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The credit channel during times of financial stress: A time varying VAR analysis

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Abstract

This paper investigates in the contribution of financial stress to gdp and price developments as well as in the strength of the credit channel, as part of the monetary policy transmission mechanism, especially in times of high financial stress. Therefore, a TVP VAR with stochastic volatility is estimated and a structural financial stress shock, a monetary policy shock and a productivity shock are identified by using sign restrictions. Moreover, the imposed identification relies on a monetary DSGE model with financial frictions in the form of moral hazard with bankers running away with a fraction of the assets they manage. As the estimation sample spans from 1984Q1 to 2012Q4 the implied impulse responses of the model are verified by re-simulating the model over a wide range of parameter calibrations as to account for a decline of inflation persistence and changing monetary policy as well as changes in the risk-adjusted premium and leverage ratio of the financial intermediaries over time. It is shown that structural financial stress as well as monetary policy shock are drivers of real economic activity and prices. Especially during the recent financial crisis and also in the course of the dot-com crisis financial stress has had negative impacts on gdp and prices whereas monetary policy was able to counteract declines of gdp but was not able to offset deflationary developments. The contributions to the risk-adjusted financing premium show that the credit channel in deed has been of increased importance during times of high financial stress. Thus, the paper provides evidence for the implications of recently developed DSGE models with financial frictions in the banking sector.

JEL-Classification: E44, E52, C11

Keywords: Financial stress, Monetary transmission mechanism, TVP VAR

1 Introduction

The global financial crisis that started in 2007 severely affected banks balance sheets. As the value of banks' assets decreased, so did real economic activity. Government interventions followed to rescue or resolve commercial banks and therewith transferred asset value losses from the financial to the public sector, increasing public debt and fiscal expenditures. Also, because of expansionary monetary policy efforts, interest rate spreads as well as GDP only recover slowly .

In that context, it is particularly interesting to isolate the impact of two seemingly important drivers of the events, namely financial stress on the one hand and monetary policy on the other. I aim to illustrate the contribution of financial stress to real economic activity and prices as well as the ability of monetary policy to counteract the impact of financial stress. In that analysis I rely on the accelerative mechanism of the credit channel of monetary policy that has been assumed to be particular effective within times of financial stress.

I aim to pin down the effect of a structural shock to financial intermediaries on economic activity, prices and interest rate spreads for the US economy. Moreover, I investigate in the presence of the credit channel of the monetary transmission mechanism, taking into account the evolution of financial markets and real markets as well as the episodic nature of financial stress by using a time-varying parameter vector autoregressive model (TVP VAR) with stochastic volatilities.

I add to the existing literature in two aspects. Firstly, empirical work¹ on the effect on the interplay between financial stress and real economic activity so far assumes financial stress to be an exogenous regime shifting indicator for financial crisis. In contrast, I apply structural identification based on a monetary DSGE model with financial frictions in the banking sector. Secondly, as I employ a TVP VAR with stochastic volatility I am able to capture the evolution of financial market structure and the real economy as well as possible implications for the dynamics of a financial stress and monetary policy shock.

¹Hubrich & Tetlow (2015),Cardarelli, Elekdag & Lall (2011)

The paper is organized as follows. In the second section I present a literature review. In the third section shows the empirical methodology , including the econometric model, the data and the identifying assumptions. The results will then be presented in the fourth section followed by conclusions in the fifth section.

The paper is organized as follows. In the second section we shortly present related literature. The third section outlines the dynamics of the underlying structural model and the results from the parameter-variation. The fourth section depicts the empirical methodology, including the econometric model, the identifying assumptions and the data. The results will then be presented in the fifth section followed by conclusions in the six section.

2 Related literature

The global financial crisis revived the research on financial intermediation in DSGE models. A variety of new and rethought sources of financial frictions in General Equilibrium Macroeconomic Models has recently been presented in the macroeconomic literature. For example, Curdia & Woodford (2010) introduce financial frictions in form of households with distinct impatience to consume which induce a financial intermediation function and find that extending the Taylor rule by credit volume leads to the socially optimal monetary policy. Gerali, Neri, Sessa & Signoretto (2010) develop a banking sector with rigid interest rate setting by banks and imperfect competition in the financial sector. Christiano, Motto & Rostagno (2013) elaborate on the implication of increases in the dispersion of risk in a classical asymmetric information with costly state verification (financial accelerator) model. Christiano & Ikeda (2013) show that the first-best allocation is achieved by imposing leverage restrictions when financial frictions stem from moral hazard in form of unobserved bankers' effort. However, it is not solely desirable to pin down the source of financial friction that affect real economic activity. The form of financial friction is sought to replicate the observable dynamics of the recent financial crisis; a decline in the quality of capital underlying banks

assets, the subsequent deterioration of intermediaries' balance sheet followed by a sudden increase in interest rate spreads and a decline in credit supply as well as a fall of GDP and prices.

One of the forefront models that is able to capture these line of events is the model of Gertler & Karadi (2011). They introduce moral hazard as the possibility of bankers to abscond a part of the deposits they manage and 'run way' with it. In a follow-up version of the model in Gertler, Kiyotaki et al. (2010) they enrich the system by inducing an interbank market and show that a decline in interbank lending renders shocks to the banking sector even more severe. The most recent version of the model includes a roll-over deposits side of financial intermediaries that leads to an increase of the probability of a bank run. This in turn induces a fire sale of bank assets in the event of a shock to banks' net worth. We choose this model as theoretical foundation for our identifying assumptions, as the '*running away*' model provides a throughout modelling approach for the banking sector that yields dynamic responses mimicking well those observed in the recent crisis.

Empirical work on the interplay between financial stress and economic activity has been evolving quickly since the start of the financial crisis but neglects structural interpretation of the aforementioned models. Hubrich & Tetlow (2015) estimate a Markov-switching VAR model for the US and find that financial stress events reduce economic activity and are highly detrimental for the economy. Moreover, they find that monetary policy is weak during these times. Afonso, Baxa & Slavik (2011) study the effects of fiscal policy in different regimes of financial stress on the US, UK, Germany and Italy using a threshold VAR model. They show that fiscal policy is growth enhancing in times of low as well as in times of high stress. Mallick & Sousa (2013) study the effects of a financial stress shock in a Bayesian Structural VAR for the euro area and find that the financial stress shock drives fluctuations in output and requires a sharp response of monetary policy.

Apart from sudden devaluation of banks' assets or increasing costs of funding in financial markets, monetary policy might affect economic activity via intermediation activity of

banks through the credit channel even more in recessions when credit constraints are binding. Kashyap & Stein (1995) and Kashyap & Stein (2000) provide evidence for the significance of the credit channel in US using bank lending data on a micro level. They show that it is costly for banks to raise uninsured deposits after a tightening of monetary policy. Similar evidence is provided by Ehrmann & Worms (2004), Angeloni, Kashyap & Mojon (2003) and Holtemöller (2002) for euro area countries using macroeconomic data. In contrast, Romer, Romer, Goldfeld & Friedman (1990) argue that the importance of the credit channel was undermined by the possibility of bank funding via covered bonds and asset-backed securities as well as certificate deposits. Indeed, in the decade prior to the financial crisis the market volumes for securitizations increased enormously and banks adopted a new business model: 'Originate, repackage and sell', helping the banks to hedge risk underlying granted credits. In this vein, Loutskina & Strahan (2009) as well as Altunbas, Gambacorta & Marques-Ibanez (2009) provide empirical evidence for a weakening of the bank lending channel as growing activity of banks on the security markets increased banks' balance sheets and liquidity position. Also, international financial integration has led the effect of monetary policy on credit supply to abate. Ashcraft (2006) show that loan granting of banks that are affiliated to international bank holding companies face lower costs of raising external funding and can absorb changes in policy rates better than unaffiliated banks. Also, Cetorelli & Goldberg (2012) provide evidence that increasing globalization of banks diminished the lending channel through cross-border banking of internal capital markets.

