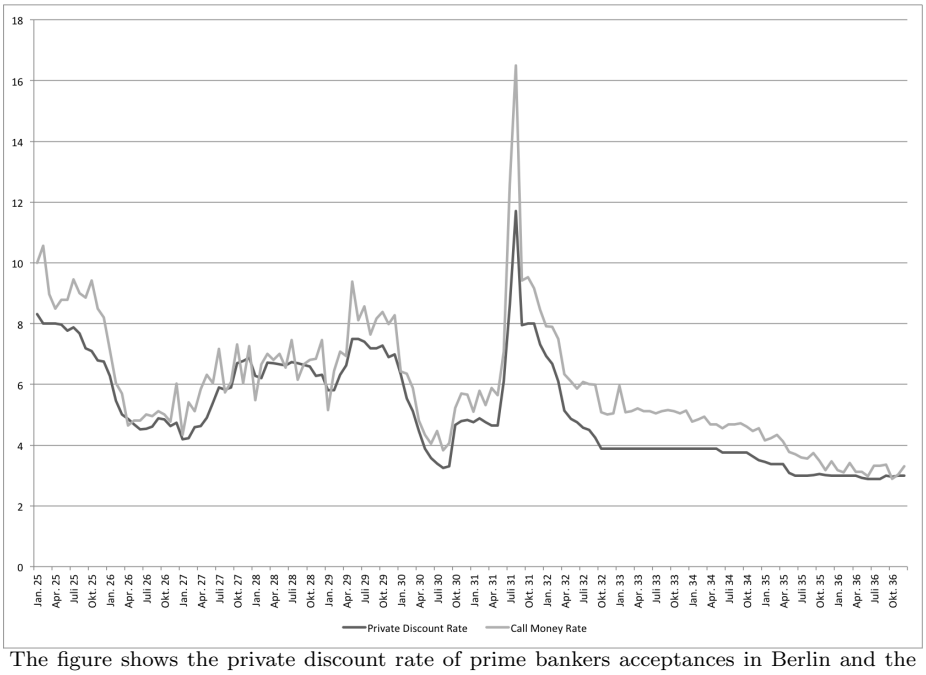
A.1 Data

Table A.1: Variable descriptions and data sources

Variable	Description	Start	End	Source	Indicator
Ind Prod	Index of Industrial Production (1928=100)	1.1925	12.1934	Stat. Handb.	No. 10
Investment	Production of Investment goods (1928=100)	1.1925	12.1934	Konj. Stat. Handb. and Wochenbericht des Inst. f. Konjunkturforschung	No. 13
r	Call Money Rate *Tägliches Geld* (percent)	1.1925	12.1934	Stat. Handb.	No. 123
Credit	Advances *Debitoren* (Mio. RM)	1.1925	12.1934	Stat. Handb.	No. 133

SA: Seasonally Adjusted; Stat. Handb.: Statistisches Reichsamt (1936, 1937)

Figure A.1: Interest Rates in Germany

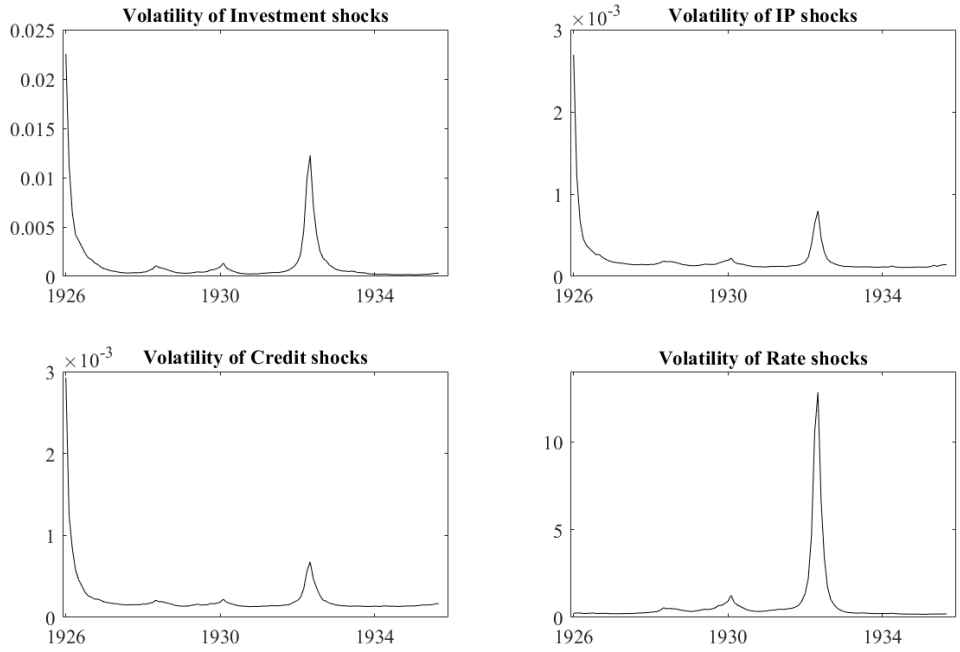


The figure shows the private discount rate of prime bankers acceptances in Berlin and the call money rate (Tägliches Geld). The series are taken from Statistisches Reichsamt (1936, 1937).

