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THE CREDIT SUPPLY CHANNEL OF MONETARY POLICY: EVIDENCE FROM A FAVAR MODEL WITH SIGN RESTRICTIONS

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Abstract

We test whether the credit channel of the monetary policy was present in the United States' economy from January 2001 to April 2016. To this end, we use a factor augmented vector autoregression (FAVAR) and we impose sensible theoretical sign restrictions in our structural identification scheme. We use the expected substitution effect between bank commercial loans and commercial papers to identify the credit supply channel. We found that the credit channel appears to have operated in the US economy during the sample period. However, when we split the sample we found that the credit channel did not operate after the subprime crisis (close to the Zero Lower Bound of the interest rate). This result is robust to changing the sign restriction horizons. It supports current views in the literature regarding the ineffectiveness of the credit channel as a mean to foster real economic activity during crises episodes.

Keywords: Credit Channel, FAVAR, Sign Restrictions, Monetary Policy.

JEL Codes: E51, E52, C32

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1. Introduction

Monetary policy, as the main tool available for policy makers within the paradigm of business cycles stabilization, is supposed to have a significant effect on economic activity, at least in the short run (Bernanke and Blinder 1992; Woodford 2003; Galí 2015). Such effects may appear by different means, which include traditional expected impacts of monetary policy on real investment and consumption (Hicks 1937; Jorgenson 1963), effects related to nominal and real exchange rate dynamics (Mundell 1963; Obstfeld and Rogoff 1995), impacts on the composition of firm's and financial institutions' balance sheets (Bernanke and Blinder 1988; Bernanke and Gertler 1995; Kashyap and Stein 1995) and impacts on the wealth of households through variations in stock market prices (Tobin 1969), among others[3].

One traditional channel of the monetary policy, identified in the field following the seminal work by Bernanke and Blinder (1988), is the bank-lending channel. Under the assumption that from the firm's perspective, funding by issuing bonds is not a perfect substitute for funding through bank loans, these authors argue that monetary policy would operate not only by impacting interest rates in the bond market but also by influencing the credit supply decisions made by financial institutions. This would modify the balance sheet of the lenders and, in turn, would affect the optimal consumption and investment paths of the agents within the economy. This effect should be more significant for those agents mostly dependent on external funding to conduct their consumption and investment plans, such as small firms (Kashyap et al. 1993; Kwan 2010).

3 See Boivin et al. (2010) for a recent survey of this literature.

Recently, the role of banks in the transmission of monetary policy has been of interest for policy makers, precisely due to the role of such financial institutions during the 2007-2009 crisis, as a vehicle for the propagation and amplification of the monetary shocks to the real economy (Peek and Rosengren 2012). The literature has highlighted that increasing levels of uncertainty during the crisis, alongside a significant liquidity reduction experienced during that period (Stock and Watson 2012; Bordo, et al. 2016), might have led banks to reduce the monetary policy transmission, compared to the pre-crisis period, as the interest rate approached its Zero Lower Bound-ZLB (Adams-Kane et al. 2015; Apergis and Cristou 2015). Such lack of effectiveness of the monetary policy can be seen as part of a long run tendency, as documented by Endut et al. (2017) and Vera (2012), or alternatively, it can be seen as a recent phenomenon, starting approximately in 2011, when the interest rate in the Treasury yields curve, at two and three years to maturity, became more or less insensitive to the news. In both cases, traditional fiscal and monetary policies may have lost their efficacy, as documented by Swanson and Williams (2014).

In this document, we add to the literature by implementing a novel alternative methodology based on factor augmented vector autoregressions and sign restrictions seeking to identify the credit channel of the monetary policy. This enables us to address some potential critiques to the policy effect identification scheme on the credit supply variables on a macro basis. Basically, we address issues regarding potentially omitted variables and their related confounding dynamics and possible theoretical model misspecifications simultaneously. This is important because, as argued by Kashyap et al. (1993), it is not feasible to identify the effect of changes in the reference rate on the credit supply simply by looking at the behaviour of the banks' aggregated loans after the policy interventions. The reason is that, after a monetary contraction, bank loans may drop because of a reduction in the aggregated demand which is to be expected from the traditional interest rate channel. This is not related to the decisions about credit supply made by the financial institutions and therefore should be disentangled from the total effect before calculating the pass-through from the interest rates to the bank's credit supply.

Kashyap et al. (1993) also propose a way to handle this conundrum. They suggest analysing the firms' balance sheet movements in the liabilities side, looking for changes in alternative funding mechanisms available to companies after the credit reduction has occurred. That is, an increment in the amount of commercial papers issued by firms is expected after a reduction in the credit supply provided by banks. One could use this information to properly identify the supply side in the credit reduction dynamics. If a reduction in bank loans occurs *joint to* an increase in the volume of commercial papers issued by firms, we could argue in favour of the existence of the credit supply channel, and the confounding variation associated with the aggregated demand would be effectively isolated.

We follow the suggestion by Kashyap et al. (1993) to identify the pass-through of the interest rates to the credit supply. However, unlike them, we introduce the substitution effect that exists between bank loans and commercial papers in a FAVAR set up. As is well known, the FAVAR framework allows the researcher to condition the estimation results on richer information and to control for other possible confounding dynamics, otherwise absent from the model.

Finally, we naturally impose the substitution effect in our model using sign restrictions. Sign restrictions have the additional advantage of addressing the problem of model identification uncertainty in a systematic way, which is fundamental in macroeconomic empirical exercises.

Our main results support some past views in the field that cast serious doubts on the existence of the credit channel during crisis episodes. This result is robust to changes in the monetary policy variables, and to changes on the horizon of the sign restrictions.

This document is organized as follows. In section 2, we revise our methodological set up in more detail, which involves describing FAVAR models and sign restrictions. We also describe our data in this section. We present our main results in section 3, including some robustness exercises. Section 4 summarizes our main conclusions, policy implications and some limitations of our study.

2. Methods and Data

We use a FAVAR model to identify the structural monetary innovations of the system using theoretical sign restrictions. In our baseline scenario, our restrictions involve that a positive shock on the interest rate must be followed, during at least twelve months, by positive dynamics in the same variable (to guarantee the direction of the shock). Second, a positive shock to the interest rate must induce a reduction of bank loans for at least twelve months. Afterwards, to properly distinguish between the credit channel (*the contractionary monetary policy shock inducing a curbing of credit supply*) and the traditional interest rate channel of the monetary policy (*the contractionary monetary policy shock inducing a curbing of credit demand*), we analyze the impulse-response functions recovered from a shock to the interest rate on the series of commercial papers. In the case that commercial papers series increases after the original positive shock to the interest rate, we could argue in favor of the credit channel existence during the sample period.

This last step allows us to elucidate whether the credit channel is present in the sample period, controlling for possible confounding effects. The confounding effects may appear due to other sources of variations, induced by changes in terms of market liquidity and shrinking demand expectations, following an increment in the interest rate. Nevertheless, we perform, in section 3, several robustness exercises, changing the horizons of our restrictions, which confirm our main findings.

2.1. Factor augmented vector autoregressions

Bernanke et al. (2005) proposed FAVAR models aiming to overcome two important criticisms to the original VARs. Namely, when using traditional VARs, the researcher is forced to exclude too many variables from the analysis because otherwise it is not feasible to achieve first-order efficient estimations of the dynamics within the system. This is due to the high number of coefficients associated with each variable, which needs to be estimated in this traditional framework. Therefore, the model can handle a relatively low maximum number of shocks, given by the number of variables that generate feasible estimates. This strategy leaves unexplained different dynamics outside the system that may be of interest for the researcher or the policy maker. It also lacks control on the confounding dynamics associated with such variables, which might lead to inconsistent estimators. Second, the FAVAR approach allows the research to construct direct estimations of abstract concepts such as ‘economy activity’, ‘interest rates’ or ‘prices’, among others, without having to resort to proxy-variables, which might be inaccurate or difficult to justify. For the aforementioned reasons, FAVAR models have currently become a major tool for economic analysis, and numerous studies have used them to improve estimations of different macroeconomic dynamics, particularly in the context of identification and quantification of the monetary policy effects on real and nominal variables (Belviso and Milani 2006; Jimborean and Mésonnier 2010; Dave et al. 2013; Ellis et al. 2014; Munir and Qayyum 2014; Eickmeier, et al. 2015).

Formally, let $\boldsymbol{Y_t}$ be a $M \times 1$ vector of observable variables, which captures the main dynamics in the economy. $\boldsymbol{F_t}$ be a $K \times 1$ vector of factors that contains unobservable variables, which are not included in $\boldsymbol{Y_t}$. The joint dynamics of $(\boldsymbol{Y_t}, \boldsymbol{F_t})$ are given by:

$$\begin{bmatrix} \boldsymbol{F_t} \\ \boldsymbol{Y_t} \end{bmatrix} = \boldsymbol{A}(\boldsymbol{L}) \begin{bmatrix} \boldsymbol{F_{t-1}} \\ \boldsymbol{Y_{t-1}} \end{bmatrix} + \boldsymbol{V_t}, \tag{1}$$

where $\boldsymbol{A}(\boldsymbol{L})$ is a polynomial in the lag operator of order d, and $\boldsymbol{V_t}$ is a vector of errors with zero-mean and variance-covariance matrix $\boldsymbol{Q}$. Equation 1 is a FAVAR model. This model cannot be estimated directly because the factors $\boldsymbol{F_t}$ are non-observable. Therefore, such factors must be estimated in the process, using techniques such as principal components, singular value decompositions or the Kalman filter.

In this paper, the total number of informational series included in the factor estimations, $\boldsymbol{X_t}$, are N, where $K + M \ll N$. We follow one of the strategies proposed by Bernanke et al. (2005), which consists of two steps: in the first step, we estimate the common components of the system, $\boldsymbol{C_t}$, using the first $K + M$ principal components of $\boldsymbol{X_t}$. Then, we extract from $\boldsymbol{C_t}$ the variation explained by the observable factors contained in $\boldsymbol{Y_t}$. This is possible simply by using the residuals of a linear projection of $\boldsymbol{C_t}$ onto $\boldsymbol{Y_t}$. We labelled these residuals as our new estimated factors $\widehat{\boldsymbol{F}}_t$. Replacing $\boldsymbol{F_t}$ by $\widehat{\boldsymbol{F}}_{\boldsymbol{t}}$ in equation 1 enables us to estimate the model parameters by ordinary least squares regressions. It is also possible to construct non-orthogonalized impulse response functions (IRF) in this case, using the MA representation of the system in equation 1. The MA representation exists under suitable stationary conditions as in any VAR model[4].