3 Structural financial stress shock

I am interested in the consequences of changing financial conditions on the interest rate spread and real economic activity. Therefore, I base my identification on impulse response functions implied by the monetary DSGE model with financial frictions of Gertler & Karadi (2011). This model captures well the mechanism and sources behind the deterioration of banks

balance sheet in 2008, the subsequent decline in intermediation, an increase in interest rate spreads and the following economic downturn. Gertler & Karadi (2011) introduce a new form of financial friction in an otherwise standard monetary DSGE framework by including a banking sector with moral hazard occurring in the form of bankers *'running away'* with a part of the money they manage. As this innovative part of the model implies the calibration of two novel parameters and is originally calibrated for recent the US data, I firstly describe the main mechanism and implications of the model, I secondly verify whether resulting impulse response functions are sensitive to the calibration variations of the two new parameters as well as key parameters of price setting and monetary policy rule. I then impose sign restrictions implied by impulse responses Gertler & Karadi (2011) for three shocks: a financial stress shock, a monetary policy shock, a productivity shock.

3.0.1 Financial stress in a DSGE model with bankers *'running away'*

Gertler & Karadi (2011) develop a quantitative monetary DSGE model similar to the ones of Christiano, Eichenbaum & Evans (2005) and Smets & Wouters (2007), incorporating financial frictions through moral hazard in the banking sector. The agency problem is induced by the fact that bankers can sideline a fraction of deposits and *'run away'* with it. A striking implication for understanding the interplay of financial markets and real economic activity of this model is that a negative shock to the return on banks assets reduces banks net worth, pushes up interest rate spreads and results in a sharp decline of GDP and prices. In such a situation government equity injections into the banking system as well as government taking over a part of the financial intermediation in the economy is shown to be welfare increasing, contrasting to models including other forms of financial frictions like *'unobserved bank effort'*, adverse selection and asymmetric information and monitoring costs. I now turn to the main outline of the model but refer the reader to Gertler & Karadi (2011) for derivation and a detailed description. In the model, households lend funds to competitive financial intermediaries for a gross return R_{t+1} . The financial intermediaries use the deposits to lend

to capital producing firms, receiving the stochastic return R_{kt+1} . In every period the financial intermediaries have the possibility to sideline a fraction λ of available funds. The households in turn may recover the remaining share $1 - \lambda$ by forcing the intermediary into bankruptcy, but λ is lost. As a consequence, the households will only be willing to lend to the financial intermediaries as long as the incentive constraint is fulfilled according to which the losses from cheating have to be always at least as large as the possible gains (see equation 9 in Gertler & Karadi (2011)). This constraint "limits the intermediaries leverage ratio to the point where the banker's incentive to cheat is exactly balanced by the cost. In this respect the agency problem leads to an endogenous capital constraint on the intermediary's ability to acquire assets." ((Gertler & Karadi 2011) , p.10). This implies that a financial intermediary responds to a decline in its net worth by lowering the rate on deposits to strengthen the depositors confidence and avoid withdrawals. This then drives up the risk-adjusted financing premium of the intermediaries; the return on deposits, and the return on their assets, $R_{kt+1} - R_{t+1}$. With frictionless financial markets, this risk-adjusted financing premium is assumed to be zero in the model. However, a sudden decline in the quality of capital underlying banks assets deteriorates the return on banks asset and therewith the net worth of financial intermediaries and credit supply declines. Banks reduce their rate on deposits as to prevent depositors to take their money elsewhere. Due to a lack of bank funding, intermediation falls and credit supply declines, inducing a downturn in economic activity. As prices and output fall, monetary policy reacts expansionary. Financial intermediaries slowly build up their net worth to previous levels to match their equilibrium leverage ratio and therewith the economy recovers. For sudden changes of monetary policy the underlying agency problem yields an accelerating effectiveness in form of the credit channel as models with asymmetric information and costly state verification of Bernanke, Gertler & Gilchrist (1999). Thereby, expansionary monetary policy reduces the financing premium as it lowers refinancing costs for financial intermediaries. As net worth of financial intermediaries and sudden changes of the quality of capital non-observable, I rely on a financial conditions indicator as a proxy for

Table 1: Calibration

Parameter	Value	Description
Households		
β	0.99	Discount rate
h	0.815	Habit formation parameter
χ_0	3.4	Starting value for the labor utility weight
φ	0.276	Inverse Frisch elasticity of labor supply
Financial intermediaries		
λ_0	0.381	Starting value for the fraction of divertible funds
ω_0	0.002	Starting value of proportional starting up funds
θ	0.9716	Survival probability of bankers
Intermediate good firms		
ζ	7.2	Elasticity of marginal depreciation wrt the utilization rate
U	1	Steady state capital utilization rate
$\alpha(U)$	0.33	Capital share
δ	0.025	Depreciation rate
η_I	1.728	Elasticity of investment adjustment cost
Retail firms		
ϵ	4.167	Elasticity of substitution between goods
γ	$\tilde{\gamma}$	Calvo parameter
γ_P	$\tilde{\gamma}_P$	Price indexation parameter
Monetary policy and government		
ρ_i	$\tilde{\rho}_i$	Interest smoothing parameter
κ_π	$\tilde{\pi}$	Inflation coefficient
κ_y	$\tilde{\kappa}_y/4$	Output gap coefficient
$\frac{G}{\bar{Y}}$	0.2	Government expenditures over GDP

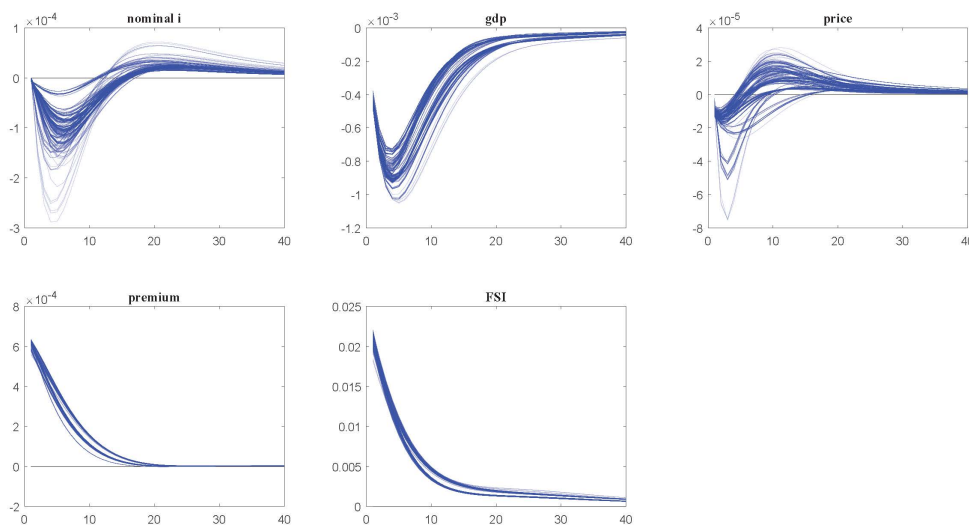
changes in quality of banks assets and/or variations of banks net worth.

Because the model in Gertler & Karadi (2011) is calibrated for recent US data, I re-simulating the model over a wide range of parameter calibrations as to account for a decline of inflation persistence and changing monetary policy as well as changes in the risk-adjusted premium and leverage ratio of the financial intermediaries over time. The latter two parameters are novel parameters in the DSGE literature and stem from the intermediary sector in the model. The calibration for the simulation exercise are shown in table 1.