A.2 Stochastic volatility

Figure A.2 demonstrates the importance of allowing

Figure A.2: Stochastic volatility of shocks



A.3 Robustness

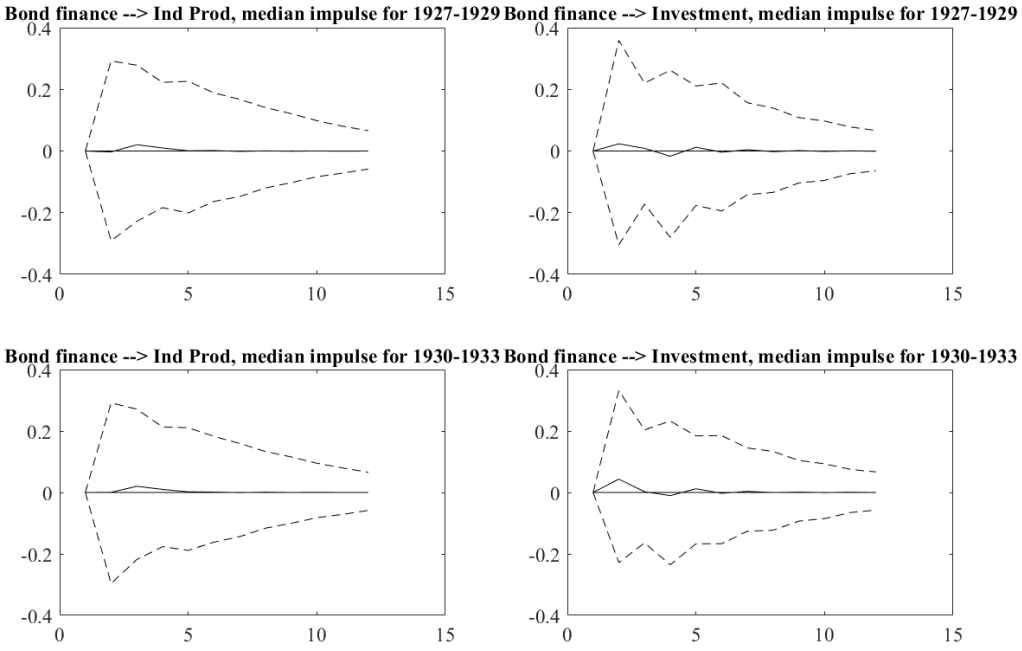
A.3.1 Foreign bond issuance

Investment, as our literature review above suggest, may have been driven by factors pertaining to the financial markets more broadly as opposed to the banking system alone. Particularly, the reversal of international capital flows in 1930/31 is a likely factor that put severe strain companies that relied on long-term financing abroad (Accominotti and Eichengreen, 2016). To examine this, we test the robustness of our results using an indicator for market-based finance: the sum of domestic and foreign bond issuance (available in: Statistisches Reichsamt (1936)).

Our results presented above are robust to the inclusion of this variable. Figure A.3 shows that bond issuance did not meaningfully impact investment or industrial production, whereas figure A.4 shows that the impact of bank credit shocks on investment and industrial production remain significant after bond finance is included in the VAR-specification.[17] This reinforces our argument that bank credit was an important driver of macroeconomic conditions in Germany during the period at issue.

[17]The VAR retains the same lag structure as used above

Figure A.3: Impulse responses of industrial production and investment from bond issuance



A.3.2 Alternative investment series

We experimented with using domestic orders of new machinery as an alternative indicator for domestic investment. As figure A.5 shows, the result of credit constraints being important is significant, although the response of the alternative indicator is meaningfully larger.

