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Macroeconomic Factors and Bank Risk*

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Abstract

The interplay between banks and the macroeconomy is of key importance for financial and economic stability. We analyze this link using a Factor Augmented Vector Autoregressive Model (FAVAR) which extends a standard VAR for the U.S. macroeconomy with a set of factors summarizing conditions in the banking sector. We use the model to analyze bank risk, bank returns, and bank lending. We take data of more than 2,000 commercial banks from the U.S. Call Reports. We assess the importance of common versus idiosyncratic risk at the bank level and the heterogeneous transmission of macroeconomic and asset price shocks to individual banks. Our paper has four main findings. First, average bank risk declines following expansionary shocks. Results for individual banks reveal that 1/3 of all banks increase risk after a monetary loosening. In this sense, our results are partly in support of the risk-taking channel. Second, bank lending increases following expansionary shocks. Third, the correlation between bank risk and return depends on the underlying macroeconomic shock. Fourth, banks' responses to macroeconomic shocks exhibit a high degree of heterogeneity. We find that riskiness and internationalization are determinants of banks' risk and lending exposure to monetary policy shocks, and that liquidity, in addition, determines banks' lending exposure.

JEL codes: E44, G21

Keywords: FAVAR, monetary policy, risk-taking channel, lending channel, banking

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1 Motivation

The interplay between macroeconomic factors and risks in banking is of importance for financial and economic stability. For example, the bubble on housing markets and loose monetary policy are often cited as main origins of the crisis that started in 2007, and monetary policy has reacted to problems in the banking sector by injecting liquidity. In this paper, we analyze the feedback between the banking sector and the macroeconomy for the pre-crisis period. We empirically model individual banks' risk, return, and lending together with macroeconomic factors in a Factor Augmented Vector Autoregressive Model (FAVAR) in the tradition of Bernanke et al. (2005). In our model, developments in the banking sector can have an impact on macroeconomic dynamics, and macroeconomic developments can affect individual banks.

The FAVAR extends a standard macroeconomic VAR which comprises GDP growth, inflation, house prices, stock price inflation, and monetary policy interest rates with a set of factors which we extract from a large set of individual bank-level data. The banking data comprise non-performing loans to total loans, equity capital to total capital, return on assets, and loans to assets for a balanced panel of more than 2,000 U.S. banks. Data are taken from the U.S. Call Reports. We decompose the banking data in common and idiosyncratic (i.e. bank-specific) components. We identify a set of macroeconomic (and asset price) shocks and assess their transmission through the banking system. We also make use of the rich information on individual banks incorporated in the dataset (also available to regulators) and assess how individual banks react to macroeconomic shocks. We thus address the issue that, in the presence of frictions on financial markets, effects of macroeconomic shocks should exhibit a substantial degree of heterogeneity.

We answer the following questions. First, what is the role of macroeconomic shocks for the banking sector? Second, what is the role of the banking sector for the macroeconomy? Third, what are the sources of bank heterogeneity? How important are idiosyncratic shocks and how important is the asymmetric transmission of common (banking and macro) shocks to individual banks, and which bank-level features explain the exposure of individual banks to macroeconomic factors?

The answers to the above questions have important implications also for regulatory policy. The exposure of banks to macroeconomic factors (and thus the procyclical impact of capital regulations) features prominently in recent proposals for regulatory reforms. Rochet (2008), for instance, argues that banks with a large exposure to macroeconomic shocks should be denied access to emergency assistance by the central bank. According to his proposal, banks with a low exposure to macroeconomic shocks should have access to the lender of last resort facilities. Banks should face a capital requirement and a deposit insurance premium that

increases with their exposure to macroeconomic factors. Similarly, Farhi and Tirole (2009) argue that banks which react more to macroeconomic factors should be regulated more tightly. Gersbach and Hahn (2009) propose a regulatory framework under which a bank's required level of equity capital depends on the equity capital of its peers and, in this sense, on the macroeconomic environment. If an adverse shock hits the economy and drives down equity ratios for all banks, capital requirements will be relaxed. Implementing these proposals requires information about individual banks' exposures to macroeconomic factors. Our results inform this debate.