The variables with tilde indicate that the respective parameters are varied over a certain range. In particular, I re-simulate the model over all possible combinations of the calvo

parameter $\tilde{\gamma} = [0.9, 0.779, 0.6]$, price indexation parameter $\tilde{\gamma}_P = [0.4, 0.241, 0.2]$, the interest rate smoothing parameter $\tilde{\rho}_i = [0.9, 0.8, 0.1]$, the inflation coefficient $\tilde{\pi} = [6, 1.5, 0.5]$, the output gap coefficient $\tilde{\kappa}_y = [0.7, 0.5, 0.1]$, the risk-adjusted financing premium $R_k - R = [0.12, 0.075, 0.05, 0.025, 0.003]$ and the leverage ratio $\phi = [40, 20, 15, 4]$ over the intervals, respectively. The intervals include the original parametrization of Gertler & Karadi (2011) as midpoints and extreme values taken from VAR and DSGE literature related to the decline in inflation persistence² and changes of monetary policy³, except the intervals for the risk-adjusted premium and the leverage ratios. These interval for the premium is taken from the statistics of the excess bond premium used in the estimation and the interval of the leverage ratio is taken from Kalemli-Ozcan, Sorensen & Yesiltas (2012).

Figure 1: Gertler-Karadi financial stress shock



Figures 1, 2 and 3 display the 25% quantile of collected impulse response functions for a 'bank net worth shock', 'monetary policy shock' and a 'productivity shock' of the re-simulated of all possible the parameter variation of Gertler & Karadi (2011) model that are closest to zero. The signs of all 4860 impulse response functions collected are consistent with the baseline calibration and are qualitatively not sensible to the parameter variation.

²Fuhrer & Moore (1995) and references therein

³Svensson (1999) and references therein

Figure 2: Gertler-Karadi monetary policy shock

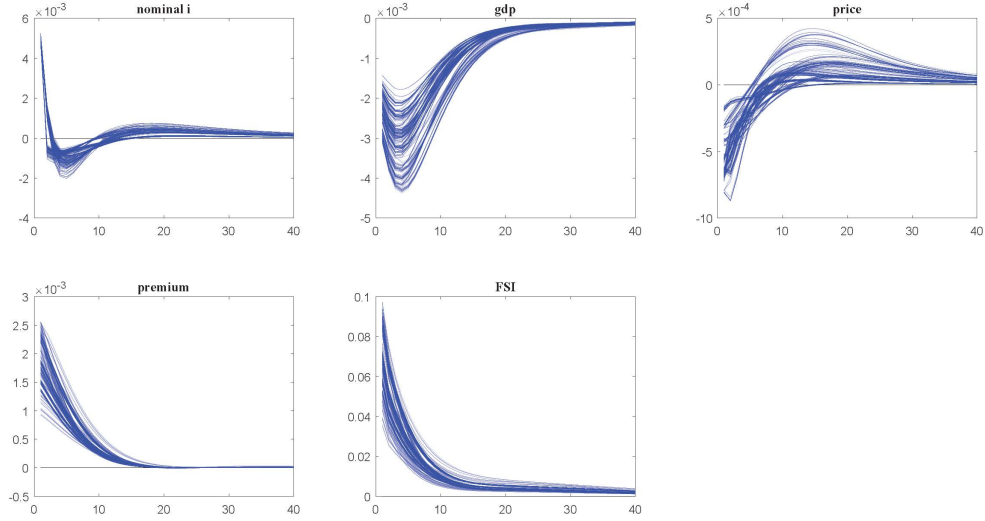
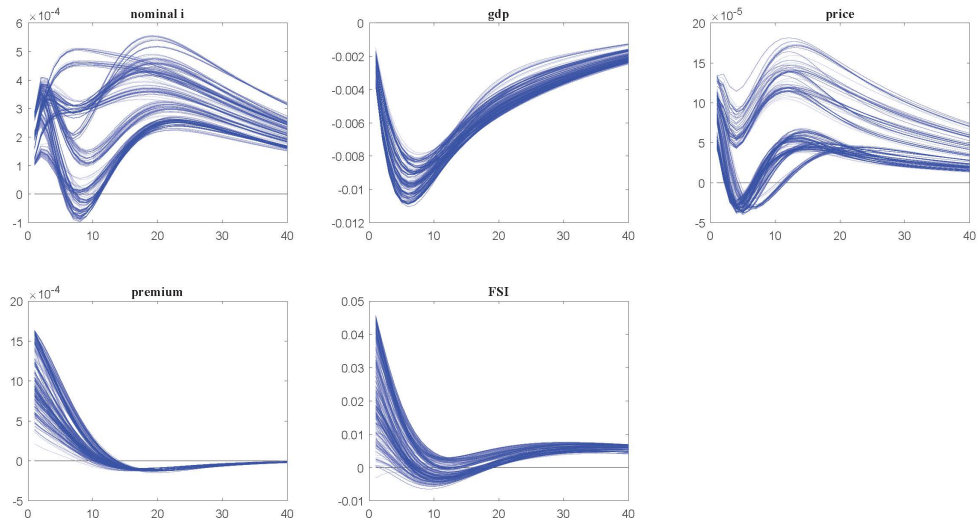


Figure 3: Gertler-Karadi capital productivity shock



4 The Empirical Methodology

4.1 The Econometric Model

I employ a vector autoregressive model with time-varying coefficients (TVP VAR) and stochastic volatility in the style of Primiceri (2005). The model is well suited for my analysis for several reasons. First, it allows to account for institutional and structural changes of financial markets and the real economy that effect agents' economic behaviour by allowing

coefficients to change over time. Second, the TVP VAR discriminates between changes in coefficients and changes in volatility of the underlying variables. This means the response to structural shocks or the size of structural shocks can differ over time. In this line, Gambetti & Musso (2012) and Bijsterbosch & Falagiarda (2015) use the model to investigate in the evolution of loan supply shocks in the US, UK and the euro area. Third, the framework facilitates the identification of a structural financial stress shock. Empirical work relating financial stress and macroeconomic dynamics often treat financial conditions as an exogenous state variable to identify discrete regime shifts of dynamic responses to conventional macroeconomic shocks or policy measures. However, my choice of empirical model allows me to analyse the real economic consequences of changes in the conditions of the banking sector. Consider the reduced-form TVP VAR model of the following form:

$$y_t = B_{0,t} + B_{1,t}y_{t-1} + \dots + B_{k,t}y_{t-k} + u_t \quad t = 1, \dots, T \quad (1)$$

where y_t is an $n \times 1$ vector of endogenous variables $y_t = [i_t, gdp_t, \pi_t, pre_t, f_t]'$, where i_t is a measure short term interest rate, gdp_t is real GDP, π_t is the GDP deflator, pre_t is the spread between the deposit rate and the lending rate and f_t is the financial stress indicator. $B_{0,t}$ is a $n \times 1$ vector of time-varying intercepts, $B_{j,t}$ for $j = 1, \dots, k$ are $n \times n$ matrices of time varying coefficients and $\theta_t = vec(B_t')$. Also, u_t are heteroskedastic unobservable shocks with a variance covariance matrix Ω_t . Consider the triangular reduction of Ω_t of the following form

$$A_t \Omega_t A_t' = \Sigma_t \Sigma_t' \quad (2)$$

with A_t having a lower triangular form

$$A_t = \begin{pmatrix} 1 & 0 & \cdots & 0 \\ \alpha_{21,t} & 1 & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ \alpha_{n1,t} & \cdots & \alpha_{nn-1,t} & 1 \end{pmatrix} \quad (3)$$

and Ω_t being

$$\Sigma_t = \begin{pmatrix} \sigma_{1,t} & 0 & \cdots & 0 \\ 0 & \sigma_{2,t} & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & \sigma_{n,t} \end{pmatrix} \quad (4)$$

Then $y_t = B_{0,t} + B_{1,t}y_{t-1} + \dots + B_{k,t}y_{t-k} + A_t^{-1}\Sigma_t\epsilon_t \equiv X_t'\theta_t + A_t^{-1}\Sigma_t\epsilon_t$ with $t = 1, \dots, T$ and $X_t' = I_n \otimes [1, y'_{t-1}, y'_{t-2}, \dots, y'_{t-k}]$. Consider a vector α_t to be the non-zero and non-one elements of A_t and let σ_t be the vector of the diagonal elements of Σ_t . As in Primiceri (2005), the time varying elements of θ_t and α_t are assumed to be random walks and the elements of σ_t are modelled as geometric random walks. Thus the dynamics of time variations in parameters can be summarized as:

$$\begin{aligned} \theta_t &= \theta_{t-1} + \nu_t \\ \alpha_t &= \alpha_{t-1} + \zeta_t \\ \log \sigma_t &= \log \sigma_{t-1} + \eta_t \end{aligned} \quad (5)$$