2.2. Sign restrictions and identification of structural shocks

The reduced form VAR in equation 1 can be rewritten in terms of white noise innovations, $\boldsymbol{V_t}$, as

$$\begin{bmatrix} \widehat{\boldsymbol{F}}_{\boldsymbol{t}} \\ \boldsymbol{Y_t} \end{bmatrix} = \begin{bmatrix} \overline{\boldsymbol{F}} \\ \overline{\boldsymbol{Y}} \end{bmatrix} + \boldsymbol{C}(\boldsymbol{L})\boldsymbol{V_t}, \tag{2}$$

where $\overline{\boldsymbol{F}}$ and $\overline{\boldsymbol{Y}}$ are the unconditional means of the processes, and $\boldsymbol{C}(\boldsymbol{L})$ is a polynomial in the lag operator of infinite order. Structural innovations can be recovered from the system in equation 2, imposing theoretical restrictions on the VAR. That is, post-multiplying the matrices in $\boldsymbol{C}(\boldsymbol{L})$ by a matrix $\widetilde{\boldsymbol{B}}$, which contains as many theoretical restrictions as needed to just-identify the system (or to achieve partial identification, depending on the interests of the researcher). In this case, it follows that $\widetilde{\boldsymbol{B}}^{-\boldsymbol{1}}\boldsymbol{V_t} = \boldsymbol{\varepsilon_t},$ and therefore, $\boldsymbol{C}(\boldsymbol{L})\widetilde{\boldsymbol{B}} = \boldsymbol{\Phi}(\boldsymbol{L})$, where $\boldsymbol{\varepsilon_t}$ is a vector of dimensions $(M + K) \times 1$, which contains the structural innovations, and $\boldsymbol{\Phi}(\boldsymbol{L})$ are the structural IRFs of the system, as stated in equation 3:

4 Such standard conditions can be found for instance in Lütkepohl (2006).

$$\begin{bmatrix} \widehat{\boldsymbol{F}}_t \\ \boldsymbol{Y}_t \end{bmatrix} = \begin{bmatrix} \overline{\boldsymbol{F}} \\ \overline{\boldsymbol{Y}} \end{bmatrix} + \boldsymbol{\Phi}(\boldsymbol{L})\boldsymbol{\varepsilon}_t \,. \tag{3}$$

One approach proposed by Sims (1980) to carry out the whole system identification is to understand $\widetilde{\boldsymbol{B}}$ as one of the triangular matrices arising from the Cholesky factorization of the variance-covariance matrix in the reduced form model, $\boldsymbol{Q}$. Nevertheless, this approach has been subject to many criticisms (Faust 1998; Canova and De Nicolo 2002) on the grounds that, given a Cholesky factorization, any orthonormal rotation on it will produce a different model with different dynamics associated with the structural innovations. Such models are, *ex ante*, equally valid as the original Cholesky factorization, just under a different theory.

Uhlig (2005) proposes to handle this pervasive uncertainty about the structural modelling strategy, constructing numerous structural models (matrices $\widetilde{\boldsymbol{B}}$) and using them to estimate structural IRFs. Afterwards, he proposes to select a set of IRFs that agree with the theoretical restrictions the researcher is sure (or at least confident) to impose on the data generating process. Such a set-identification strategy delivers a group of IRFs, which are in principle equally valid, given the restrictions on the signs of their components. Finally, some descriptive statistics may be used to portray the set of structural IRFs that conforms to the imposed restrictions. In this study, we use the median and some high (86th) and low percentiles (14th).

We propose using sign-restrictions to identify the structural monetary innovations in the system because sign-restrictions allow us to focus precisely on the cases in which the credit supply channel might be operating. After a contractionary monetary innovation that impacts the interest rate of the economy, a reduction in banks loans must be expected. This reduction may be due to a *reduction of the credit demand* by households and firms, but also to a r*eduction of the credit supply* by financial institutions. Thus, our first restriction is to be imposed on the bank loans dynamics. In short, bank loans must reduce after the monetary innovation is observed.

Nevertheless, in order to disentangle the reduction of the bank loans due to the supply of credit and that due to the credit demand, we also need to analyze the dynamics after the shock followed by commercial papers. Commercial papers are a substitute of bank loans, which can be used as a funding source by firms, when they face a shortage of credit (that is a reduction of the credit supply). Therefore, if the credit supply channel of the monetary policy is operating after a contractionary monetary innovation, we should observe an increment in the issuing of commercial papers. That is, we should observe firms seeking for alternative sources of liquidity to compensate the credit supply reduction. On the contrary, a reduction of commercial papers after the shock would imply that firms are not attempting to substitute banks loans and, therefore, the original reduction of bank loans should not be attributed to a credit shortage, but instead to a reduction in the firms' willingness to issue new debt (i.e. demand considerations). The substitutive nature of bank loans and commercial papers has been emphasized by Kashyap et al (1993) who introduced it on an Instrumental Variable (IV) setting.

Selected sign restrictions must be based on solid theoretical grounds[5] because the whole identification strategy relies on the imposed signs. We summarized the sign restrictions in our baseline scenario as follows:

- Following an increment in the interest rate, we expect an increment in the FED funds rate for at least twelve months. This horizon has been selected following Endut et al. (2017), who have shown that 12 months is the minimum persistence that allows for consistent results with those extracted from traditional monetary modelling frameworks (i.e. Bernanke and Blinder 1992; D'amico and Farka 2011; Keating et al. 2014). This guarantees that we are identifying a shock with a consistent sign i.e., a positive shock. Conversely, we could have imposed a negative restriction following a reduction in the interest rate, which is equivalent because our model is symmetric.
- We expect bank-loans to the firms to decrease after a monetary contraction, during at least twelve months. Nevertheless, in section 3.3 we carry out several robustness exercises, in which we imposed less stringent requirements on the loans behaviour.

- The effect on prices of monetary policy shocks is traditionally unconstrained as to be able to identify if there exists a price puzzle within the system (given the fact that getting rid of this puzzle is one of the original motivations for using FAVAR models). Regarding some potential restrictions on the non-borrowed reserves, we opted for not to include them because these series are extremely flat before the crisis

[5] We also attempted to identify the response of the bank loans to an interest rate shock, using a traditional Cholesky factorization, and also imposing a decreasing in the issuing of commercial papers one month after the shock, and setting free bank loans. In both cases, we were not able to identify plausible scenarios, in the sense that the estimated IRFs of traditional variables such as economic activity or prices, presented counterintuitive dynamics after the shocks. These results are available upon request.

in 2007-2008 and therefore sign restrictions would not identify any behavior supported on them.

- Finally, we set the dynamics of the series of commercial papers free.

The latter point allows us to identify the cause of the decrease in the bank loans that we are imposing, using the substitution effect that exists between bank loans and commercial papers. In case that we find a positive response of the commercial papers to the interest rate shock, we can identify the source of the variation as arising from the credit supply side, instead of the credit demand. On the contrary, if there is no reaction in the commercial papers series (or the reaction is negative), there will be no evidence to support the credit supply channel from the data.

2.3. Data

In our baseline estimations we use monthly data from January 2001 to April 2016 for a total of 183 observations, the largest time span available for the commercial papers series on a monthly basis from our data source. Then, we split our sample into two periods. The first period accounts for 82 observations (January 2001- October 2007), and the second accounts for 101 (November 2007- April 2016). We used 99 series in the construction of our unobservable factors (including the FED interest rate, volume of issued commercial papers, commercial and industrial loans by banks). A detailed description of the series and the transformations applied to each before attaining stationarity is provided in Table 3 of the Appendix. All data were obtained (seasonally adjusted, when required) from the web page of the Federal Reserve of Saint Louis (FRED).

Given our data, we have that $\boldsymbol{Y_t}$ consists of the variables: new issuing of commercial papers, the FED funds interest rate, and the bank loans. On its side $\widehat{\boldsymbol{F}}_{\boldsymbol{t}}$ consists of five estimated factors (unobservable in nature), which account for the 42.87% of the variance of the system (99 variables). As follows

$$\boldsymbol{Y_t} = \{Commercial\ Papers, Federal\ Funds\ Rate, Loans\}$$

$$\widehat{\boldsymbol{F}}_t = \{factor\ 1, factor\ 2, factor\ 3, factor\ 4, factor\ 5\}$$

3. Results and Discussion

3.1. Factors

We use an information criterion (IC) proposed by Bai and Ng (2002) to determine the number of unobservable factors. In particular, we use the criterion given by

$$IC(K) = ln\big(S(K)\big) + K\ g(N,T), \tag{4}$$

where $S(K) = (NT)^{-1} \sum_{i=1}^{N} \sum_{t=1}^{T} \left(x_{it} - \lambda_i^{K\prime} \hat{F}_t^K \ - \lambda_i^M {Y_t}^M\right)^2$ is the prediction error divided by NT. K is the number of factors, $g(N,T)$ is a loss function such that $g(N,T) = \frac{N+T}{NT} ln\left(\frac{NT}{N+T}\right)$ and $\lambda_i^K,\ \lambda_i^M$ are the factor loadings[6] estimated via principal components. The number of factors is set according to:

$$\widehat{K_{IC}} = \underset{0 \leq K \leq K_{max}}{argmin} IC(K), \tag{5}$$

6 We asume that the full set of variables in the FAVAR X_t is related to the factors as follows: $X_t = \Lambda^f \boldsymbol{F_t} + \Lambda^y \boldsymbol{Y_t} + e_t$, where Λ^f is an N x K matrix of unobservable factor loadings that contains the loadings λ_i^K and Λ^y is an N x M observable matrix of factor loadings.

where K_{max} is the maximum allowed number of factors. We set the maximum number of factors equal to 16.

According to the criterion above, the number of optimal unobservable factors in our model is five and consists of 3 lags[7] (Figure 1). These five factors explain 42.87% of the total variation in the system, which is clearly a high proportion (the expected explained variance by five random factors is only above 5.05%). Thus, five factors certainly reduce the dimension of the problem while preserving a high variation within the model.

----Insert Figure 1----

We calculate the Pearson's correlation coefficient between the first five factors and some macroeconomic variables to gain intuition about what they represent. This is an informal analysis, included to motivate possible interpretations of our empirical factors, which are used here mainly as a control for possible confounding dynamics, otherwise absent from the model. The highest correlations (in absolute values) in each case are presented in Table 1. As can be seen, the first and the fourth factors are related to industrial and production activities in the economy as well as consumption. Factors 3 and 5 capture the dynamics of interest rates, and Factor 2 reflects general price dynamics in the economy.