Figure A.4: Impulse responses of industrial production and investment from loans controlling for bond issuance

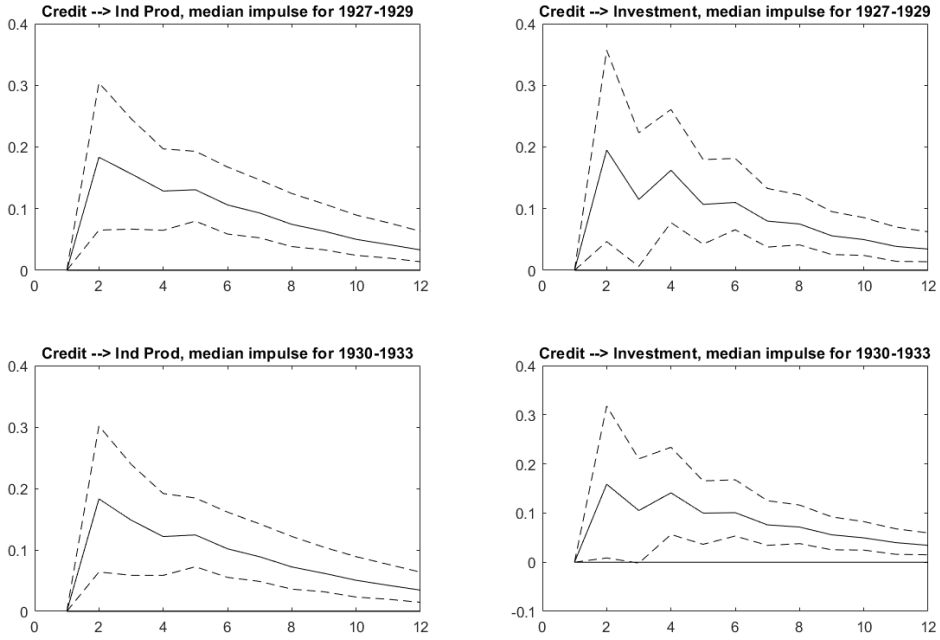
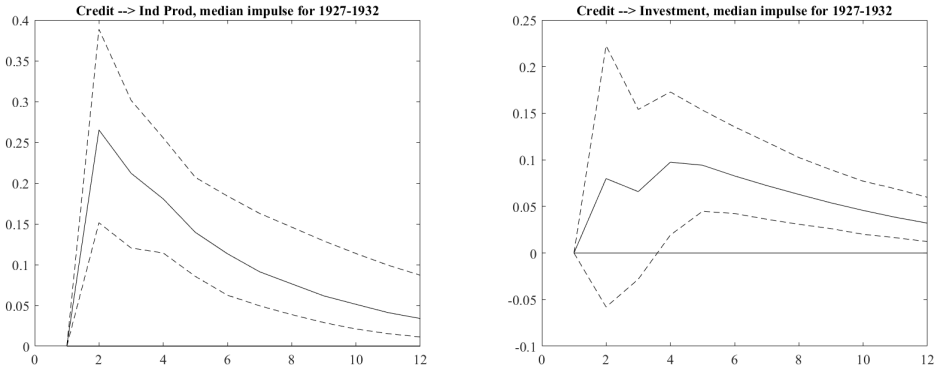


Figure A.5: Impulse responses of industrial production and investment from loans with alternative investment indicator



A.4 Priors

Bayesian priors are a convenient way to provide some degree of restriction to what values the parameters can take. In a time-varying model they are particularly important, because they also determine the amount of time-variance that can take place (Primiceri, 2005).

The priors of the parameters in the TVP-VAR with data-based priors specified can be outlined as follows

Define $\boldsymbol{x}_t = [1, y_{t-1}..., y_{t-p}]'$ and $\boldsymbol{z}_t = \boldsymbol{I}_n \otimes \boldsymbol{x}_t$. We then separate $\boldsymbol{z}_t\boldsymbol{\beta}_t$ such that: $\boldsymbol{z}_t\boldsymbol{\beta}_t = \boldsymbol{z}_t\boldsymbol{\alpha} + \boldsymbol{z}_t\boldsymbol{\alpha}_t + \boldsymbol{\epsilon}_t$. In this way, $\boldsymbol{\beta}_t$ is separated into a time-varying and time-invariant part. Define also $\kappa = N\rho + 1$, the number of parameters.