Furthermore, the innovations of the model are assumed to be jointly normally distributed. And the variance covariance matrix of $\epsilon_t, \nu_t, \zeta_t$ and η_t is assumed to be

$$V = Var \begin{pmatrix} \epsilon_t \\ \nu_t \\ \zeta_t \\ \eta_t \end{pmatrix} = \begin{pmatrix} I_n & 0 & 0 & 0 \\ 0 & Q & 0 & 0 \\ 0 & 0 & S & 0 \\ 0 & 0 & 0 & W \end{pmatrix} \quad (6)$$

where S is assumed to be block diagonal, which implies that the coefficients of the contemporaneous relations among variables are assumed to evolve independently in each equation (Primiceri 2005). I present the main results in form of structural impulse response functions and counterfactual series. The impulse response functions for each point in time and the counterfactual series are calculated using the moving average representation of the form

$$\begin{aligned} \Phi_t^i &= J' B_t^i J \text{ with } J = [I_n : 0_n \times n(k-1)] \\ y_t &= \sum_{i=0}^{\infty} \phi_t^i u_{t-i} = \sum_{i=0}^{\infty} \phi_t^i A_t^{-1} A_t u_{t-i} = \sum_{i=0}^{\infty} \phi_t^i A_t^{-1} \epsilon_{t-i} \end{aligned} \quad (7)$$

4.2 Identification

I impose sign restrictions implied by the recalibrated versions of the model of Gertler & Karadi (2011) to identify three shocks, namely a monetary policy shock, a financial stress shock and a productivity shock. Moreover, I impose as many restrictions as necessary to achieve identification of the three shocks, leaving two shocks unidentified to soak up further disturbances. As pointed out in Kilian & Murphy (2012) I therewith narrow the set of admissible responses, as I can exclude the possibility that the financial stress shock is just an endogenous reaction to other shocks. Also, productivity shocks as well as monetary policy shocks are considered to be the most important drivers of business cycles in the macroeconomic literature. My identification implies that an expansionary monetary policy shock shifts up GDP and prices and lowers the risk-adjusted financing premium via credit

channel as in shown in figure 2 (for a restrictive monetary policy shock respectively). I assume that a negative supply shock decreases GDP and increases prices. An unexpected increase of the financial stress indicator lowers the monetary policy rate, GDP, prices and raises the premium.

Table 2: Imposed sign restrictions

Shock	policy rate	gdp	prices	premium	FSI
monetary policy	-	+	+	-	*
financial asset	-	-	-	+	+
productivity	*	-	+	*	*

To obtain the structural shocks I apply a similar algorithm as the one suggested by Rubio-Ramirez, Waggoner & Zha (2010), including the QR decomposition to obtain impact multiplier matrices. As pointed out by Kilian & Murphy (2012) and also Inoue & Kilian (2013) the vector of pointwise posterior median responses do not match response function of admissible models. To overcome this problem I employ a proposal of Fry & Pagan (2011) and compute the response function that has minimum distance to the median response.

4.3 Data and Estimation

Due to the high dimensionality and non-linearity I rely on Bayesian estimation techniques to estimate the presented model. Gibbs sampling, a type of Markov Chain Monte Carlo (MCMC) methods, is used to draw from conditional posteriors of low dimension as to obtain joint and marginal distributions for the parameters of interest. The choice of the priors is consistent with Primiceri (2005), which has been also used by Gambetti & Musso (2012) and Bijsterbosch & Falagiarda (2015). Thus, I assume the priors for the time varying coefficients, the simultaneous relation coefficients and the log volatility to be normally distributed. I use the first 40 time points as a training sample to calibrate the priors. Hence, the mean and four times the variance of B_0 as well as A_0 are calibrated as the point estimates and four times the variance of time invariant OLS VAR estimates of the training sample. The prior

for the mean of $\log\sigma_0$ is the logarithmic OLS estimates of the standard errors of the training sample and the variance covariance is chosen to be the identity matrix.

$$\begin{aligned}
B_0 &\sim N(B_{OLS}, 4 * V(B_{OLS})) \\
A_0 &\sim N(A_{OLS}, 4 * V(A_{OLS})) \\
\log\sigma_0 &\sim N(\log \sigma_{OLS}, I_n)
\end{aligned} \tag{8}$$

The hyperparameters S, Q , and W are assumed to be distributed as independent inverse Wishart. The priors for W and S are set to have degrees of freedom such that they exceed the dimension of the matrix of W and the blocks of S , respectively, by one. For Q the degrees of freedom are set to the size of the training sample. The scale matrices for Q, S , and W are constant fractions of variances of the respective OLS estimates of the training sample times $k_W^2 = 0.01, k_S^2 = 0.1$ and $k_Q^2 = 0.01$ as well as the degrees of freedom, respectively. The setting of k_W^2, k_S^2 and k_Q^2 implies diffuse and uninformative priors. Accordingly, the priors for the hyperparameters can be summarized as

$$\begin{aligned}
Q &\sim IW(k_Q^2 * 40 * V(B_{OLS}), 40) \\
W &\sim IW(k_W^2 * N + 1 * I_n, N) \\
S_i &\sim IW(k_S^2 * M_i + 1 * V(A_{i,OLS}), M_i) \\
&\text{with } i = 1, \dots, I,
\end{aligned} \tag{9}$$

where I is the number of blocks in S , $A_{i,OLS}$ reflect corresponding blocks of A , M_i is the number of the elements of $A_{i,OLS}$ that are neither zeros nor ones and N is the number of endogenous variables entering the model. We refer the reader to Primiceri (2005) and Del Negro & Primiceri (2013) for the details of the Gibbs sampling algorithm. We draw 20000 times, where 10000 draws are defined as the burn-ins. From the remaining 10000 Gibbs draws I then keep every tenth. The convergence diagnostics of my estimation can be found in appendix. For the estimation of the TVP VAR model I use quarterly seasonally adjusted data for real gdp and cpi for 1973Q1 to 2012Q4 from the Bureau of Economic

Analysis. To approximate the risk-adjusted premium I use the excess bond premium of Gilchrist & Zakrajšek (2012) as this captures the cyclical changes between default risk and credit spreads or in other words the unanticipated default risks of the financial sector. As an approximation of a sudden movements of banks assets I use the financial conditions indicator of Hatzius, Hooper, Mishkin, Schoenholtz & Watson (2010). Moreover, I use the federal funds target rate provided by the federal reserve as the nominal interest rate that is the main instrument for monetary policy. As to account for unconventional monetary policy measures and the zero lower bound we use the shadow rate of Wu & Xia (2014) from 2004Q4 to 2014Q4. For the estimation I use quarterly changes of prices and gdp.