----Insert Table 1----

[7] This is the minimal order for which the residuals are uncorrelated in time.

Finally, each factor is plotted in Figure 2. We also trace the dynamics of Factor 1 against an industrial production index in Figure 3, as an argument in favour of interpreting this factor as an indicator of ‘economic activity’.[8]

----Insert Figure 2----

----Insert Figure 3----

3.2. Impulse response functions

We use sign restrictions to construct theoretical impulse-response functions, as explained before. We drew from 75,000 simulations, 75,000 $\widetilde{\boldsymbol{B}}$-matrices that represent different theoretical models. Then, we chose according to our restrictions a subset of IRFs. Our restrictions allow us to study the dynamics of the system after facing a positive shock to the interest rate[9], alongside a reduction in bank loans. That is, Figures 4 to 9 show the dynamics of the Fed funds rate, bank loans, the economic activity factor, the interest rate factor, the price factor, and the series of commercial papers, after a positive shock to the interest rate. We report the median of the selected IRFs, and the percentiles 86th and 14th. We plot only the responses for the period January 2001 to April 2016. In the next sub-section, we also report the IRFs associated with the commercial papers for two subsamples (2001-2007 and 2007-2016).

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[8] We also estimate our model using subsets of variables seeking to identify each factor directly, instead of recovering them from the whole data set. All the qualitative results reported in what follows remain and they are available upon request.

[9] The shocks are symmetric, so it makes no difference in the argument to instead claim a reduction in the market interest rate.

In general lines, we document expected negative effects in terms of economic activity, negative effects on prices[10] and positive effects on the market interest rate after an increment on the reference interest rate. We also can observe a positive effect on the issuing of commercial papers three months after the shock. This can be interpreted as evidence in favour of the operation of the credit channel during the sample period. Our main results are robust to using the median target approach by Fry and Pagan (2011). That is, a positive response of the commercial papers series is recorded 3-4 months after the shock.

----Insert Figure 4----

----Insert Figure 5----

----Insert Figure 6----

----Insert Figure 7----

----Insert Figure 8----

----Insert Figure 9----

3.3. Robustness

Figures 4 to 9 summarize our main results. Nevertheless, they are subject to potential criticisms regarding the sample used in the estimation, the horizon at which the sign restrictions are imposed, or the proxy used to measure the monetary policy stance.

[10] We have rotated the sing of the IRF associated to the price factor to present the results in a more intuitive fashion. Note that factor is identified up to a column sign rotation and in our case, it presents a negative correlation with the price series

Regarding the sample, one could claim that it is not feasible to identify an increment in the interest rate followed by increments in the next 12 months on the same variable, near the ZLB. This could lead to disregarding some IRFs that might potentially agree with the credit supply channel. For this reason, we constructed the IRFs of the commercial papers using information from January 2001 to October 2007 to avoid the ZLB in our estimations. We estimate the IRFs using the remaining sample period from November 2007 to April 2016 for the sake of completeness.

We also perform an informative analysis changing the horizons at which we impose the sign restrictions on the whole sample and on the two subsamples. We do so because one could claim that, for instance, a sign restriction that forces bank loans to decrease in the same month that the interest rate increases is a very stringent requirement. We acknowledge this situation, which could be related to a possible delay in the reaction of bank loans to a change in the interest rate. Consistently, we estimate IRFs using different horizons for the sign restrictions. In particular, we impose the restriction over the bank loans IRFs: i) from the third to the sixth month, ii) from the sixth to the ninth month, and iii) from the third to the ninth month. We assume in all the cases above that an interest rate increment is followed by a change with the same sign on their own lagged dynamics for 12 months. We also relax the last requirement allowing for restrictions on the bank loans and the interest rate to operate during the same time span, specifically, at months: i) from zero to three, ii) from zero to six and, iii) from zero to twelve. All the combinations are reported in Table 2, alongside the number of structural IRFs that we were able to identify in each case. The IRFs' commercial papers are plotted in Figures 10, 11 and 12.

----Insert Table 2----

----Insert Figure 10----

----Insert Figure 11----

----Insert Figure 12----

As can be observed, our main conclusions hold in any case. For the pre-crisis sample, there are restriction sets that lead to identify a positive peak on the IRFs of commercial papers around month 4[11] after the shock, which may be interpreted as evidence in favour of the existence of the credit supply channel. However, in all the cases when this peak is found (restriction from the 1st to 6th, 3rd to 6th months and 3rd to 9th), there is also a negative peak in the function around the fifth month after the shock. This negative peak can be associated to a reduction in the use of external debt as a funding mechanism in favour of new shares issuing.

We would like to emphasize on the fact that in the second part of our sample (2007-2016), although it is possible to identify some scenarios for which an increment in the interest rates is followed by a reduction in bank loans, those are very few (less than 10% in all the cases, and between 7 and 16 IRFs in the vast majority of cases). That is, bank loans do not tend to decrease after an increment in the interest rate, neither as a consequence of the credit channel nor due to any other channel through aggregate demand.

We also attempted to recover the structural IRFs by directly imposing a restriction on the commercial papers. That is, we impose the restriction that after a positive shock to the Fed

[11] Our results are robust to reducing the number of factors to two factors (this increasing the degrees of freedom), in the pre-ZLB and post-ZLB sample periods.

funds rate, commercial papers series must increase, and we leave unconstrained the dynamics of bank loans (we use several horizons for the restrictions). Nevertheless, we were not able to recover any structural IRF with the required characteristics. We do not report the results here, but those confirm our previous results. In this case, there are not theoretical scenarios that agree with both, an increment in the interest rate *and* an increase in commercial papers, which can be recovered from the data.

As an additional robustness exercise, we estimated the IRFs associated to a traditional VAR model (without factors) and we compared them with the functions derived from our FAVAR specification. The main results are summarized in Figures 13 and 14. As can be observed in the former figure, after a positive shock to the interest rate, the FAVAR model is able to generate responses with the expected theoretical signs and persistence. That is, after a positive shock to the interest rate, the economic activity factor decreases for around six months, while the price factor decreases in the two following years. On the contrary, the traditional VAR specification portrays an increment in production and a negative response of prices (which has the correct sign but lacks persistence), after the increment in the interest rate has occurred.

----Insert Figure 13----

----Insert Figure 14----

Regarding the credit channel variables, in figure 14 we observe that surprisingly the responses of commercial papers and loans to the interest rate shock are similar independently of the model employed. Nevertheless, the estimations from the FAVAR model are smoother and display higher persistence than those arising from the VAR model.

The FAVAR with sign restrictions model also incorporates into the modeling framework the “model uncertainty” inherent to the identification assumptions. It also allows to incorporate in the system information that otherwise would be intractable (Bernanke, 2005). For these reason, we rely on the estimations of the FAVAR framework instead of the VAR model.

Finally, the evidence documented above is also robust to change the monetary policy variable in our estimations by and alternative indicator proposed by Wu and Xia (2016). Those authors construct a shadow interest rate, using a dynamic factor model, which has two advantages over the traditional interest rate used in our baseline exercise. Namely, the shadow interest rate considers a richer information set when approaching monetary policy conditions and, this rate presents a greater variability after 2008 compared to the traditional FED’s rate. In this case, once again, we were not able to recover IRFs that fit our theoretical sign restrictions after the crisis period. We do not report these results here, but they are available upon request.

3.4. Discussion

We report two main findings: first, after the crisis, in the vicinity of the ZLB of the interest rate, it is very difficult to construct hypothetical theoretical scenarios in which an increment (or conversely, a decrease) in the interest rate is followed by a reduction (increment) in the series of banks loans. This result evidences a lack of effectiveness of the monetary policy through bank lending activities both because of a possible change in the credit supply or due to a variation in the aggregate demand (and consequently, in the credit demand). This is a general result, which casts doubts about the effectiveness of the monetary policy in stimulating real private investment during crisis periods and in inducing the apparition of new credit funds provided by banks to this end.

Second, when these sorts of hypothetical scenarios can be isolated (mainly before the crisis and in the entire sample), we document some evidence on the existence of the credit supply channel. That is, commercial papers react positively to changes of the interest rate three months after the interest rate shock.

This result is in line with some previous studies in the literature such as the study of Apergis and Cristou (2015) that uses quantile regressions and document ineffectiveness of the monetary policy during recession episodes, when the nominal interest rates are close to the ZLB. It is also related to the group of studies referenced in the introduction, which provide evidence against the credit channel of the monetary policy in recent times as part of a long-term trend in the US economic dynamics (Vera 2012; Adams-Kane et al. 2015; Endut et al. 2017; Olmo and Sanso-Navarro 2015).

Moreover, related conclusions by Dave et al. (2013), in favor of the existence of the credit supply channel of the monetary policy, are supported on an analysis of the aggregate bank loan dynamics, after a monetary policy shock has occurred. As was mentioned before, analyzing the aggregate dynamics of the bank loans presents the drawback of blending the responses due to the "supply" and the "demand" sides of the narrative. That is, after a contractionary monetary policy shock, a decrease of the aggregate demand is expected, following the traditional interest rate channel. This in turn may be followed by a reduction of new credit demand for consumption or investment. Nevertheless, the credit channel of the monetary policy refers to the supply side of the narrative, and for this reason it is necessary to isolate the variation due only to supply-side considerations. We do so using sign-restrictions with respect to a substitutive good of bank loans, namely the issuing of commercial papers. Our identification assumption drives our results as to conclude that the credit supply channel operates during the sample period but does not operate during crisis period.

Conclusions

We find evidence on the existence of the credit supply channel of monetary policy for the US economy in our sample (from January 2001 to April 2016). This result holds under alternative identification schemes, but does not hold during crisis episodes.

We added to the literature that uses aggregated series to identify the credit supply decisions by banks following a change in the interest rate. Our empirical strategy blends FAVAR models with sign restrictions, which is new to the literature regarding the credit channel, and this enables us to control for model uncertainty (in the structural identification setting) and for omitting variables, simultaneously. This addresses some critics about possible confounding dynamics that could emerge in the process of identifying credit supply decisions and allows us to isolate the credit supply channel from other channels acting through the credit demand.

