Identification of financial factors in economic fluctuations*

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Abstract

We estimate demand, supply, monetary, investment and financial shocks in a VAR identified with a minimum set of sign restrictions on US data. We find that financial shocks are the main drivers of fluctuations in output, stock prices and in the external finance premium but they have a very limited effect on inflation. Financial shocks imply a countercyclical response of the external finance premium that is countercyclical also to all the other shocks with the exception of the monetary policy shock.

Keywords: VAR, sign restrictions, financial shocks, external finance premium.

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1 Introduction

The recent financial crisis has revived the debate in the profession on what are the main sources of business cycle fluctuations. The Real Business Cycle (RBC) literature, see for example Kydland and Prescott (1982), has for a long time emphasized the primacy of technology shocks. The New Keynesian (NK) literature has extended the RBC set-up to include nominal and real frictions and has highlighted the role of shocks to aggregate demand. More recently, several papers have found a dominant role for shocks in the capital accumulation equation that affect the transformation process of investment into productive capital, Justiniano et al. (2010), Liu et al. (2011), Gertler and Karadi (2011).\textsuperscript{1} In the aftermath of the Great Recession the focus has shifted on shocks that are originating in the financial sector and several recent papers, both in the RBC and in the NK tradition, have found a dominant role for financial shocks, see for example Jermann and Quadrini (2012) and Cristiano et al. (2012) among others. In particular, Cristiano et al. (2012) have shown that the use of financial variables in the estimation of a model with financial frictions is crucial to identify the primacy of financial shocks and to distinguish them from more traditional investment shocks.

The objective of our paper is to quantify the importance of the disturbances discussed in the literature on Dynamic Stochastic General Equilibrium (DSGE) models (technology, demand, monetary, investment and financial shocks), and in particular the possible dominant role of financial shocks, in the context of a Vector Autoregression (VAR) identified with a minimum set of sign restrictions estimated on US data. Our approach is complementary to the DSGE approach and our restrictions are motivated by the DSGE approach. However, the advantage of using a structural VAR is that we do not have to impose the very tight cross-equation restrictions that are a defining feature of DSGE models. Therefore, our approach is more flexible, it imposes little structure on the data and, at the same time, can be used to discriminate between

\textsuperscript{1}These shocks include shocks to the marginal efficiency of investment, capital depreciation shocks and quality of capital shocks. For simplicity we label this kind of shocks as investment shocks. For a comparison, see Furlanetto and Seneca (2011).
DSGE models that have different implications for the variables that we leave unrestricted in the estimation.

Our main result is that financial shocks emerge as the main drivers of output, investment, stock prices and external finance premium. This is in line with the DSGE evidence provided by Cristiano et al. (2012) and Jermann and Quadrini (2012). Nevertheless, these shocks explain only to a very limited extent the volatility in inflation and in the interest rate that react mainly to demand, investment and monetary shocks. A suggestive interpretation for this result is that monetary policy authorities may respond mainly to inflation and, implicitly, may accord limited attention to financial disturbances that happens to be non-inflationary. This view is supported by evidence in Christiano et al. (2011) who document that inflation is low during stock market booms in historical data.

Our paper contributes to three strands of the literature. First we contribute to the large literature on the use of sign restrictions in structural VARs, (cf. Faust (1998), Uhlig (2005), Canova and De Nicolo (2002); cf. also Fry and Pagan (2011) for a critical survey on this literature). One issue with sign restrictions is the so called “multiple shocks problem”, i.e. the fact that the restrictions imposed can be potentially consistent with more than one shock. This is particularly true when only one shock is identified. In our paper we identify five shocks in the baseline case and therefore the ”multiple shocks problem” is potentially less serious. In that sense, the closest paper to our exercise is Peersman and Straub (2006) who also identify a large number of shocks to put the New Keynesian model by Smets and Wouters (2003) to a test. We differentiate from Peersman and Straub (2006) by focusing on financial shocks. Lippi and Nobili (2010) and Peersman (2005) also estimate VARs with several shocks but concentrate their attention on other disturbances.