Our paper contributes to recent literature analyzing the link between bank risk and the macroeconomic environment. According to the so-called risk-taking channel (Rajan 2005, Borio and Zhu 2008), low policy interest rates may trigger increased risk-taking either by increasing net worth and thus encouraging lending to high-risk borrowers and/or by inducing a "search for yield". Therefore, the risk-taking channel is closely related to the lending channel of monetary policy. Recent empirical work using bank-level data finds some evidence that lower interest rates increase banks' risk (Altunbas et al. 2009, Jiménez et al. 2007, Ioannidou et al. 2009, Eickmeier and Hofmann 2009). While the focus of these papers is on bank-specific risk, Tarashev et al. (2009a) show that banks' exposure to macroeconomic risk also increases the degree of systemic risks in banking, i.e. the probability that the entire financial system is in distress.¹

Our set-up allows us to make several contributions. First, the FAVAR model allows analyzing the dynamic interaction between bank-specific and macroeconomic developments in a flexible way while taking into account the endogeneity of both, macro- and banking factors. Several VAR-studies allow for the interaction between credit and macroeconomic factors (e.g. Eickmeier et al. 2007, Ciccarelli et al. 2009), but these studies do not focus on bank-specific effects. The above bank-level studies on the risk-taking channel, in contrast, allow macroeconomic factors to affect bank risk, but macroeconomic factors are not allowed to be influenced by bank risk or other banking variables. We find both, effects of macroeconomic (and asset price) shocks on banks, and effects of shocks occurring in the banking sector on the macroeconomy.

Second, the FAVAR model allows including a large number of bank-level variables. We can explicitly exploit the interconnectedness of banks and the impact of macroeconomic developments on different banking variables. The need to account for the interconnectedness of financial institutions is one key insight of the recent crisis (Brunnermeier 2008, IMF 2009). Moreover, we simultaneously model the risk and the return of banks, thus accounting for the

¹ Additional determinants of systemic risk include banks' probabilities of default and the degree of size concentration in banking (Tarashev et al. 2009a).

fact that, in “search for yield”, banks may increase risk (Rajan 2006, Hellwig 2008).² We find that the correlation between the risk and the return of banks depends on the underlying macroeconomic shock. In addition, we can assess the exposure of each individual bank to macroeconomic shocks. We find that banks react in a very heterogeneous way to common shocks and assess the reasons between the heterogeneous reactions.

Third, previous papers analyzing the risk-taking channel regress bank-level risk on variables such as the monetary policy interest rate, GDP growth, and asset prices (Altunbas et al. 2009, Jiménez et al. 2007, Ioannidou et al. 2009).³ The latter are reduced-form constructs, and their developments may reflect the pass-through of possibly very different types of shocks. Instead, we consider (loosely) identified orthogonal macroeconomic and asset price shocks which allow us to better disentangle the common drivers of banking developments. One finding is that bank risk tends to decline in response to expansionary shocks while lending increases. The shapes of impulse response functions and the fraction of the variation accounted for depend, however, on the type of the shock.

Fourth, FAVAR models have previously been fitted to large macroeconomic datasets.⁴ The methodology, however, allows exploiting even richer information, and its application also to micro-level data is the natural next step. To the best of our knowledge, our study is the first linking a FAVAR model to a micro dataset.⁵

In the remainder of the paper we proceed as follows. In Section 2 we relate our paper to the existing theoretical and empirical literature. In Sections 3 and 4 we present the data and the methodology, respectively. In Section 5 we provide and discuss the empirical results and conclude in Section 6.

2 Theoretical Background and Previous Empirical Literature⁶

2.1 *Theoretical Background*

Theoretical contributions explaining the exposure of banks to macroeconomic risk need to assume some degree of frictions on financial markets. In a complete markets setting, banks should be exposed to idiosyncratic but not to macroeconomic risks (Hellwig 1997). Moreover,

² See Beck (2008) for a discussion of previous empirical literature on banks’ risk-return trade off.

³ These papers address the issue that monetary policy is endogenous by either approximating monetary policy of the countries studied by foreign policy rates or by Taylor rule gaps, i.e. deviations of the policy rate from the rate implied by the Taylor rule (Altunbas et al. 2009).

⁴ See, e.g., De Nicolò and Lucchetta (2010) for an application to systemic risk.

⁵ Den Reijer (2007) applies a principal components-based factor model to a micro dataset of Dutch staffing employment and carries out forecasts but no structural analysis.

⁶ See Freixas and Rochet (1998, Chapter 6) for a review of the bank lending channel and the financial accelerator model and Degryse et al. (2009, Chapter 6) for the corresponding empirical evidence.

models assuming financial contracts that isolate banks from macroeconomic shocks miss important interactions between banks and the macroeconomy during financial crises (Zhang 2009). In this section, we summarize implications of recent models modeling such financial frictions (see also Table 1).