We acknowledge the point made by Peek and Rosengren (2012) in the sense that an aggregated answer should be complemented by a more micro-oriented answer. Nevertheless, the aggregated answer is worthwhile on its own right because it considers other possible confounding dynamics though the factor structures, which are not considered in the micro setting (represented by factors, related to prices, economic activity, interest rates and so on). It also considers the aggregation effect of the individual banks responses, which is poorly addressed in more micro-oriented settings.

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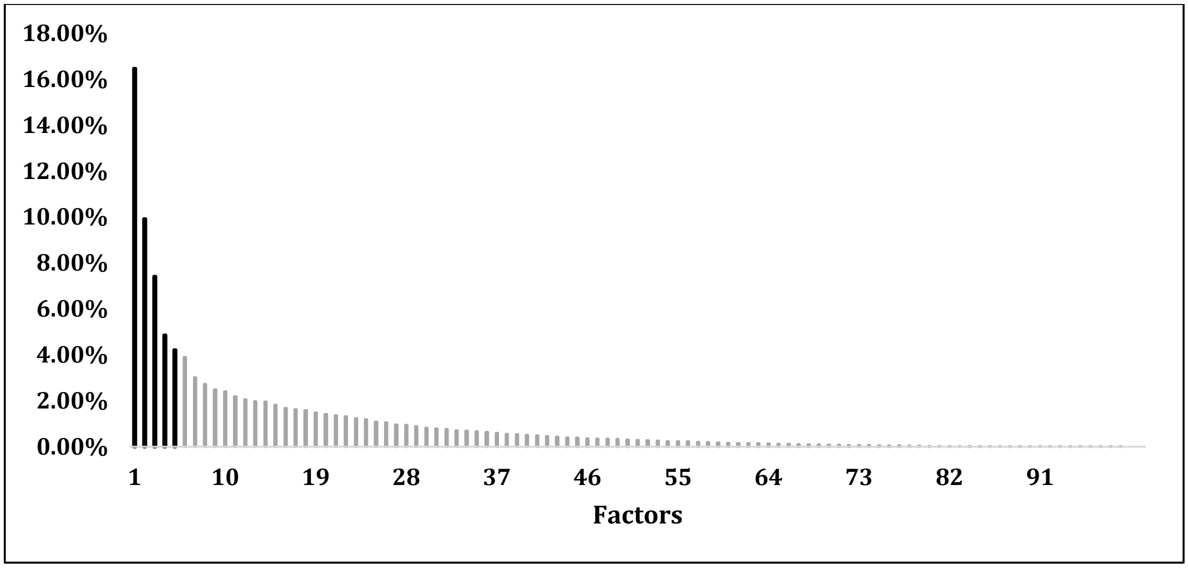
Appendix

Fig. 1 Percentage of variance explained by the 99 principal components



Note: The percentage of explained variance in the system is plotted against the k-th principal components. The number of optimal factors to include in the model is five, following the AIC criterion. The black bars correspond to the total of variance explained by the first five factors (42.87%).

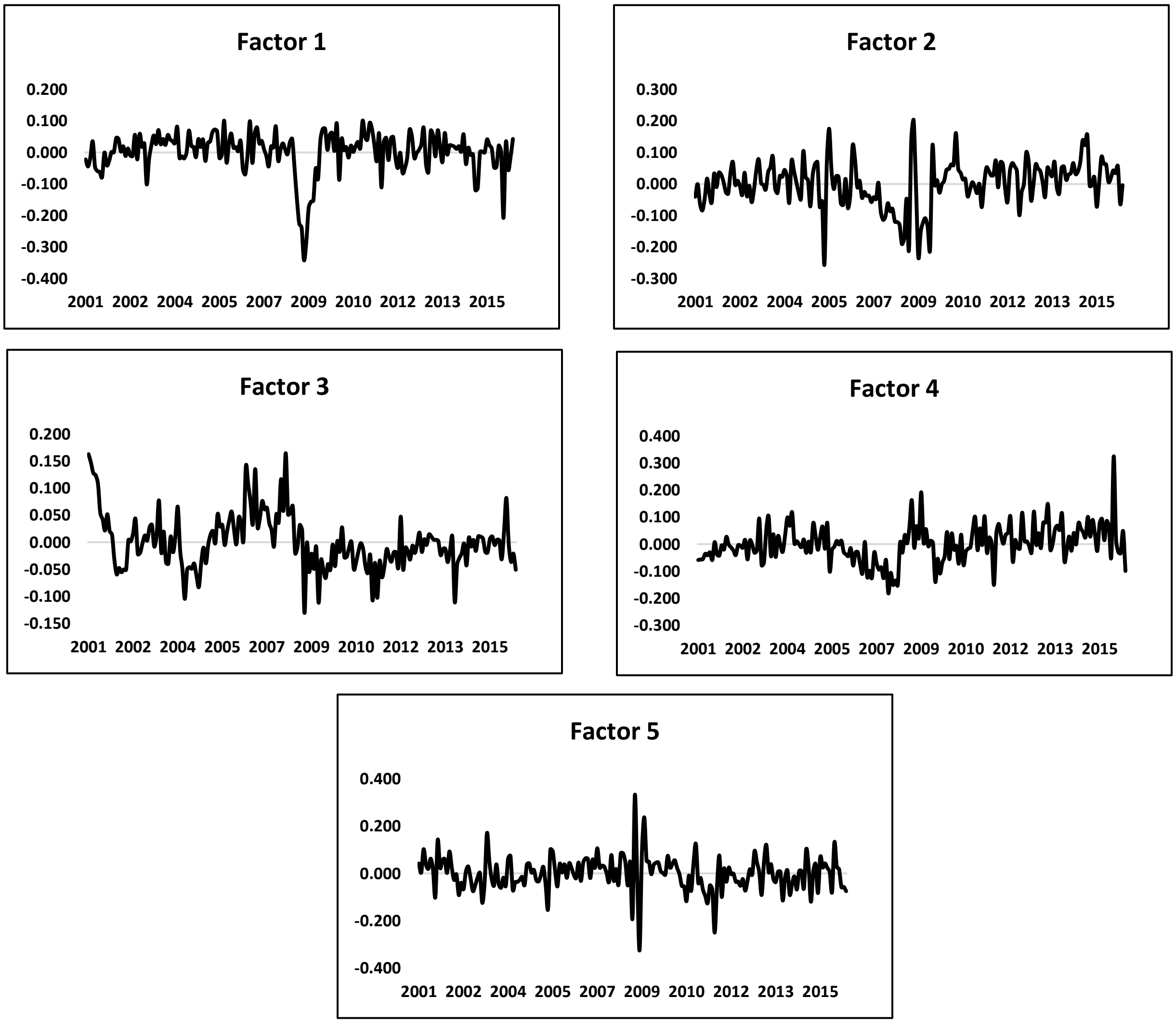
Table 1. Correlation between factors and macroeconomic variables

Factor 1	Correlation
Producer Price Index: Intermediate Materials	0.71
Industrial Production Index: Durable Materials	0.70
Personal Consume Expenditures	0.69
Consumer Price Index: All items less Food	0.66
Industrial Production Index: Manufacturing	0.66
Consumer Price Index	0.66
Factor 2	**Correlation**
Personal Consume Expenditures Deflactor: Non-Durable	-0.68
Consumer Price Index: Commodities	-0.68
Consumer Price Index	-0.68
Consumer Price Index: All items less Medical Care	-0.67
Consumer Price Index: All items less Food	-0.67

Consumer Price Index: Transportation	-0.65
Factor 3	**Correlation**
Spread: 6 Months Tresasury Bonds – Federal Funds Rate	-0.69
Spread: 1 Year Tresasury Bonds – Federal Funds Rate	-0.68
Spread: 10 Years Tresasury Bonds – Federal Funds Rate	-0.67
Spread: 5 Years Tresasury Bonds – Federal Funds Rate	-0.66
Spread: Aaa Bonds– Federal Funds Rate	-0.71
Spread: 3 Months Tresasury Bonds – Federal Funds Rate	-0.71
Factor 4	**Correlation**
Industrial Production Index: Final Production	-0.48
Industrial Production Index: Manufacturing	-0.42
Industrial Production Index	-0.41
Capacity Utilization	-0.41
1 Year Tresasury Bonds Rate	0.46
5 Year Tresasury Bonds Rate	0.44
Factor 5	**Correlation**
10 Year Tresasury Bonds Rate	0.66
Bond Yield: Moody's Aaa Corporate	0.65
5 Year Tresasury Bonds Rate	0.60
Bond Yield: Moody's Baa Corporate	0.59
Industrial Production Index: Non-Durable Materials	0.46
1 Year Tresasury Bonds Rate	-0.46

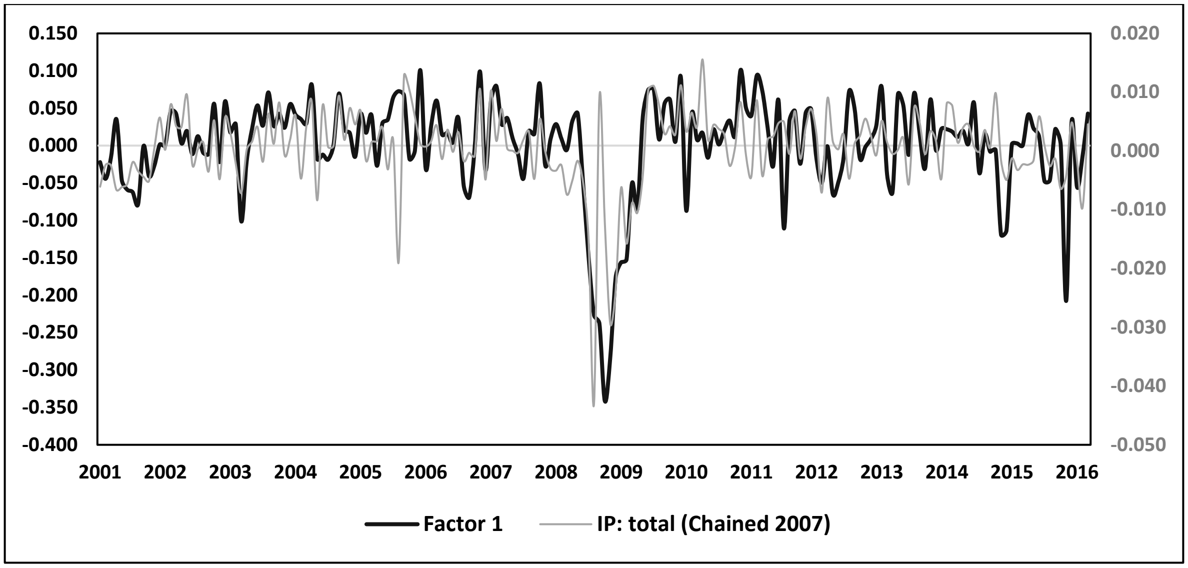
Note: Highest correlations between the factors in our model and some macroeconomics variables. Factors 1 and 4 are more related to industrial and production activities; Factors 3 and 5 to interest rates; and Factor 2 appears to capture the general price dynamics in the economy.