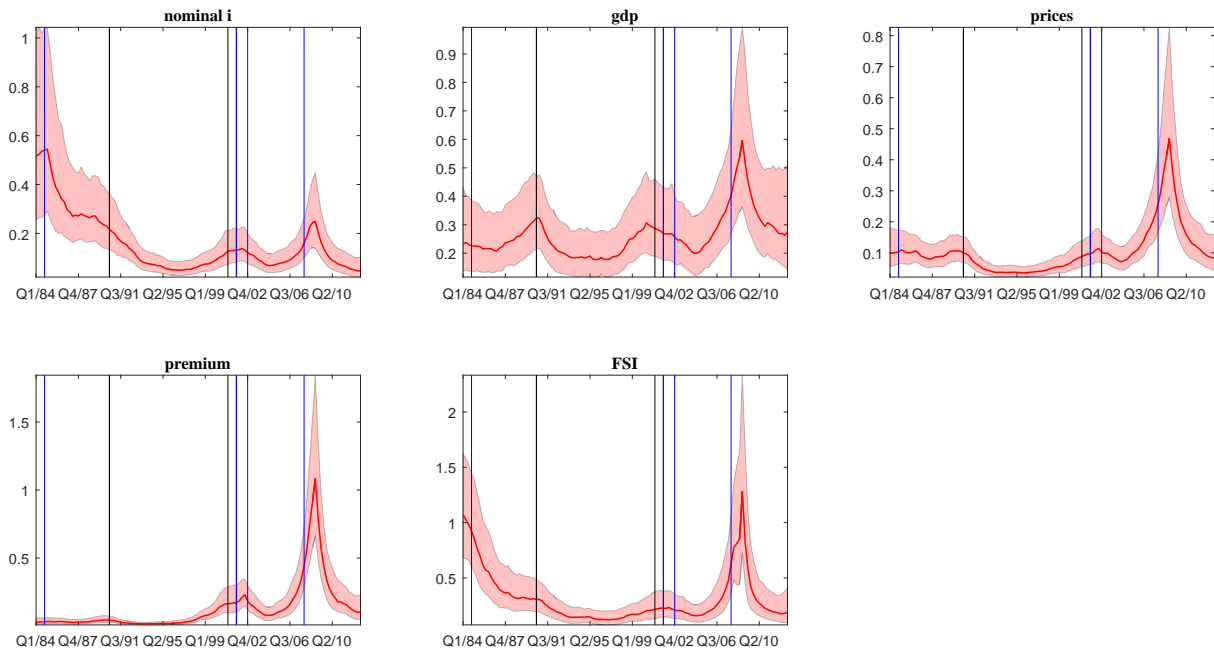
5 Results

Evolution of volatilities

Figure 4 shows the evolution of time-varying variances of the five variables included in the estimation, whereby the thick line depicts the median of the variance posteriors and the shaded area indicates the corresponding 68% probability bands for each quarter of the sample. To relate the variance series to financial and real economic turbulences the graphs indicate recession peaks taken from the NBER business cycle dating with black vertical lines and events of financial distress that are not listed in the NBER business cycle dates with blue vertical lines. All residual variance show significant time variation. In the course of the financial crisis starting in 2007Q2 volatilities of all variables, except the federal funds rate peak. The volatility of federal funds rate also increases from 2007Q2 until 2009Q3 but is roughly half the median variance at the beginning of the sample in 1984Q1. The decreased during the first half of the sample can be related to end of the restrictive monetary policy stance in the Volcker-area at the beginning of the eighties. Moreover, the volatility of all variables increased for the dotcom crisis peaking at Q12001 (black line). This increase in volatility persists through out the events of exceptional losses for the DJAMI Q32001 and

Q22002 (blue lines) for financial stress index, premium and the federal funds rate. Moreover, the recession in the early nineties (90/91) is especially variance increasing for gdp and prices. The volatility of the premium starts rising in the late eighties and again declines nearly to previous levels around 2003, when credit standards were lax and excess credit growth prevailed. A steady increase of the pure financial premium during the mid eighties until the late nineties, except the 90/91 crisis. since the mid 1990. Overall, figure 4 supports the use of stochastic volatilities of the VAR model.