We contribute also to the recent literature on the identification of financial shocks both in DSGE models and VAR and FAVAR models. Our definition of a financial shock is very simple and intuitive: it is a shock that generates an investment and a stock market boom. Our
restrictions are inspired by Cristiano et al. (2012) and Jermann and Quadrini (2012) but are consistent also with all estimated DSGE models with financial shocks that we have found in the literature. Other contributions on financial shocks using VAR and FAVAR models include Gilchrist et al. (2009), Gilchrist and Zakrajsek (2011), Amir Ahmadi (2009), Helbling et al. (2011), Eickmeier and Ng (2011), Eickmeier et al. (2011), Fornari and Stracca (2011), Hristov et al. (2012), Meeks (2012). Our contribution to this literature is the use of a theory based identification strategy.

Finally, we contribute to the literature on the cyclical properties of the external finance premium that we leave unrestricted in our estimation exercise (De Graeve (2008), Gelain (2010), Walentin (2005), Gelain et al. (n.d.)). We find that the external finance premium is countercyclical in response to all shocks but the monetary policy shock. We believe that our results can be useful as empirical evidence to validate DSGE models with financial frictions.

The paper is organized as follows. Section 2 describes the econometric models and discusses the identification strategy. Section 3 presents the results for the baseline version of our model. In Section 4 we present a couple of extensions to disentangle different kinds of financial shocks. In Section 5 we discuss the results on the cyclical properties of the external finance premium. Finally, Section 6 concludes.

2 The model and the identification strategy

Consider the following VAR model:

\[ y_t = C_B + \sum_{i=1}^{P} B_i y_{t-i} + u_t, \]  

where \( y_t \) is a \( N \times 1 \) vector containing all \( N \) endogenous variables, \( C_B \) is a \( N \times 1 \) vector of constants, \( B_i \) for \( i = 1, ..., P \) are \( N \times N \) parameter matrices, and \( u_t \) is the \( N \times 1 \) one-step ahead prediction error with \( u_t \sim N(0, \Sigma) \). The prediction error \( u_t \) can be written as linear
combination of structural innovations $\epsilon_t$

$$u_t = A\epsilon_t$$

with $\epsilon_t \sim N(0, I_N)$, where $I_N$ is the an $N \times N$ identity matrix and where $A$ is a non-singular parameter matrix. The variance covariance matrix has thus the following structure $\Sigma = AA'$. Given the fact that the variance covariance matrix is symmetric, $N(N-1)/2$ further restrictions are needed to derive $A$ from this relationship.

One popular way of imposing the required restrictions on $A$ is to use the Cholesky decomposition. In this identification procedure the parameter matrix $A$ is restricted to be lower triangular implying a recursive identification scheme. Although computationally very convenient, the recursive identification cannot be justified theoretically given the variables used in this paper. Any other form of exclusion restrictions applied to our system would also evoke contradictory statements. This leads us to rely on a different mapping from the reduced form innovation to the structural innovations.

To identify the structural shocks $\epsilon_t$ we impose sign restrictions on impulse responses (see, e.g. Faust (1998), Canova and De Nicolo (2002), Uhlig (2005))\textsuperscript{2}. This approach allows to identify structural shocks without any exclusion restrictions on the parameters of the model. Only information about the signs of the impulse responses is needed.

To incorporate the sign restrictions, especially given the number of variables we include and the number of shocks to be identified at the same time, we use the more efficient algorithm as described in, e.g. Rubio-Ramirez et al. (2010).

The procedure applied in this paper works as follows. In a first step we draw $A$ using the Cholesky decomposition, producing uncorrelated shocks that correspond to shocks from an exactly identified model. To form combinations of the structural shocks emanating from the recursively identified model we first perform a QR decomposition of $X = QR$, where $X$ is

\textsuperscript{2}See also Fry and Pagan (2011) for a summary of the literature on sign restrictions.
drawn from $X \sim N(0, I_N)$. Then, we generate candidate impulse responses from $AQ$ and $B_i$ for $i = 1, \ldots, P$ and check if the generated impulse responses satisfy the sign restrictions. If the sign restrictions are not satisfied we draw a new $X$ and iterate over the same procedure again until the sign restrictions are satisfied.

The following table summarizes the restrictions that we use in our VAR:

<table>
<thead>
<tr>
<th></th>
<th>Supply</th>
<th>Demand</th>
<th>Monetary</th>
<th>Investment</th>
<th>Financial</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Inflation</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Interest rate</td>
<td>NA</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Investment/Output</td>
<td>NA</td>
<td>-</td>
<td>NA</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Stock market</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

where NA means that the response of the variable is left unrestricted. Importantly, restrictions have been imposed only on impact and this is the minimum set of restrictions to achieve identification.