Fig. 2 Factors 2001-2016



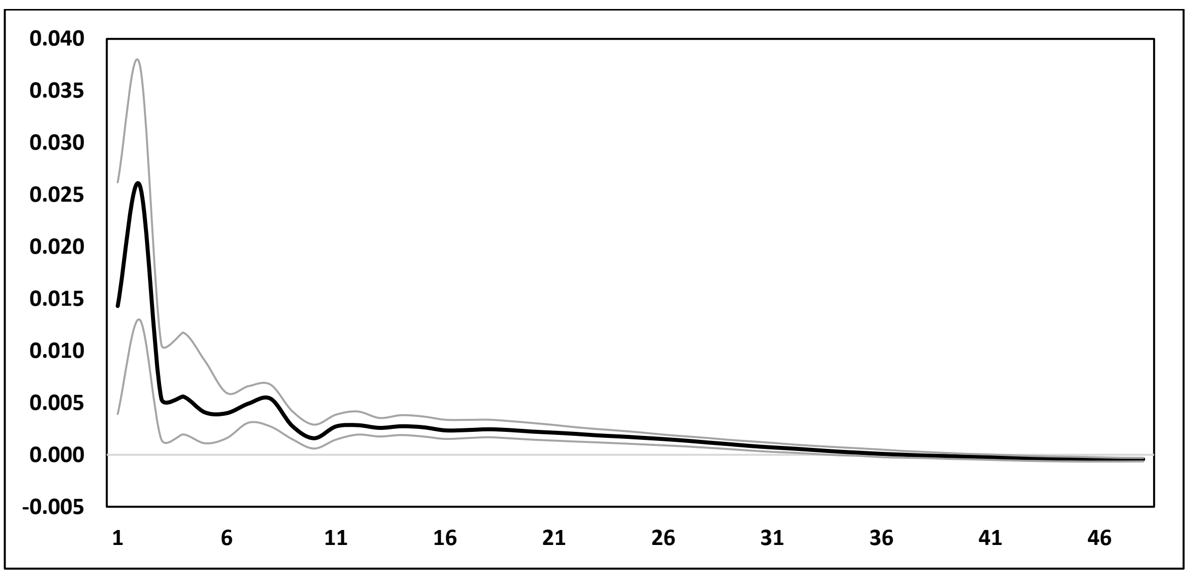
Note: Factors included in our FAVAR. Factors 1 and 4 are related to production and consumption, while Factors 3 and 5 are related to interest rates, and Factor 2 is related to prices.

Fig. 3 Industrial production index and factor 1 (economic activity)



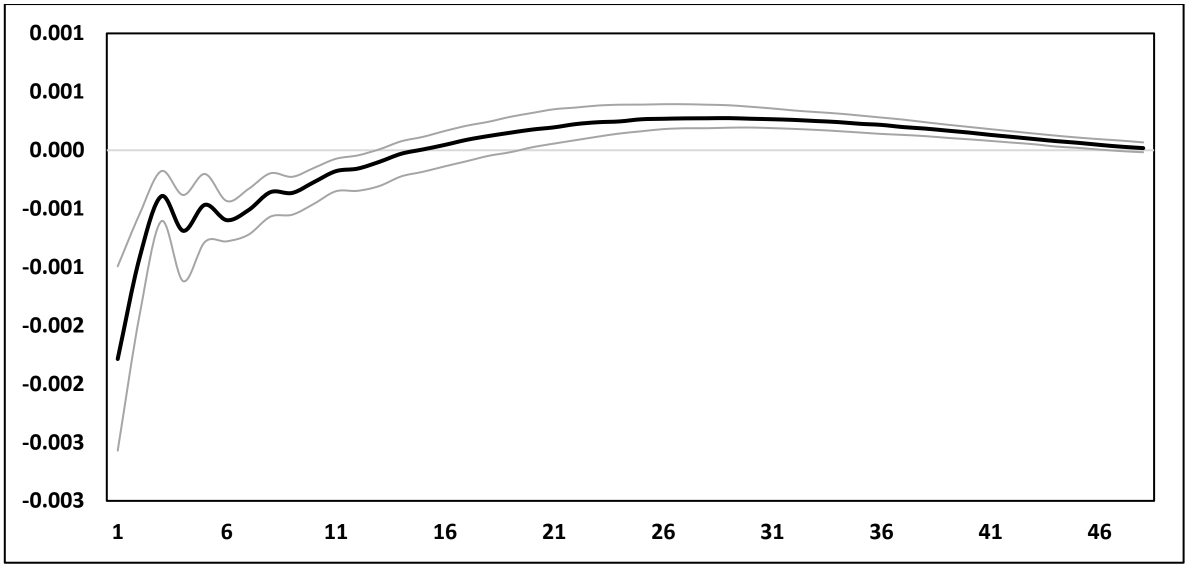
Note: The plot illustrates the remarkable similar paths during the sample period of Factor 1 and an Industrial production Index.

Fig. 4 Response of the federal funds rate to a contractionary monetary shock



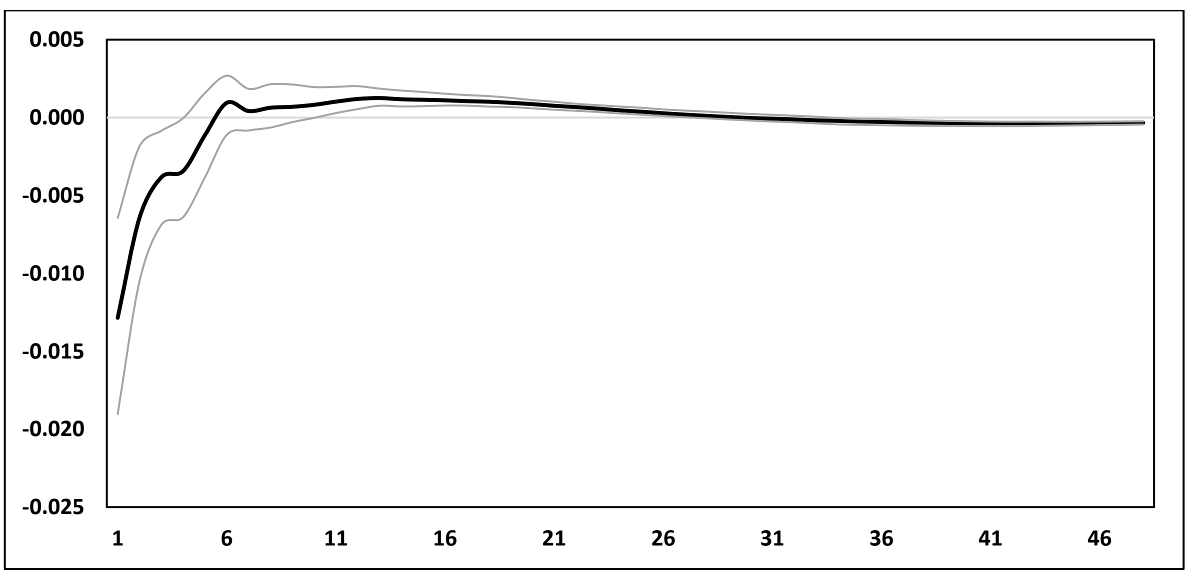
Note: The black line is the median of the identified IRFs, following a positive shock to the interest rates. The grey lines are credibility bands of the IRF at the 84th and 16th percentiles. The IRFs were calculated using the full sample from 2001 to 2016.

Fig. 5 Response of the bank-loans to a contractionary monetary shock



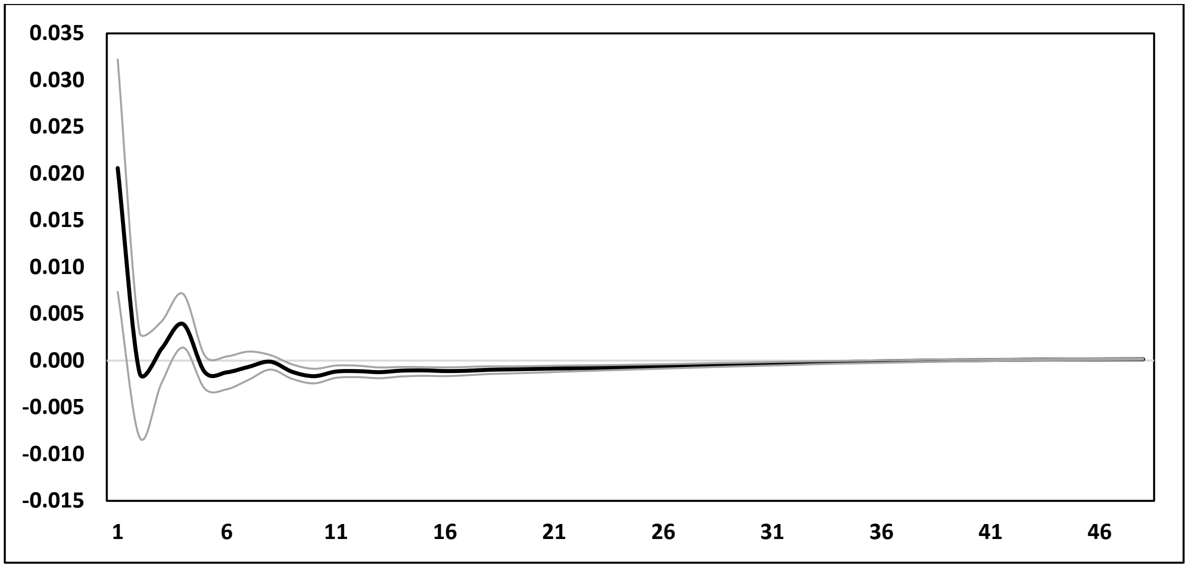
Note: The black line is the median of the identified IRFs, following a positive shock to the interest rates. The grey lines are credibility bands of the IRF at the 84th and 16th percentiles. The IRFs were calculated using the full sample from 2001 to 2016.