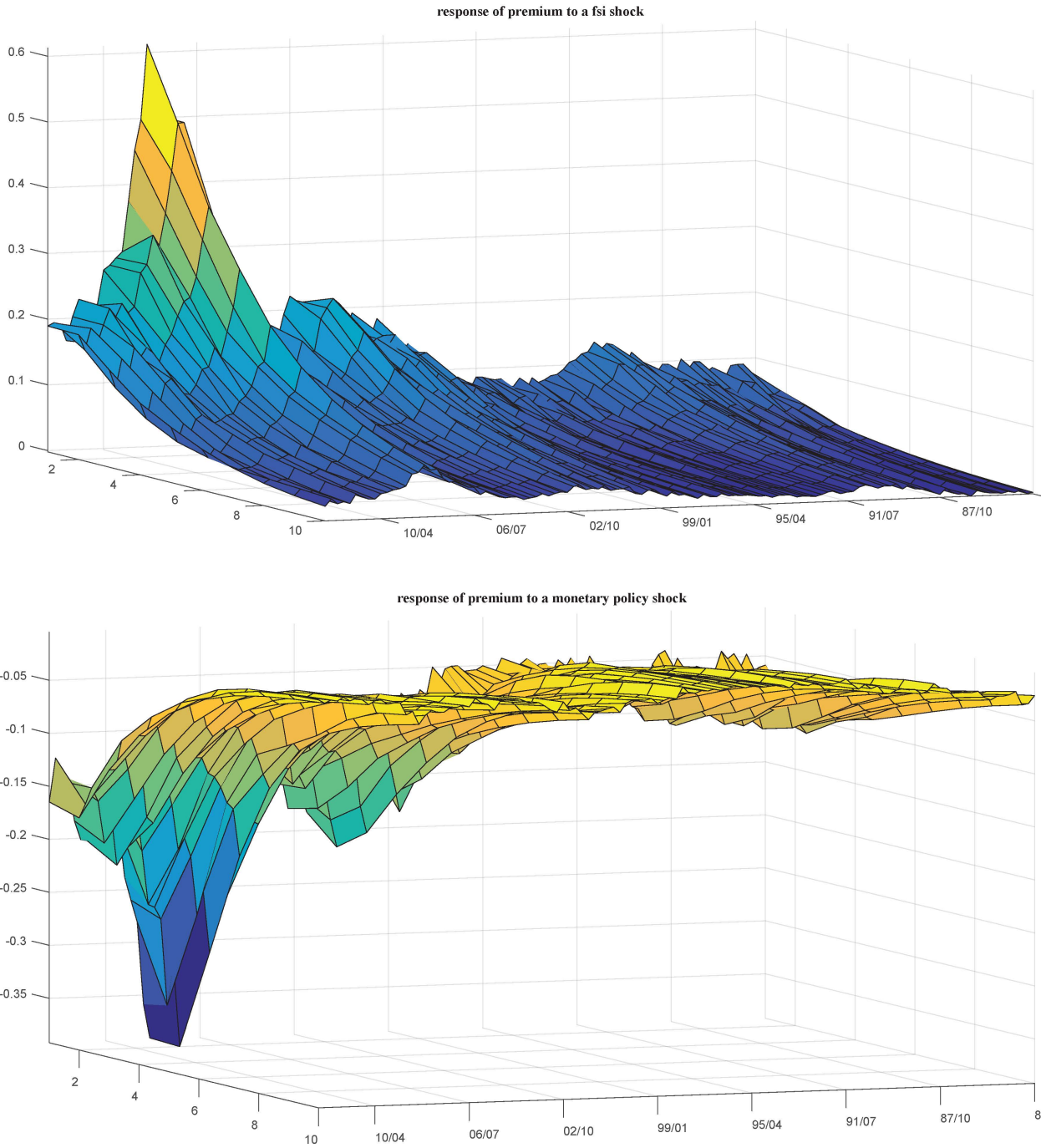
Figure 4: Stochastic volatility



Impulse responses and counterfactual analysis

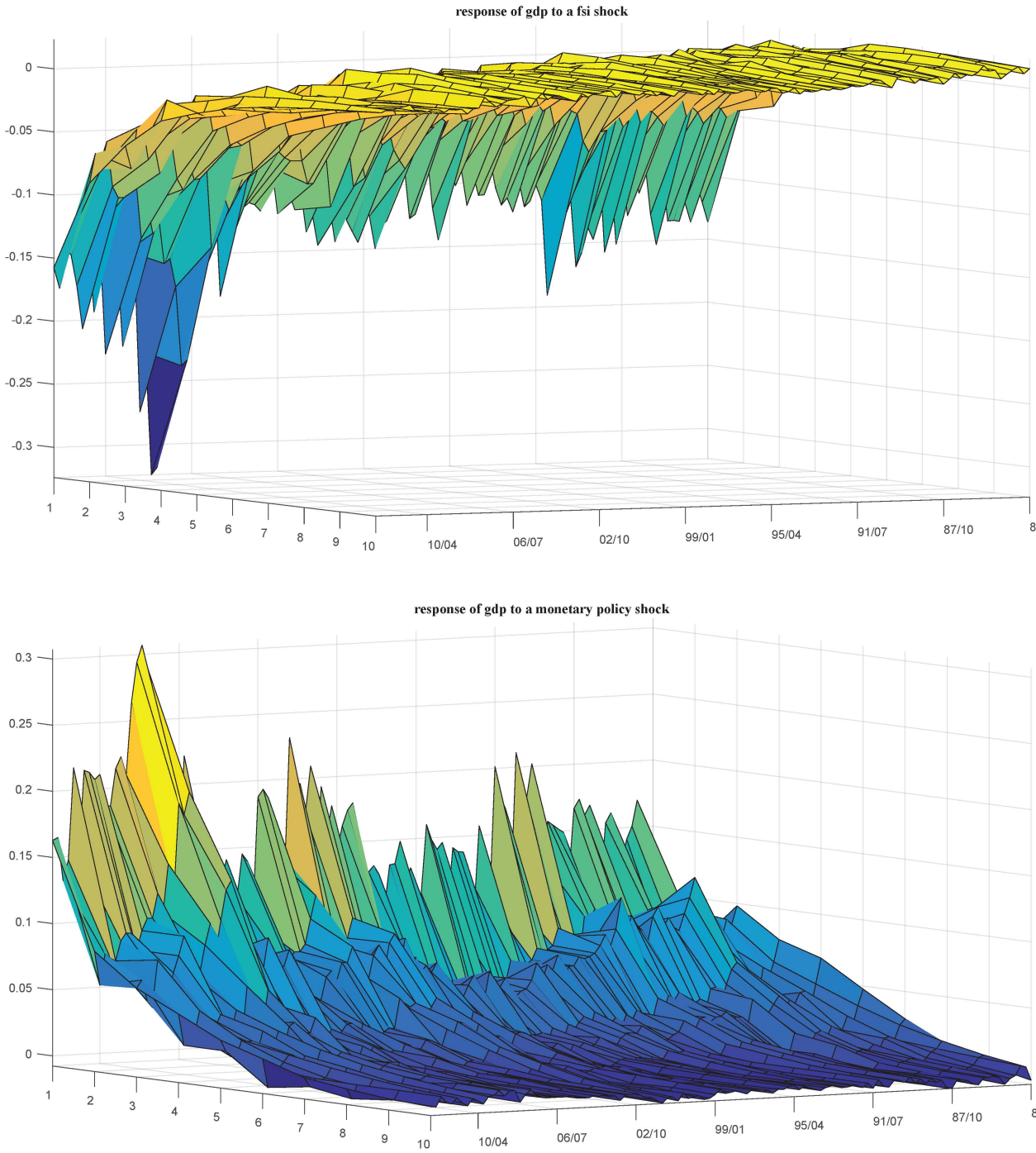
Now I turn to the median impulse responses of the financial stress shock and the monetary policy shock for each quarter between Q21984 until 2012Q2. As it can be seen in the upper graph of figure 5, an unexpected shock to financial stress increases the premium at least over four quarters through the sample period. The impact and persistence of a fsi shock to the premium is altered during the financial crisis, namely the dotcom crisis and the recent global financial crisis, where impact and persistence of the response to the latter is roughly double

Figure 5: Evolution of impulse responses of premium to a financial stress shock and a monetary policy shock



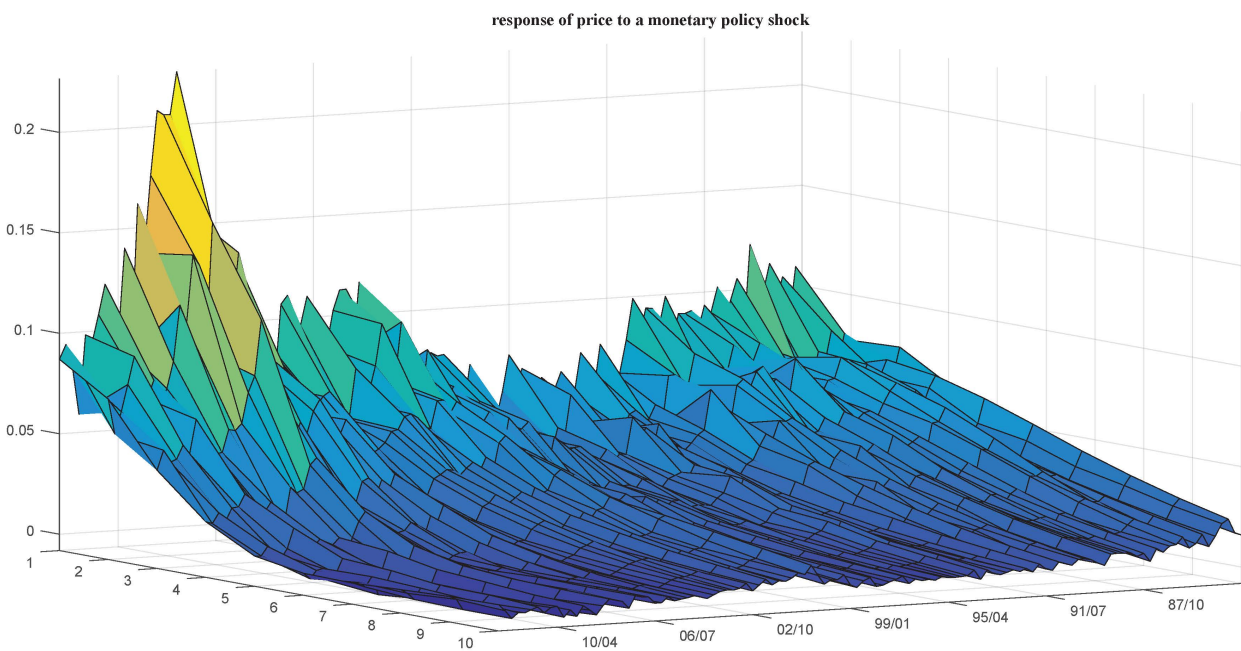
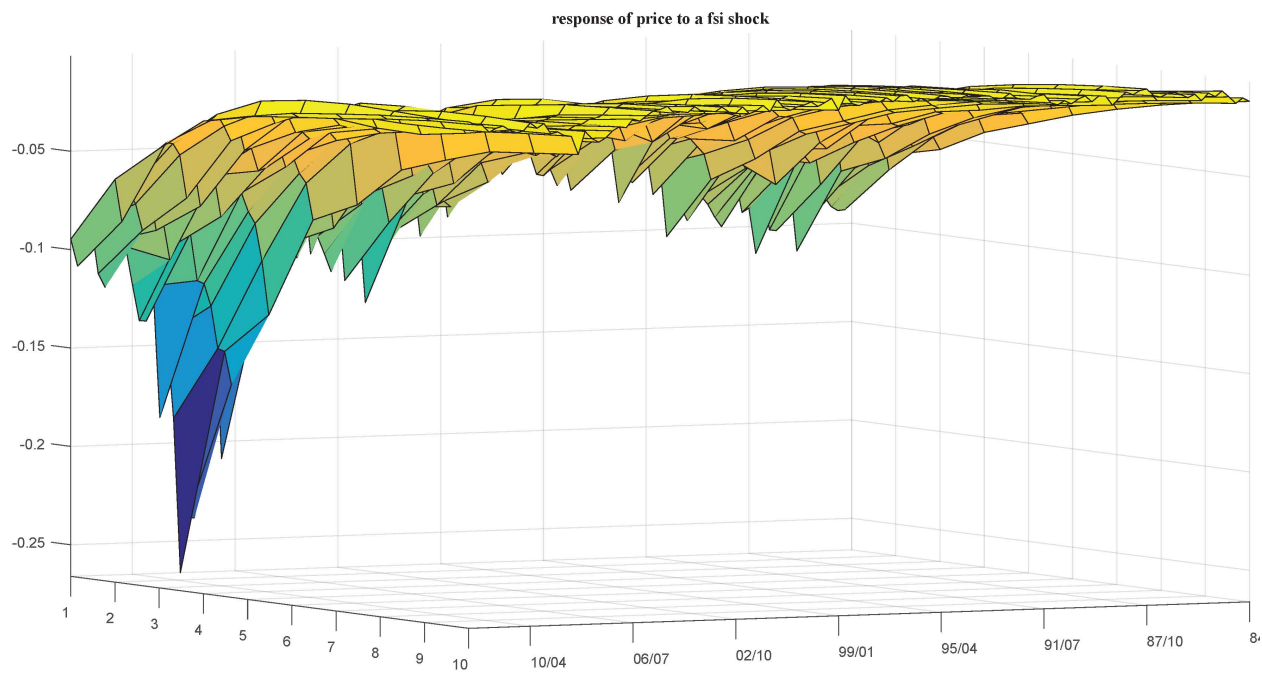
on average compared to the dotcom crisis periods. Figure 5 shows the negative responses of the premium to an unexpected expansionary monetary policy shock. Until the late nighties