A part of the estimation algorithm therefore differs from the Primiceri (2005) one in that we sample $\boldsymbol{\beta}_t$ in two steps: the constant and time-varying part. Start with the time-invariant part:

1. We first draw $\boldsymbol{\alpha} \sim N(\bar{\boldsymbol{a}}, \bar{\boldsymbol{V}}_\alpha)$, with $\bar{\boldsymbol{\alpha}} = \bar{\boldsymbol{V}}_{\boldsymbol{\alpha}}(\sum_t \boldsymbol{z}_t\boldsymbol{\Omega}_t^{-1}\boldsymbol{y}_t^*)$; $\bar{\boldsymbol{V}}_\alpha = (\boldsymbol{V} + \sum_t \boldsymbol{z}_t\boldsymbol{\Omega}_t^{-1}\boldsymbol{z}_t)$, $\boldsymbol{V} = diag(\tau_1..., \tau_m)$ *and* $\boldsymbol{y}_t^* = \boldsymbol{y}_t - \boldsymbol{z}_t^{'}\boldsymbol{\alpha}_t$
2. Sample τ_i that do not refer to intercepts (these are set to 2): $\tau_i \sim IG(\rho_{i1}, \rho_{i2})$. We set $\rho_{1i} = \kappa_1 + 0.5$; $\rho_{2i} = 0.5 \times \ \alpha_i^2 + \kappa_2$.
3. Sample $\boldsymbol{\alpha}_t$ using Carter-Kohn algorithm, where the initial condition $\boldsymbol{\alpha}_0$ is set to zero.
4. Sample $Q \sim IW(\kappa + 1, 0.01 \times \boldsymbol{V})$

Where $N(\cdot)$, $IW(\cdot)$ and $IG(\cdot)$ denote the normal, inverse Wishart and inverse gamma distributions, respectively. The estimation algorithm is as in Primiceri (2005) after $\boldsymbol{\beta} = \boldsymbol{\alpha} + \boldsymbol{\alpha}_t$ and $\boldsymbol{Q}$ have been sampled. See Korobilis (2014) for details.

With these definitions, the priors of the model can then be summarised as follows:

$$\boldsymbol{\alpha}_0 \sim N(\bar{\boldsymbol{a}}, \bar{\boldsymbol{V}}_{\boldsymbol{\alpha}}) \; where \tag{9}$$

$$\bar{\boldsymbol{\alpha}} = \bar{\boldsymbol{V}}_\alpha(\sum_t \boldsymbol{z}_t\boldsymbol{\Omega}_t^{-1}\boldsymbol{y}_t^*) \; ; \; \bar{\boldsymbol{V}}_{\boldsymbol{\alpha}} = (\boldsymbol{V} + \sum_t \boldsymbol{z}_t\boldsymbol{\Omega}_t^{-1}\boldsymbol{z}_t) \; ; \tag{10}$$

$$\boldsymbol{V} = diag(\tau_1..., \tau_m) \; and \; \boldsymbol{y}_t^* = \boldsymbol{y}_t - \boldsymbol{z}_t^{'}\boldsymbol{\alpha}_t \tag{11}$$

$$\tau_i \sim IG(\rho_{1i}, \rho_{2i}) \; where \tag{12}$$

$$\rho_{1i} = \kappa_1 + 0.5; \; \rho_{2i} = 0.5 \times \ \alpha_i^2 + \kappa_2 \tag{13}$$

$$\boldsymbol{Q} \sim IW(\kappa + 1, 0.01 \times \boldsymbol{V}) \tag{14}$$

$$\boldsymbol{H}_0 \sim N(\hat{\boldsymbol{H}}_0, c_h \cdot \boldsymbol{I}_N) \tag{15}$$

$$\boldsymbol{A}_0 \sim N(\hat{\boldsymbol{A}}_0, c_a \cdot V(\hat{\boldsymbol{A}}_0)) \tag{16}$$

$$\boldsymbol{W} \sim IW(k_W^2 \cdot N, \boldsymbol{I}_N) \tag{17}$$

$$\boldsymbol{S}_i \sim IW(k_S^2 \cdot (i+1) \cdot V(\boldsymbol{S}_{prior}), (i+1)) \tag{18}$$

The other underlying parameters to be estimated are outlined in section 4. Here, S_i is the ith row of matrix S. S is block diagonal such that: $S_1 = s_1$; $S_2 = [s_2, s_3]$ and so on. W is a diagonal matrix with elements w_i.

For the data-based prior for τ_i, we set $\kappa_1 = 1$ and $\kappa_2 = 20$. As for the other priors, we use fairly uninformative values: $\bar{\boldsymbol{a}} = 0$; $V(\hat{\boldsymbol{A}}_0) = \boldsymbol{I}_N$; and $V(\boldsymbol{S}_{prior}) = \boldsymbol{I}_N$. The other priors are also consistent with the TVP-VAR literature. They are specified as follows: $k_S = 0.1$; $k_W = 0.01$; $c_a = 4$ and $c_h = 4$ (Primiceri, 2005).

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