Fig. 6 Response of factor 1 (economic activity) to a contractionary monetary shock



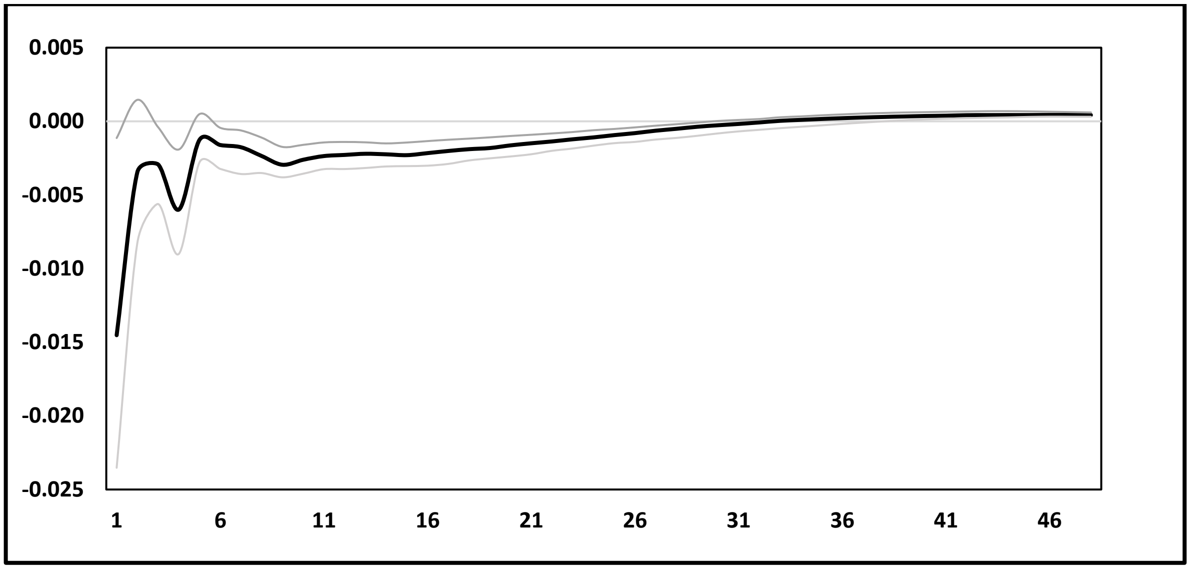
Note: The black line is the median of the identified IRFs, following a positive shock to the interest rates. The grey lines are credibility bands of the IRF at the 84th and 16th percentiles. The IRFs were calculated using the full sample from 2001 to 2016.

Fig. 7 Response of factor 5 (interest rates) to a contractionary monetary shock



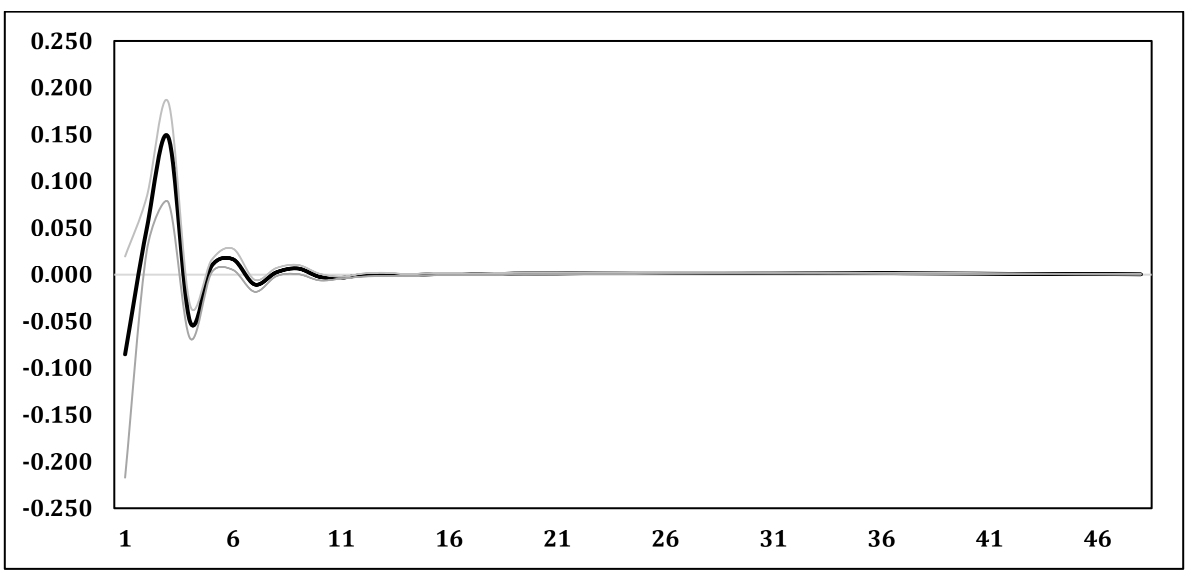
Note: The black line is the median of the identified IRFs, following a positive shock to the interest rates. The grey lines are credibility bands of the IRF at the 84th and 16th percentiles. The IRFs were calculated using the full sample from 2001 to 2016.

Fig. 8 Response of factor 2 (Prices) to a contractionary monetary shock



Note: The black line is the median of the identified IRFs, following a positive shock to the interest rates. The grey lines are credibility bands of the IRF at the 84th and 16th percentiles. The IRFs were calculated using the full sample from 2001 to 2016.

Fig. 9 Response of the commercial papers series to a contractionary monetary policy shock



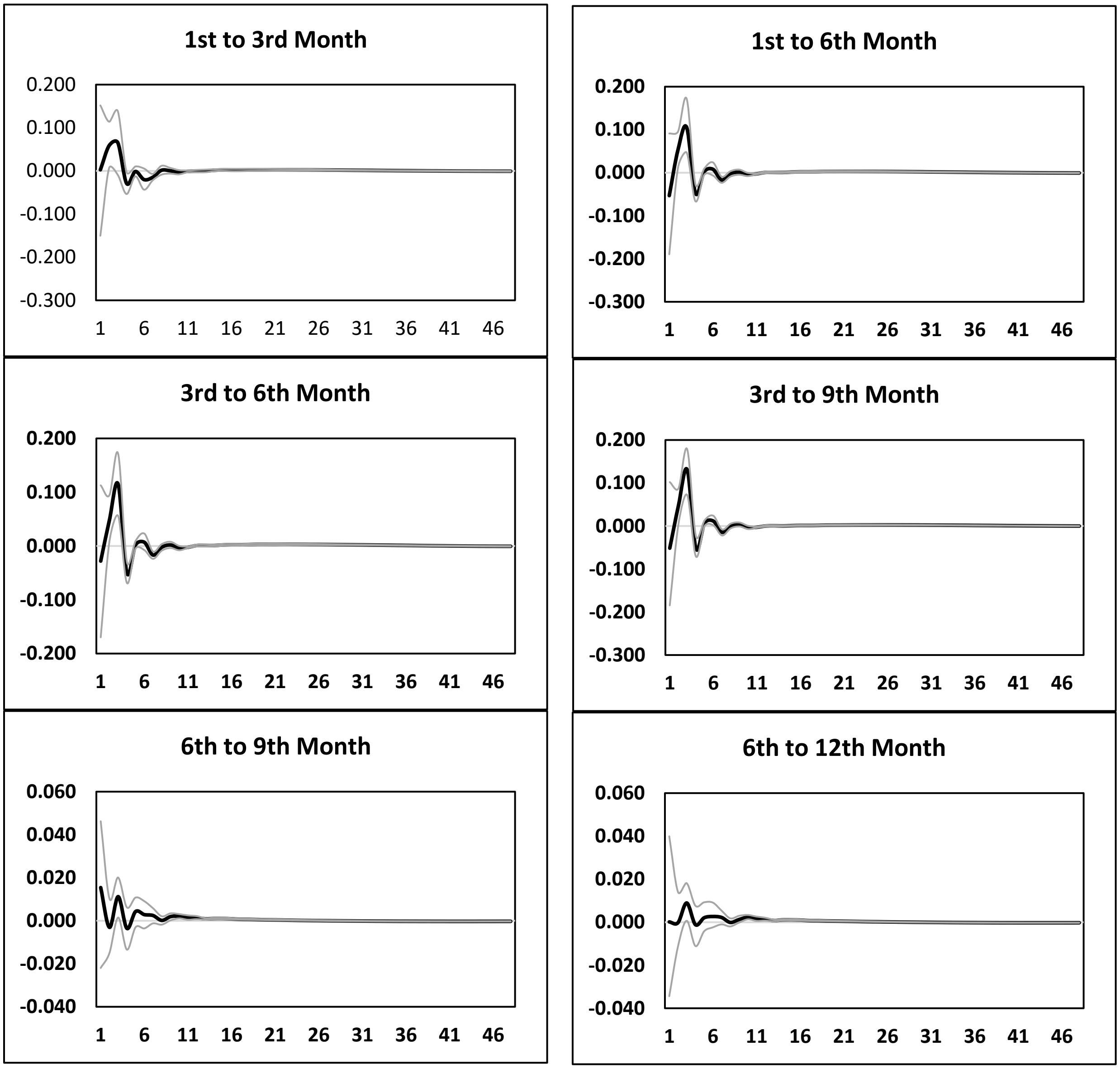
Note: The black line is the median of the identified IRFs, following a positive shock to the interest rates. The grey lines are credibility bands of the IRF at the 84^{th} and 16^{th} percentiles. The IRFs were calculated using the full sample from 2001 to 2016.