Figure 6: Evolution of impulse responses of gdp to a monetary policy shock and a financial stress shock



the premium responds only to some extent. However, during the dotcom and recent financial crisis the premium is lowered substantially, whereby responses on impact peak at -0.2 and

Figure 7: Evolution of impulse responses of prices to a monetary policy shock and a financial stress shock



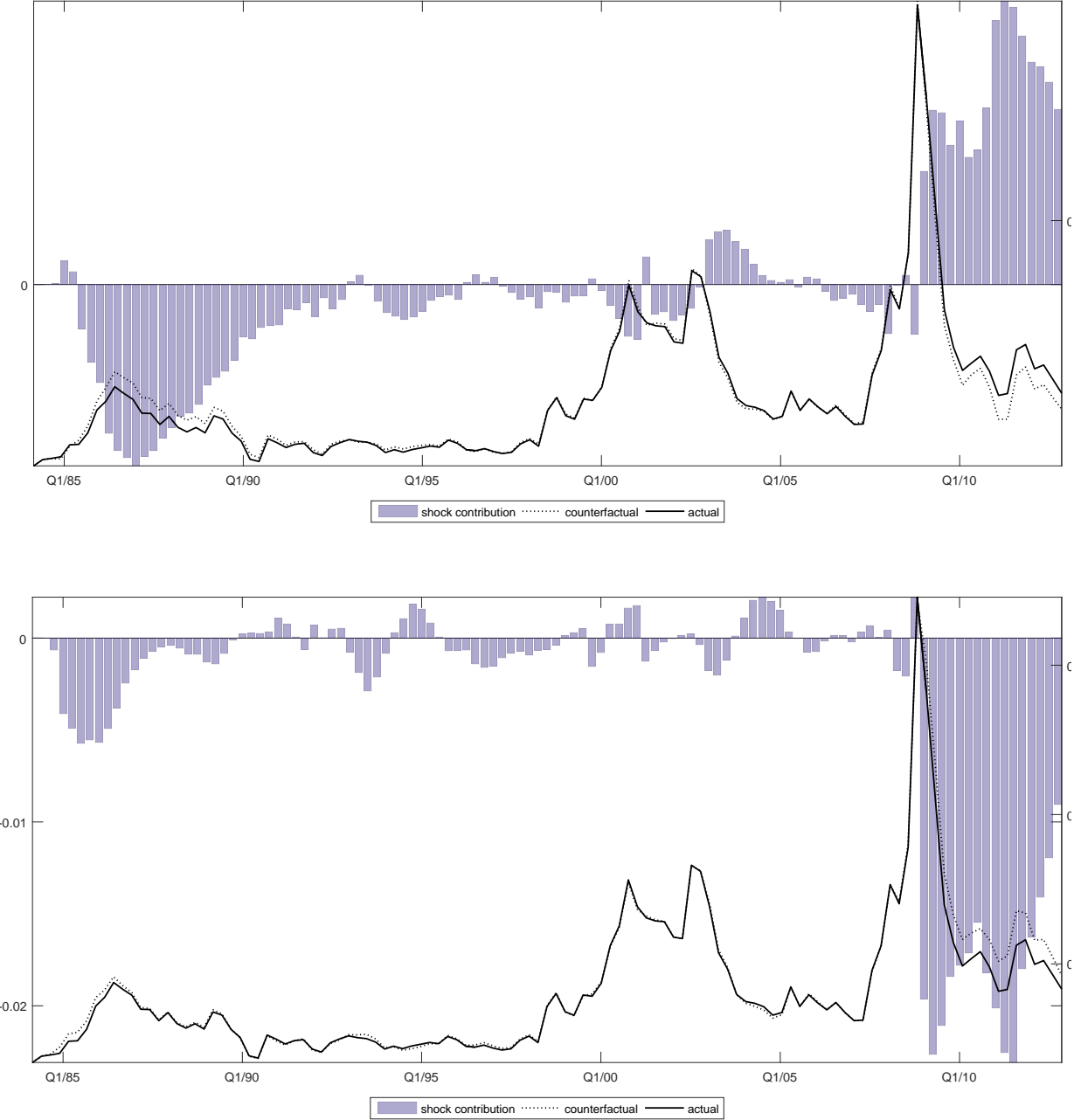
-0.36 respectively. The varying size and length of the impact of monetary policy on the excess premium might be due to an intensified financial integration and the emergence of new

complex financial products that were merely absent in the mid-eighties and mid-nineties.

The upper panels of figure 6 and 7 show the median impulse responses of gdp and prices to a fsi shock over time. For the whole sample the gdp declines for 2 to 5 quarters and prices decline for 2 to 4 quarters after an unexpected rise of the financial stress index, whereby the response of particularly strong for the recent financial crisis. As it can be seen in the lower panels of figure 6 and 7 , the response of gdp and prices to an unexpected rise in the monetary policy rate is positive for at least 4 quarters and enhanced on impact for the early nineties recession, the dot-com crisis and the recent financial crisis. Figure 8 depicts the structural shock contributions on the risk-adjusted financing premium of a financial stress shock in the upper panel and a an expansionary monetary policy shock in the lower panel as well as the actual and counterfactual series of the premium. The counterfactual series and the shock contributions reveal that financial stress is an important driver of the risk-adjusted financing premium. Especially during the recent financial crisis financial stress shocks contributed positively to the exceptionally high risk-adjusted financing premium. A similar picture emerges for the contribution of monetary policy shocks to the premium, as monetary policy substantially lowered the risk-adjusted financing premium and partly offset the financial stress shock.

The upper and lower panels of figures 9 and 10 show the contribution of a financial stress shock and a monetary policy shock to gdp and prices as well as the actual and counterfactual series, respectively. Financial stress shocks contributed to gdp development over the full sample. Also, monetary policy shocks is partly explaining real gdp development over the full sample. Whereas the contribution of monetary policy to gdp is of particular strength during crisis times. It can be seen that in most cases monetary policy was able to narrow the amplitude of the business cycle. Financial stress had its impact on price developments in the US economy. Contributions of financial stress to prices haven been particularly high (up to 1%) in times of extraordinary values of the financial stress indicator as around 1990 and 2008. Monetary policy also impacted inflation rates. It is particularly striking that during

Figure 8: Contribution of financial stress and monetary policy shock to premium actual as well as counterfactual series of premium



the global financial crisis the contribution of monetary policy to price development has been negative and therefore hardly sufficient to counteract low inflation.