Most previous work linking banks and the macroeconomy focuses on monetary policy shocks and the lending channel. Walsh (2003) distinguishes two aspects. According to the bank lending channel, policies that affect the reserves of the banking system influence the transmission of monetary impulses. If access to uninsured funding is limited due to financial friction, banks cut their lending in response to tighter monetary policy. Hence, if close, uninsured substitutes to bank deposits are missing, bank credit affects aggregated activity. According to the financial-accelerator mechanism, the availability of cash flow and the net worth of firms affect the availability of external finance. If a recession weakens firms' internal resources, the volume supply of credit declines, and the negative effects of the downturn are aggravated.

If the financial accelerator is operating, changes in interest rates may have countervailing effects on bank risk and lending. On the one hand, lower interest rates reduce the interest rate burden for firms, lower the risk of outstanding flexible loan contracts, thereby increasing the probability of repayment and the value of the underlying collateral. On the other hand, the borrowing capacity of high-risk firms increases with the availability and the volume of pledgeable assets (Bernanke et al. 1996). Risk might increase. Conversely, higher interest rates increase the agency costs of lending, banks reduce the amount of credit to monitoring-intensive firms, and they invest a greater share of their assets in safe assets ("flight-to-quality") (Bernanke et al. 1996: p. 4).⁷

Recent macroeconomic models extend the menu of shocks when analyzing the link between banks and the macroeconomy. Angeloni and Faia (2009) analyze the impact of monetary, technology, and asset price shocks in the context of a DSGE model with banks. In their model, banks use equity and deposits to finance lending to entrepreneurs. Entrepreneurs have no internal funds and require financing from banks as relationship lenders. Banks have special skills in redeploying assets that are liquidated early, and the economy is prone to bank runs.

The model also yields testable hypotheses concerning the impact of different shocks for the banking sector. Following a positive productivity shock, inflation and interest rates fall, and output increases. Since investment increases, bank lending increases as well. The decline in interest rates lowers banks' return on assets, but banks also take on more risks because they raise more deposits (the capital-asset ratio falls). An expansionary monetary policy shock increases inflation and output on impact, and lower interest rates have a negative impact on

⁷ Similar mechanisms are stressed in Matsuyama (2007) or Dell'Ariccia and Marquez (2006).

banks' profits. Banks replace deposits with equity, hence bank risk increases.⁸ Following a positive shock to the marginal return to capital,⁹ output and inflation rise on impact. Due to an increased demand for loans, bank interest rates and thus profits increase. Bank risk declines.

In Angeloni and Faia (2009), the focus is on banks' role as liquidity providers. Zhang (2009) focuses on an interaction between credit friction on the demand side (net worth of firms) and the supply side (bank capital). In her model, banks and firms share macroeconomic risks because banks cannot write contracts isolating them from macroeconomic risk. The implications of this model differ from those in Angeloni and Faia (2009) since expansionary monetary or technology shocks lower risk.¹⁰ The reason for this difference is that expansionary shocks increase firms' net worth, which has a positive impact on the borrowing capacity of firms. Implications for lending are qualitatively the same.

Recent literature has also discussed the exposure of banks to macroeconomic factors as a determinant of systemic risks in banking. In Farhi and Tirole (2009), the probability of success of projects financed by banks depends on macroeconomic shocks. Banks are allowed to choose the correlation of their portfolio risk with that of other banks. There is a strategic complementarity in the choices of banks – the higher the number of banks holding similar portfolios, the more likely is a (monetary) bail out in case of a negative shock. Banks want to fail when the largest possible number of other banks is failing. Predictions of the model differ from standard predictions of the CAPM model, which would imply that investors *minimize* their correlation of aggregate risk. One implication of the model is that a low (policy) interest rate increases risk because of increased bank leverage (a lower capital-asset-ratio). This would be in line with the model by Angeloni and Faia (2009).

In our empirical model, we will also account for housing price shocks. Goel et al. (2009) show how leverage decisions of borrowers and banks can feedback into macroeconomic stability. In their model, bank loans are secured with houses, and the probability distribution of value of collateral is affected by the aggregate lending behavior of banks. An increase in the probability that the house price is positive in the second period increases both, consumers' and banks' leverage. The fact that all bank loans are backed by the same collateral leads to an interconnectedness of otherwise independent banks.

The macroeconomic models reviewed so far have implications for the link between risk and return, which partly depend on the nature of the underlying shock. The banking literature has

⁸ Bank risk in the model by Angeloni and Faia (2009) is the probability of a bank run occurring, and this probability is determined by the distribution of the returns on lending and the liquidation value of long-term assets. In our empirical model, the proxy for bank risk will be the share of non-performing loans in total loans and the capital-asset ratio, which are positively correlated with the definition of risk in their theoretical model.