Table 2. Number of identified IRFs for each scenario, regarding horizon restrictions and sample period, with 75,000 rotations

Restriction Over Bank Loans	Restriction Over Fed Funds Rate	2001-2007	2007-2016	2001-2016
1 to 3 months	1 to 3 months	2,802 IRFs	5,083 IRFs	3,189 IRFs
1 to 6 months	1 to 6 months	518 IRFs	81 IRFs	657 IRFs
1 to 12 months (Base Scenario)	**1 to 12 months**	**232 IRFs**	**3 IRF**	**98 IRFs**
3 to 6 months	1 to 12 months	513 IRFs	16 IRF	550 IRFs
3 to 9 months	1 to 12 months	362 IRFs	7 IRF	202 IRFs
6 to 9 months	1 to 12 months	502 IRFs	15 IRFs	234 IRFs
6 to 12 months	1 to 12 months	305 IRFs	11 IRFs	103 IRFs

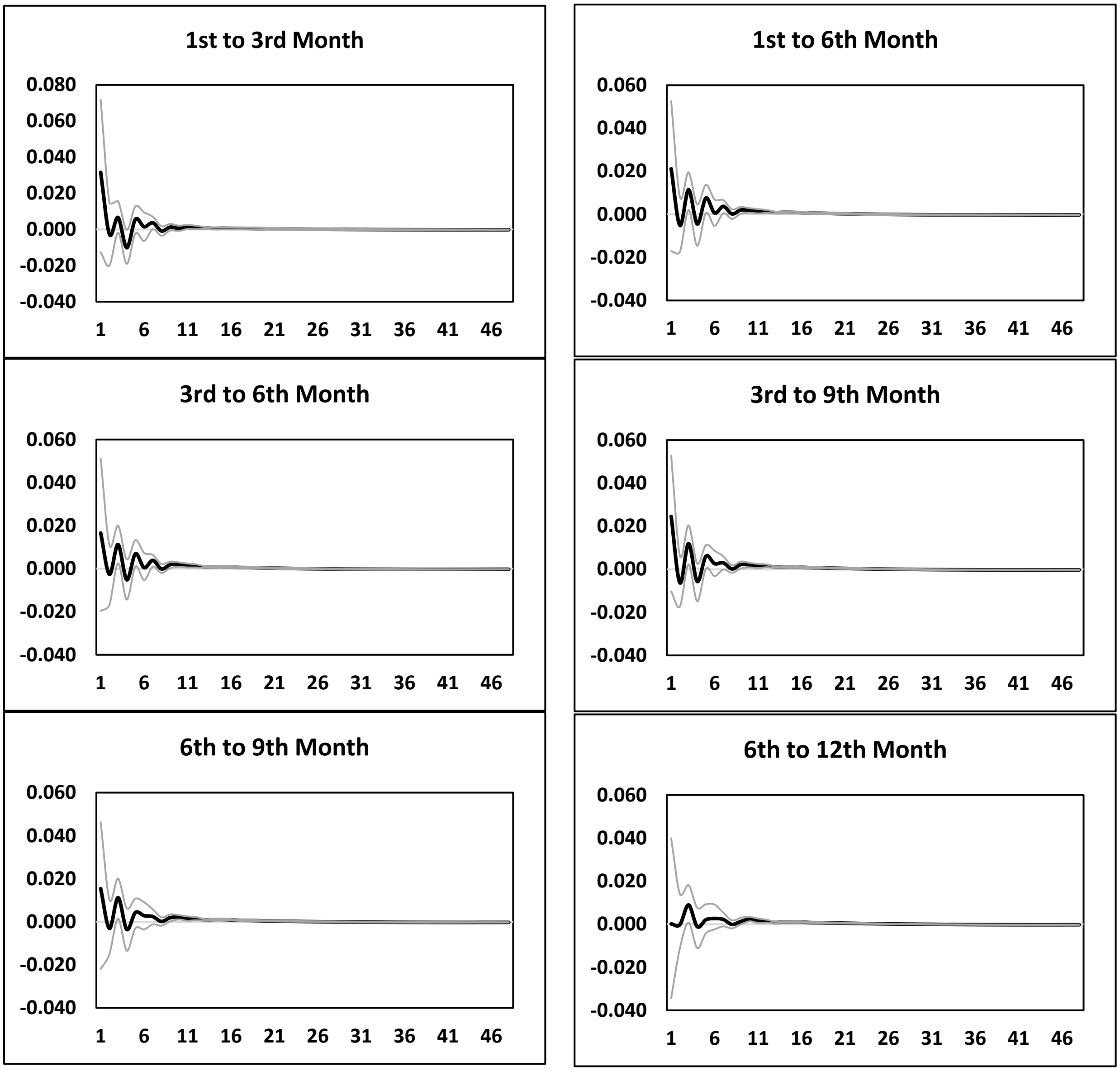
Note: In the first two columns, there is the number of periods for which the sign restrictions hold in each scenario. In columns 3 to 5, we report the number of IRFs that satisfy the restrictions in each case.

Fig. 10 Commercial papers' IRFs: 2001-2016



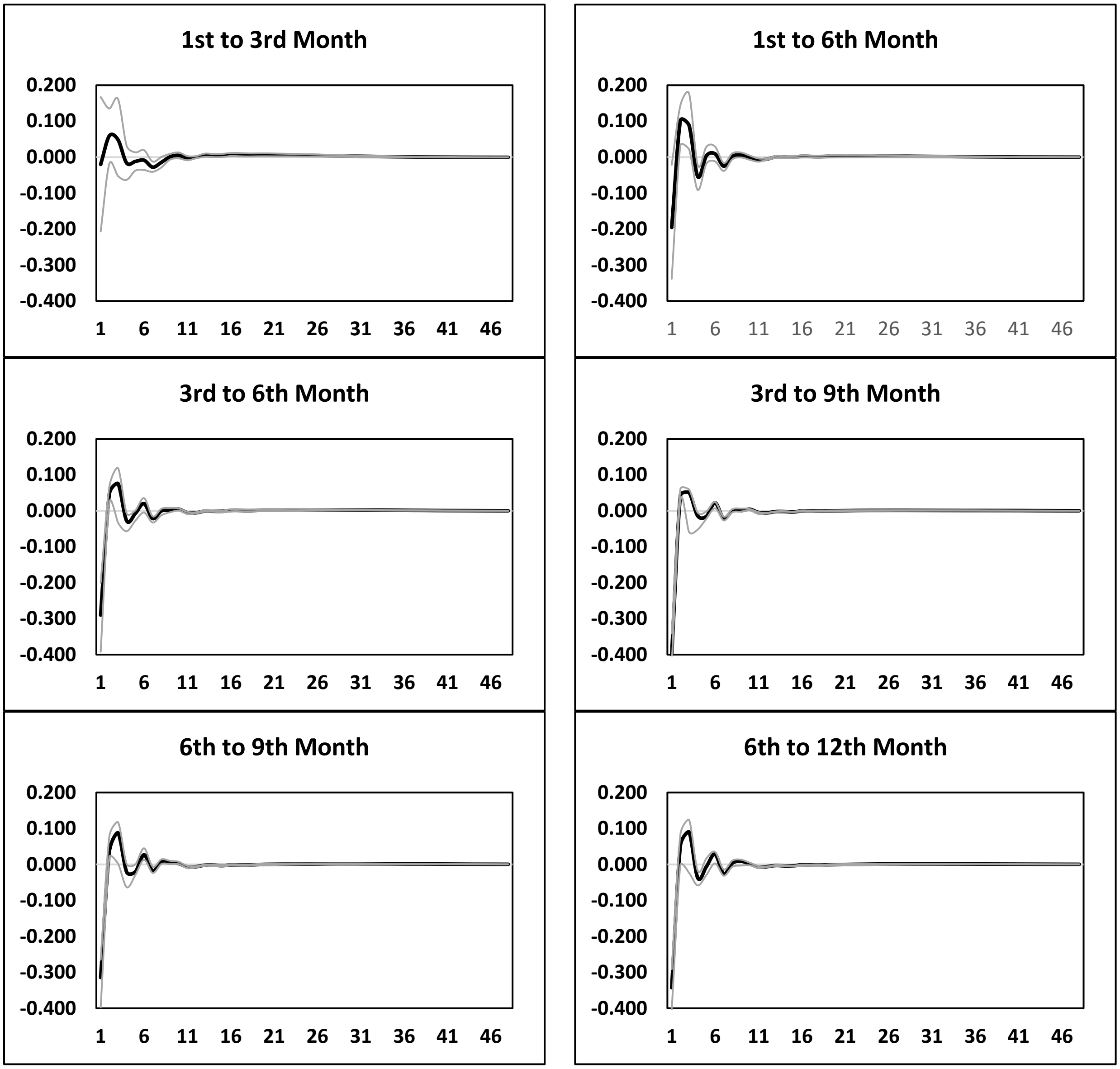
Note: The black line in each sub-plot is the median of the identified IRFs, following a positive shock to the interest rates. The grey lines are credibility bands of the IRF at the 84th and 16th percentiles.

Fig. 11 Commercial papers' IRF: 2001-2007



Note: The black line in each sub-plot is the median of the identified IRFs, following a positive shock to the interest rates. The grey lines are credibility bands of the IRF at the 84th and 16th percentiles.

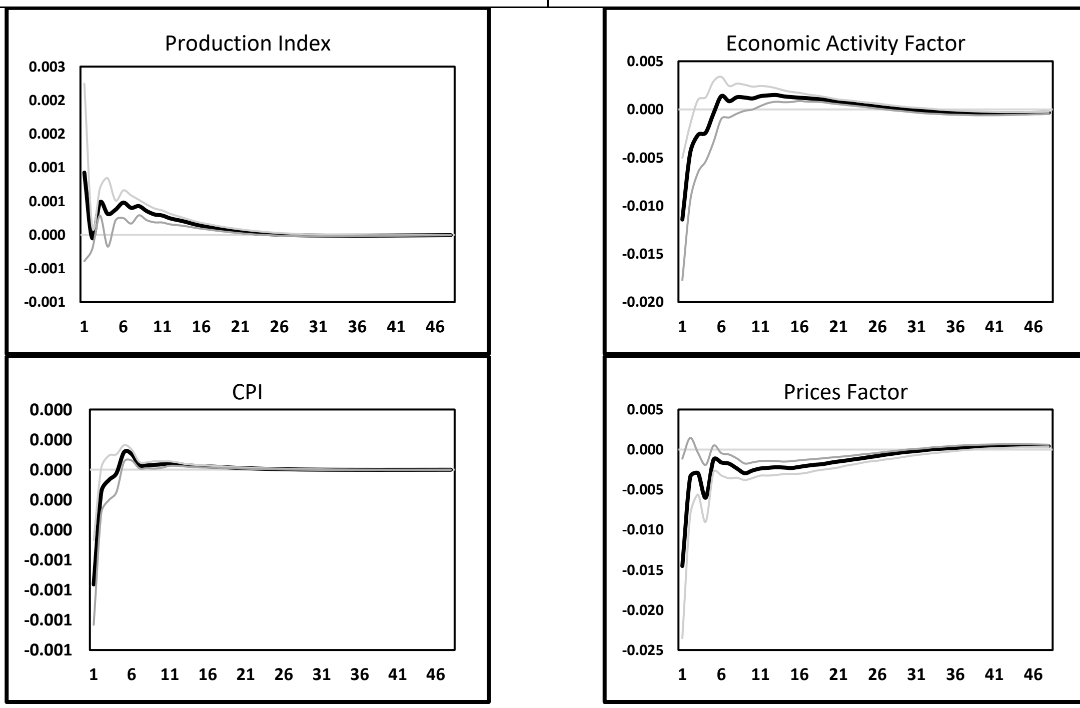
Fig. 12 Commercial papers' IRFs: 2007-2016



Note: The black line in each sub-plot is the median of the identified IRFs, following a positive shock to the interest rates. The grey lines are credibility bands of the IRF at the 84th and 16th percentiles.