Restrictions to identify demand, monetary and supply shocks are standard in the literature (see, e.g. Peersman (2005) and Peersman and Straub (2006) among others) and are consistent with a simple three equation New Keynesian model. It is more tricky to separately identify demand, investment and financial shocks.

Our strategy is the following: we use data on the ratio of investment over output and we impose that demand shocks have a negative effect on investment over output (notice that investment can still increase in response to the shock, but less than the remaining part of aggregate demand) whereas investment and financial shocks have a positive effect on investment over output. This is consistent with the idea that investment and financial shocks create investment booms, in keeping with any DSGE model with a financial side we are aware of. Importantly, we interpret our demand shock as a shock that affect the other components of aggregate demand: it could be a fiscal shock, a shock to consumption (discount factor shocks
in DSGE models) or it could be a foreign shock with a positive effect on net exports).

The use of data of investment over output enables us to identify the demand shock. Still we need to disentangle investment shocks from financial shocks. To achieve this goal, we follow closely the discussion in Cristiano et al. (2012) and we use data on the stock market. Investment shocks are shock to the supply of capital and, therefore, they lower the net worth of firms (interpreted as a proxy for the stock market). Financial shocks, instead, are shocks to the demand of capital and imply a positive comovement between output and the stock market. Therefore, the investment shock has the strongly counterfactual implication that the value of equity is countercyclical. This explains why investment shocks can be the main source of fluctuations in models that do not include financial variables (as in Justiniano et al. (2010)) whereas they lose importance in models that use financial variables as observables.

To summarize, the use of simple and intuitive restrictions on investment over output and on the stock market enables us to separately identify demand, investment and financial shocks. A financial shock is a disturbance that create an investment boom and a stock market boom. This characterization of a financial shock is very general and is consistent with several disturbances labeled as ”financial shocks ” in the recent DSGE literature. This is the case for the kind of financial shocks that are usually introduced in models with a financial accelerator a la Bernanke, Gertler and Gilchrist (1999) but also for financial shocks introduced in models with collateral constraints as in Kiyotaki and Moore (1998) and Jermann and Quadrini (2012). To the best of our knowledge our restrictions are consistent with the impulse responses for financial shocks in all models (estimated or calibrated) with a financial accelerator or with collateral constraints. A partial list includes Ajello (2012), Cristiano et al. (2012), Fuentes-Albero (2013), Gilchrist and Leahy (2002), Gilchrist and Zakrajeck (2011), Gilchrist, Ortiz and Zakrajeck (2009), Jermann and Quadrini (2012), Nolan and Thoenissen (2009) and Rannenberg (2012). For the sake of generality, in the baseline version of our model we identify only one financial shock, identified as a demand shock that creates an investment boom and a stock market boom. In a couple of
extensions we refine our identification strategy to identify different kind of financial shocks by using data on credit and residential investment. Notice that our identifying assumptions are not consistent with a specific kind of financial shock (a shock to bank capital) that has been proposed by Gerali et al. (2010) in a model with frictions in the banking sector (see also Dib (2010), Meh and Moran (2010) and Rannenberg (2012) for shocks with similar properties). The shock to the bank capital moves output and inflation in different directions in all the papers listed above. Therefore, the financial shock in our VAR does not capture bank capital shocks given that our financial shock implies a positive comovement between output and prices. In our framework this kind of shock is considered as a supply shock.

The model is estimated for the US with data in levels from 1985 Q1 to 2011 Q4. The VAR includes 5 lags. The list of endogenous variables includes GDP, inflation, interest rate, investment, stock prices and the external finance premium (that we leave unrestricted in the identification strategy and that we measure as the difference between the interest rate on BAA-rated corporate bonds and the 10-year US government bond rate). The model has six shocks and five of them are identified: supply, demand, monetary, investment and financial.