Figure 9: Contribution of financial stress and monetary policy shock to gdp and actual as well as counterfactual series of gdp

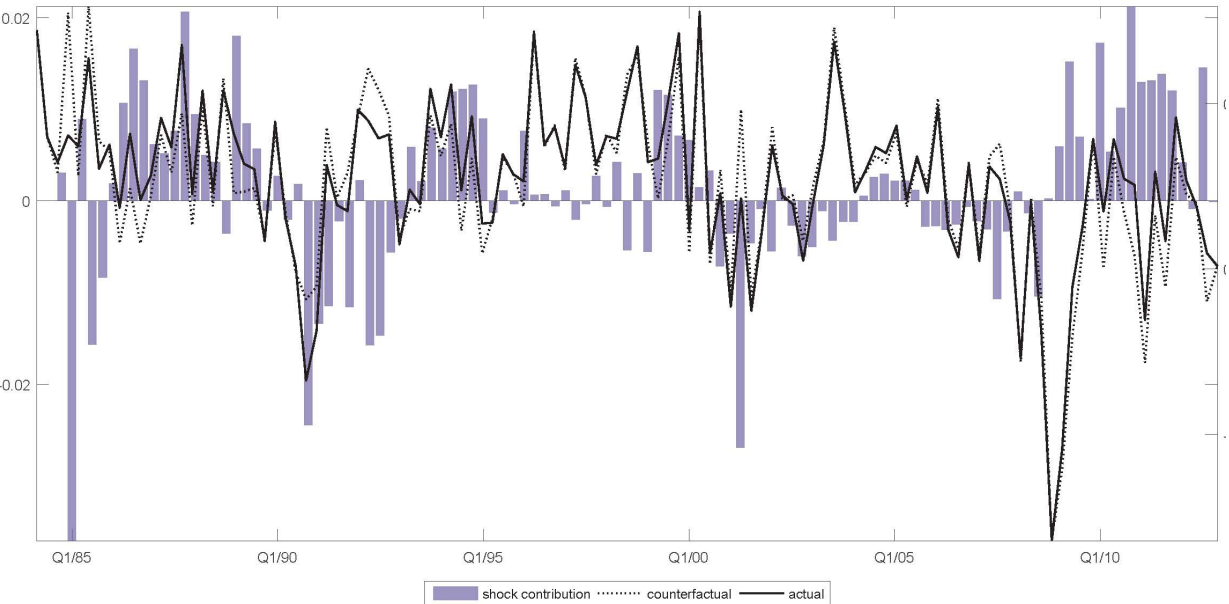
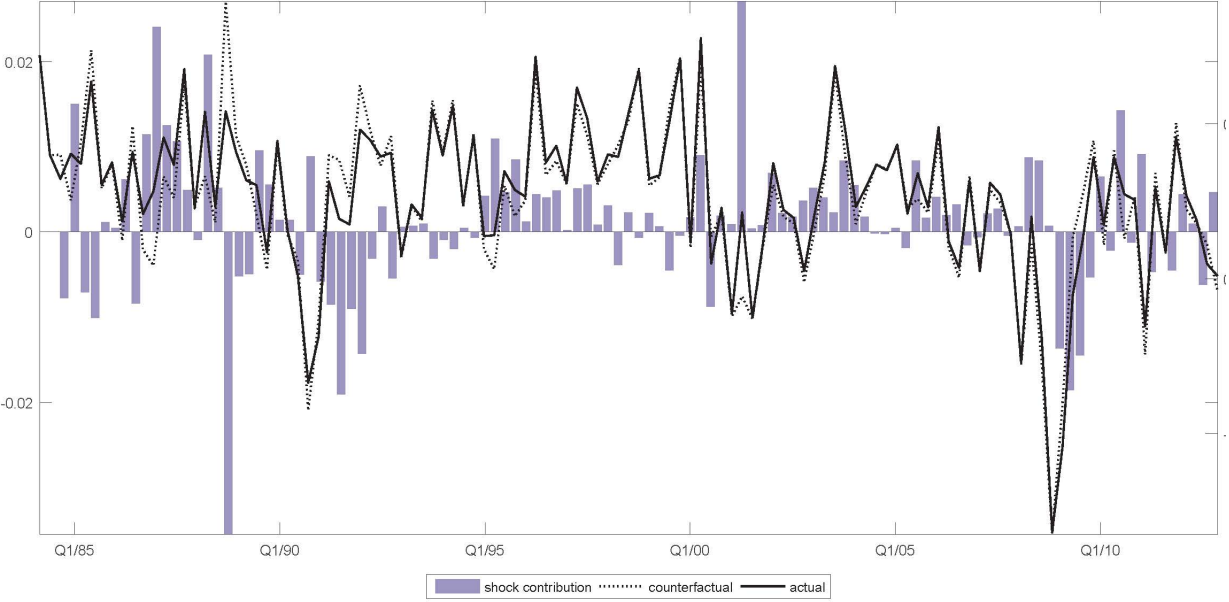


Figure 10: Contribution of financial stress and monetary policy shock to prices and actual as well as counterfactual series of prices



6 Concluding remarks

The recent financial crisis has revived macroeconomic research on the interaction of real economic activity and monetary transmission. This paper investigates in the contribution

of financial stress to gdp and price developments as well as in the strength of the credit channel, as part of the monetary policy transmission mechanism, especially in times of high financial stress. Therefore, a TVP VAR with stochastic volatility is estimated and a structural financial stress shock, a monetary policy shock and a productivity shock are identified by using sign restrictions. Moreover, the imposed identification relies on a monetary DSGE model with financial frictions in the form of moral hazard with bankers running away with a fraction of the assets they manage. As the estimation sample spans from 1984Q1 to 2012Q4 the implied impulse responses of the model are verified by re-simulating the model over a wide range of parameter calibrations as to account for a decline of inflation persistence and changing monetary policy as well as changes in the risk-adjusted premium and leverage ratio of the financial intermediaries over time. It is shown that structural financial stress as well as monetary policy shock are drivers of real economic activity and prices. Especially during the recent financial crisis and also in the course of the dot-com crisis financial stress has had negative impacts on gdp and prices whereas monetary policy was able to counteract declines of gdp but was not able to offset deflationary developments. The contributions to the risk-adjusted financing premium show that the credit channel in deed has been of increased importance during times of high financial stress. Thus, the paper provides evidence for the implications of recently developed DSGE models with financial frictions in the banking sector.

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7 Appendix

7.1 MCMC Convergence statistics

I use three convergence statistics to ensure the convergence of the MCMC algorithm. First, I look at the autocorrelation of the Gibbs draws kept at the lag of 20, whereby low levels of autocorrelation indicate that the draws are nearly independent. Second, I compute the relative numerical inefficiency suggested by Geweke (1991), which is the inverse of the ratio of the numerical variance and the variance of independent draws (Chib 2001). A 4 % tapered window for the estimation of the spectral density at frequency zero is used as in Primiceri (2005). Third, I calculate the Raftery, Lewis et al. (1992) diagnostic that indicates the

total number of runs necessary to achieve the precision for the 0.025 and 0.0975 quantiles of marginal posteriors, the desired accuracy to 0.025 and the probability of achieving the required accuracy to 0.95. Table 3 displays the results of the three convergence statistics for each country and test the mean and median, respectively. The results confirm that the MCMC sample algorithm generally convergence for all countries. The median and mean autocorrelation of the 20th lag are commonly low and the relative numerical inefficiency factors are all below 20. Moreover, the number of iterations chosen, 20000, is below the number of runs required indicated by the the Raftery and Lewis statistic.

Table 3: MCMC convergence statistics

		20th order acf		Inefficiency f.		RL runs	
		Median	Mean	Median	Mean	Median	Mean
US	S	0.01	0.01	0.97	0.95	3869	4076
	W	0.00	0.00	4.52	4.52	7681	8483
	H	0.00	5.12	5.16		6411	6400
	A	0.01	0.02	1.80	1.8	12996	14305
	B	0.00	0.00	1.95	1.95	3869	4088