Fig. 13 Response of production and prices to an interest rate shock from VAR and FAVAR models

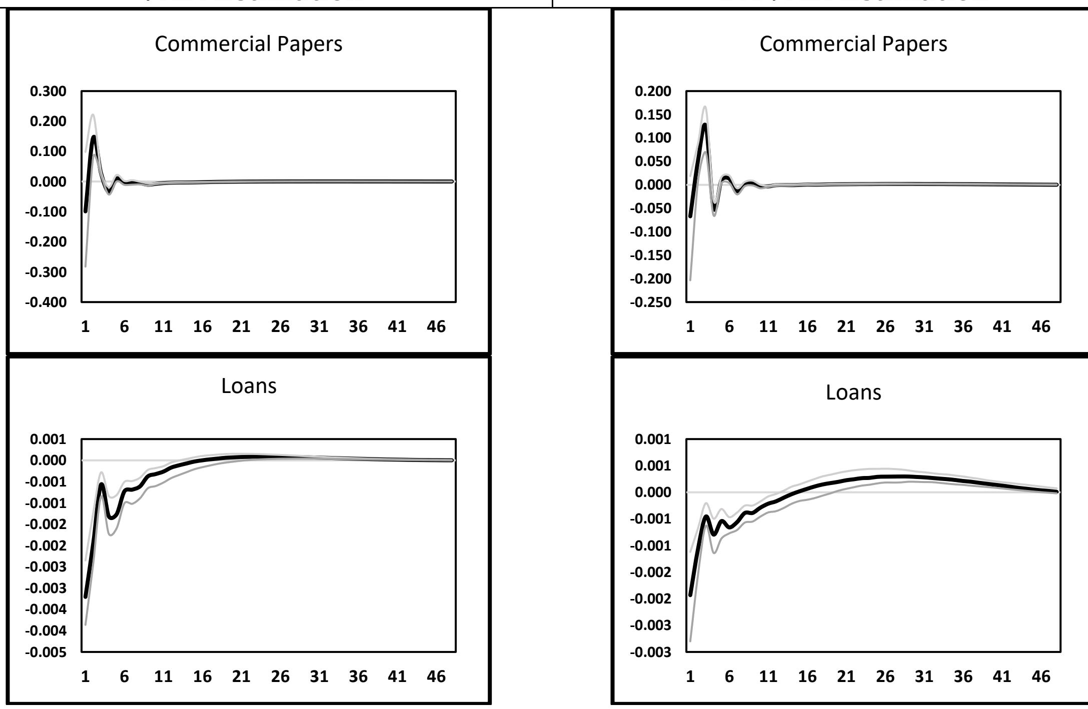
VAR Estimation	FAVAR Estimation



Note: The black line in each sub-plot is the median of the identified IRFs, following a positive shock to the interest rates. The grey lines are credibility bands of the IRF at the 84th and 16th percentiles. The responses on the left hand side correspond to a traditional VAR, while on the right hand side to our benchmark model.

Fig. 14 Response of the credit channel variables to an interest rate shock from VAR and FAVAR models

VAR Estimation	FAVAR Estimation



Note: The black line in each sub-plot is the median of the identified IRFs, following a positive shock to the interest rates. The grey lines are credibility bands of the IRF at the 84th and 16th percentiles. The responses on the left-hand side correspond to a traditional VAR, while on the right hand side to our benchmark model.

Table 3. Series and transformations to achieve stationarity

#	Variable	Conversion Method
1	Real Personal Income Chained (2009)	Growth Rate
2	Personal Income Less Transferences Chained (2009)	Growth Rate
3	Real Personal Consumption Expenditures	Growth Rate
4	Retail Sales	Growth Rate
5	Industrial Production Index-Total Index Chained (2007)	Growth Rate
6	Industrial Production Index-Consumer Goods Chained (2007)	Growth Rate
7	Industrial Production Index-Products Total Index Chained (2007)	Growth Rate
8	Industrial Production Index-Nondurable Consumer Goods Chained (2007)	Growth Rate
9	Industrial Production Index-Durable Consumer Goods Chained (2007)	Growth Rate
10	Industrial Production Index-Materials Chained (2007)	Growth Rate
11	Industrial Production Index-Business Equipment Chained (2007)	Growth Rate
12	Industrial Production Index-Durable Materials Chained (2007)	Growth Rate
13	Industrial Production Index-Manufacturing Chained (2007)	Growth Rate
14	Industrial Production Index-Nondurable Materials Chained (2007)	Growth Rate
15	Industrial Production Index-Fuels (2007)	Growth Rate
16	Leading Index	Growth Rate
17	Capacity Utilization	Growth Rate
18	Producer Price Index: Finished Goods	Growth Rate
19	Producer Price Index: Intermed Materials and Components	Growth Rate
20	Producer Price Index: Finished Consumer Goods	Growth Rate
21	Producer Price Index: Nonferrous Materials	Growth Rate
22	Producer Price Index: Crude Materials	Growth Rate
23	Consumer Price Index: All Items	Growth Rate
24	Consumer Price Index: Apparel	Growth Rate
25	Consumer Price Index: Transportation	Growth Rate
26	Consumer Price Index: Medical Care	Growth Rate
27	Consumer Price Index: Commodities	Growth Rate
28	Consumer Price Index: Durables	Growth Rate
29	Consumer Price Index: Services	Growth Rate
30	Consumer Price Index: All Items Less Shelter	Growth Rate
31	Consumer Price Index: All Items Less Food	Growth Rate
32	Consumer Price Index: All Items Less Medical Care	Growth Rate
33	Personal Consumption Expenditures Deflator	Growth Rate
34	Personal Consumption Expenditures Deflator: Nondurables	Growth Rate
35	Personal Consumption Expenditures Deflator: Services	Growth Rate

36	Commercial Papers Rate	Growth Rate
37	U.S Treasury Bills: 3 Months	Growth Rate
38	U.S Treasury Bills: 6 Months	Growth Rate
39	U.S Treasury Bills: 1 year	Growth Rate
40	U.S Treasury Bills: 5 years	Growth Rate
41	U.S Treasury Bills: 10 years	Growth Rate
42	Bond Yield: Moody's Aaa Corporate	Growth Rate
43	Bond Yield: Moody's Baa Corporate	Growth Rate
44	CP-Federal Fund Rate spread	Levels
45	3 mo-Federal Funds Rate spread	Levels
46	6 mo-Federal Funds Rate spread	Levels
47	1 yr-Federal Funds Rate spread	Levels
48	5 yr-Federal Funds Rate spread	Levels
49	10 yr-Federal Funds Rate spread	Levels
50	Aaa-Federal Funds Rate spread	Levels
51	Baa-Federal Funds Rate spread	Levels
52	Foreign Exchange Rate: Switzerland - Swiss Franc Per U.S.$	Growth Rate
53	Foreign Exchange Rate: United Kingdom- U.S.$ Per Pound	Growth Rate
54	Foreign Exchange Rate: Japan - Yen Per U.S.$	Growth Rate
55	Foreign Exchange Rate: Canada - Canadian $ Per U.S.$	Growth Rate
56	Commercial Papers Issues	Growth Rate
57	Commercial and Industrial Loans	Growth Rate
58	Manufacture's New Orders, Durable Goods Industries	Growth Rate
59	Manufacture's New Orders, Capital	Growth Rate
60	Mfrs Unfilled Orders, Capital	Growth Rate
61	Ratio, Manufacturing And Trade Inventories To Sales	Growth Rate
62	Manufacturing And Trade Sales	Growth Rate
63	Federal Funds Rate	Growth Rate
64	Housing Starts: Nonfarm	Growth Rate
65	Housing Starts: Northeast	Growth Rate
66	Housing Starts: Midwest	Growth Rate
67	Housing Starts: South	Growth Rate
68	Housing Starts: West	Growth Rate
69	Housing Authorized: Total New Private Housing Units	Growth Rate
70	Employees On Nonfarm Payrolls: Total Private	Growth Rate
71	Employees On Nonfarm Payrolls - Construction	Growth Rate
72	Employees On Nonfarm Payrolls - Manufacturing	Growth Rate
73	Employees On Nonfarm Payrolls - Trade, Transportation, And Utilities	Growth Rate

74	Employees On Nonfarm Payrolls - Financial Activities	Growth Rate
75	Average Weekly Hours of Production or Nonsup Workers Private Nonfarm - Goods-Producing	First Difference
76	Average Weekly Hours of Production or Nonsup Workers Private Nonfarm - Manufacturing	First Difference
77	Average Weekly Hours, Manufacturing	First Difference
78	Avg Hourly Earnings of Prod or Nonsup Workers Private Nonfarm - Goods Production	Growth Rate
79	Avg Hourly Earnings of Prod or Nonsup Workers Private Nonfarm - Construction	Growth Rate
80	Avg Hourly Earnings of Prod or Nonsup Workers Private Nonfarm - Manufacturing	Growth Rate
81	M1	Growth Rate
82	M2	Growth Rate
83	Currency	Growth Rate
84	M2 Real	Growth Rate
85	Monetary Base	Growth Rate
86	Depository Institutions Reserves	Growth Rate
87	Consumer Credit Outstanding	Growth Rate
88	Civilian Labor Force: Employed, Total	Growth Rate
89	Unemployment Rate: All Workers, 16 Years & Over	Growth Rate
90	Unemploy. By Duration: Average Duration In Weeks	Growth Rate
91	Unemploy By Duration: Persons Unempl Less Than 5 Weeks	Growth Rate
92	Unemploy By Duration: Persons Unempl 5 To 14 Wks	Growth Rate
93	Unemploy By Duration: Persons Unempl 15 Wks +	Growth Rate
94	Unemploy By Duration: Persons Unempl 15 To 26 Wks	Growth Rate
95	Unemploy By Duration: Persons Unempl 27 Wks +	Growth Rate
96	Initial Claims for Unemployement Insurance	Growth Rate
97	WTI	Growth Rate
98	S&P 500	Growth Rate
99	Depository Inst Reserves:Nonborrowed	Growth Rate