3 Results

In figure 1 we plot the variance decomposition derived from our model where on the horizontal axes we have the horizon (from 1 to 10 quarters) and on the vertical axes we have the percentage in aggregate fluctuations explained by each of the five shocks. The financial shock (purple color) is the main driver of output fluctuations in the first six quarters and is the main driver of the stock market, of the external finance premium and of the investment over output ratio over the all horizon. Our VAR, therefore, confirms the results in Cristiano et al. (2012), Jermann and Quadrini (2012) and, more recently, in Ajello (2012) on the importance of shocks originating in the financial sector. Importantly, inflation is explained mainly by demand shocks and not by financial shocks: this is because financial shocks have a large effect on output but a very limited
impact on inflation as it can be seen in impulse responses on figure 2. From the same figure we can also see that our financial shock looks plausible: in fact, it implies a strong countercyclical response in the external finance premium, as we expect from theory. Notice that result is a genuine feature of the data and not an identifying assumption, given that the external finance premium is left unrestricted in the estimation procedure. ³

Figure 3 to 6 present impulse responses for demand, supply, monetary and investment shocks. Notice that the supply shock plays an important role for output fluctuations (and to some extent for stock market fluctuations) at lower frequencies. Nevertheless, the sum of the four shocks that drive output and prices in the same direction explain 80 per cent of output fluctuations at higher frequencies. Notice that all shocks play a non-negligible role for output dynamics. The partial exception is given by the demand shock that has limited importance (whereas it is the main driver of inflation). In keeping with Cristiano et al. (2012), the inclusion of financial variables in the model crowds out the investment shock that maintain, however, some explanatory power. Financial shocks and supply shocks are equally important for output fluctuations at a ten quarter horizon. However, the role of sit is important to recognize that the restrictions that we imposed to identify supply shocks are consistent with standard temporary technology shocks but also with other kind of shocks. In fact, in the DSGE literature there are shocks other than technology that drive output and inflation in different directions: this is the case for price mark-up shocks Peersman and Straub (2006), shocks to the matching efficiency Furlanetto and Groshenny (n.d.) and shocks to the bank capital, Gerali et al. (2010) as discussed in the previous section. Our supply shock is capturing also the effects of these other shocks and therefore our estimated provide a lower bound for the importance of financial shocks. Monetary shocks have a protracted positive effect on output, unlike in Uhlig (1998) but in keeping with VAR models identified with exclusion restrictions (Christiano, Eichenbaum

³The blue line in impulse responses represents the median over the draws that are consistent with our restrictions. The red line represents the median target, shown to address the criticism by Fry and Pagan (2011) to the sign restrictions approach.
and Evans (1999)), although we impose our restrictions only on impact.

A key result of our paper is the limited response of inflation to financial shocks. Christiano et al. (2011) document that inflation was relatively low in each of the 18 stock market boom episodes that occurred in the past two centuries in the US. The same is true for the Japanese stock market boom of the 1980s. Papers by Adalid and Detken (2007), Bordo and Weelock (2004 and 2007) and White (2009) also draw attention on the fact that stock market booms are period of low inflation. This can be very relevant for monetary policy: a strict inflation targeter central bank may react very little to financial shocks and may perhaps favor imbalances in other variables.

4 Disentangling financial shocks

In this section we want to better specify what a financial shock is. In particular, the DSGE literature based on models with a financial accelerator mechanism has identified two key financial shocks: a shock to the net worth and a shock to entrepreneurs riskiness (risk shocks in short) (Cristiano et al. (2012)). Importantly, models based on collateral constraints (Kiyotaki and Moore (1997) Jermann and Quadrini (2012)) are characterized by shocks to the loan-to value ratio and spread shocks that operate similarly to net worth shocks and risk shocks, respectively.

Cristiano et al. (2012) show that the two financial shocks have different implications for credit: net worth shocks imply a negative comovement between output and credit whereas risk shocks imply a positive comovement between output and credit. These restrictions are respected also in Rannenberg (2012) who combines a financial accelerator on the firm side together with one the bank side (as in Gertler and Karadi (2011)). Therefore, we use data on credit in our VAR and we identify two financial shocks: net worth shocks and risk shocks, in keeping with the terminology in Cristiano et al. (2012). The minimum set of restrictions is summarized in table 2:
<table>
<thead>
<tr>
<th></th>
<th>Supply</th>
<th>Demand</th>
<th>Monetary</th>
<th>Investment</th>
<th>Net worth</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Inflation</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Interest rate</td>
<td>NA</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Investment/Output</td>
<td>NA</td>
<td>-</td>
<td>NA</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Stock market</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Credit</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
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<td>+</td>
</tr>
</tbody>
</table>

The results from the previous section are by and large confirmed, see figure 7. The share of variance that was attributed to financial shock in the previous section is now accounted for by net worth and risk shocks. The two financial shocks explain at least 40 percent of output fluctuations at all horizons and they are still dominant drivers of investment, stock prices, external finance premium and now also credit fluctuations. It is also confirmed that inflation is affected very little by financial factors.

Importantly, we see that the risk shock happens to be somewhat more important than the net worth shock at short horizons. This is especially true for GDP and credit. At longer horizons net worth shocks are the main driver of output and credit. This is qualitatively in keeping with the DSGE analysis of (Cristiano et al. (2012)) that finds, however, a much larger role for risk shocks: in their framework net worth shocks are much less important. Notice, however, that in Cristiano et al. (2012) the risk shock has also an anticipated component which is very important. In our model the risk shock is instead fully unanticipated.

5 Implications for the external finance premium

The external finance premium is a key variable in DSGE models with financial frictions. In the data the external finance premium is countercyclical unconditionally. However, there is no consensus on the conditional response of the external finance premium to structural shocks.
De Graeve (2008) finds that the premium countercyclical in response to monetary policy shocks, procyclical in response to investment shocks and weakly countercyclical in response to technology shocks using US data. Gelain (2010) find the same results on European data. However, the presence of investment adjustment costs or capital adjustment costs matters for the sign of the response of the premium to an investment shock (cf. De Graeve (2008) Walentin (2005)). Cristiano et al. (2012) find that the premium is countercyclical in response to both financial shocks and pro-cyclical in response to investment shocks.

Given the conflicting evidence on the conditional response of the external finance premium to shocks, it is surprising that there is no convincing empirical evidence on this topic. Our paper can fill this gap since we include the external finance premium in the estimation and we leave it unrestricted. As it can be seen in figure 8, our VAR implies that the premium is procyclical in response to monetary shocks and countercyclical in response to all the other shocks. These results can be used to discriminate between different kind of DSGE models with financial frictions. As far as we know, the only estimated model that deliver a procyclical premium in response to monetary shocks is GelainRodriguezpalenzuelavilagi2011 on Euro-area data. However, it is not clear what drive this result in the model.

6 Conclusion

The use of data on the ratio of investment over output and on the stock market index allow us to separately identify demand, investment and financial shocks in a VAR with sign restrictions where we have also supply and monetary shocks. We find that financial shocks are the main driver of output, stock market and external finance premium fluctuations but play a very limited role in explaining inflation dynamics. The external finance premium responds countercyclically to all shocks but the monetary policy shock.
References


and Nicolas Groshenny, “Matching efficiency and business cycle fluctuations.”


Gerali, Andrea, Stefano Neri, Luca Sessa, and Federico M. Signoretti, “Credit and Banking in a DSGE Model of the Euro Area,” Journal of Money, Credit and Banking, 09 2010, 42 (s1), 107–141.


Figure 1: Variance Decomposition

Notes: This figure shows the variance decomposition for the six variables. The red area refers to the supply shock; the green area refers to the demand shock; the blue refers to the monetary shock; the light green area refers to the investment shock; the purple area refers to the financial shock.
Figure 2: Impulse responses: Financial shock
Figure 3: Impulse responses: Demand shock

- **GDP**
  - The response of GDP shows a peak around 5-10 periods, followed by a gradual decrease.
  - The shaded area represents the 90% confidence interval.

- **Inflation**
  - The inflation response peaks around 3-5 periods, with a significant increase.

- **Interest Rate**
  - The interest rate response shows a decrease initially, followed by a slight increase.

- **Investment/Output**
  - The investment/output ratio remains relatively stable with minor fluctuations.

- **Stock Prices**
  - Stock prices exhibit a drop initially, followed by a recovery.

- **External Finance Premium**
  - The external finance premium shows fluctuations with a slight decrease over time.

The responses indicate the dynamic effects on various economic variables following a demand shock.
Figure 4: Impulse responses: Supply shock

- GDP
- Inflation
- Interest Rate
- Investment/Output
- Stock Prices
- External Finance Premium
Figure 5: Impulse responses: Monetary shock
Figure 6: Impulse responses: Investment shock
Figure 7: Variance Decomposition, financial shock decomposition

Notes: This figure shows the variance decomposition for the seven variables. The red area refers to the supply shock; the green area refers to the demand shock; the blue refers to the monetary shock; the light green area refers to the investment shock; the purple area refers to the financial risk shock; and the grey refers to the financial net worth shock.
Figure 8: Impulse responses: External finance premium