⁹ This shock can be interpreted as an asset price shock, which we will model as a stock price shock.

¹⁰ See Meh and Moran (2008) for a similar conclusion in a DSGE model featuring a double moral hazard problem between banks and investors, on the one hand, and banks and firms, on the other hand.

discussed the link between bank risk (as a proxy for financial stability) and return (as a proxy for the degree of competition) from a different angle. Allen and Gale (2004) suggest a negative relationship because more concentrated banking systems reduce incentives of bankers to lend recklessly. Boyd and de Nicolo (2005) argue that increasing market power of banks increases risk taking because banks can roll-over the higher risk associated with lower quality loans by charging higher interest rates to customers. If borrowers endogenously choose the risk of their project, an increase in lending rates increases risk due to an adverse selection effect. Martinez-Miera and Repullo (2008) show that this *risk shifting effect* is due to the assumption that loan default rates are perfectly correlated. They introduce imperfect correlation of loan default rates and show that there is an additional *margin effect*: More competition lowers loan rates, revenues from non-defaulting loans decline, and banks become riskier. Despite this general ambiguity, the impact of a lower risk-free rate on the probability of bank failure is negative (i.e. risk falls) since the margin and the risk-shifting effect reinforce each other in this case. The risk-taking channel would imply the opposite correlation.

In sum, theoretical literature has quite clear-cut implications with regard to the impact of different macroeconomic shocks on the volume of lending and the profitability of banks. Expansionary shocks should increase lending; returns of banks mirror the interest rate response. Implications for the impact of these shocks on the risk-taking of banks are less clear-cut. While some papers suggest a positive correlation between expansionary shocks and bank risk, this correlation might also be negative if a financial accelerator mechanism is at work and if banks “flee to quality”.

2.2 *Previous Empirical Literature*

Previous empirical literature on the exposure of banks to macroeconomic factors falls into three main categories: evidence on the lending channel, evidence on the risk-taking channel, and evidence on systemic risks in banking. One key finding of this literature is that the response of banks to macroeconomic factors shows a substantial degree of heterogeneity.

Lending Channel

Kashyap and Stein (2000) have suggested testing the bank lending channel by analyzing how bank lending responds to liquidity and how this response depends on the stance of monetary policy. One important lesson drawn from their result is that the effect of the bank lending channel of monetary policy depends on the degree of funding constraint a bank faces.

Subsequent studies on the bank lending channel have identified different sources of bank heterogeneity which might affect the reaction to monetary policy shocks. Kishan and Opiela (2000) and Gambacorta and Mistrulli (2004) find that capitalization is an important determinant of the ability of a banks ability to shield their loan portfolio from a tightening of monetary policy. Cetorelli and Goldberg (2008) suggest that earlier evidence on the

importance of the lending channel has overlooked cross-border lending. Using quarterly information for U.S. banks between 1980 and 2005, they find that large globally-oriented banks reduce their exposure to domestic liquidity shocks by using internal capital markets with their foreign affiliates.

Overall, evidence from the U.S. suggests that there is no strong bank lending channel operating (Walsh 2003). In contrast to the bank lending channel, the credit channel assigns importance to imperfections in economy-wide financial markets. If agency costs drive a wedge between the costs of internal and external finance, developments of net worth, cash flow, and collateral should affect lending over the business cycle. In fact, there is evidence that downturns differentially affect access to credit for high-agency-cost borrowers (Bernanke et al. 1996).

Risk-Taking Channel

The risk-taking channel (Rajan 2006, Borio and Zhu 2008) has been tested by Altunbas et al. (2009) who regress banks' expected default frequency on a monetary policy indicator, and nominal GDP growth. Results are based on a sample of listed banks. They show that the overall quality of loan portfolio increases if interest rates fall and at the same time banks take on more risk if the interest rate is below a Taylor-rule-benchmark (i.e. if a monetary tightening is expected). This is interpreted as evidence in favor of the risk taking channel. In addition, they find that higher GDP growth lowers bank risk, and that asset prices have no clear-cut impact.

Similar findings are reported in Jimenez et al. (2009). Using Spanish loan data, they find that lower interest rates have two effects. In the short run, lower interest rates reduced the probability of default of outstanding, flexible-rate loans. In the medium run, however, lower interest rates increase bank risk. Lower interest rates raise the value of collateral and induce banks to search for yield, banks extend more (new) risky loans (Gambacorta 2009). In addition, there is a large degree of heterogeneity across banks. Small banks, banks that are net lenders in the interbank market, and savings and cooperative banks take on more extra risk

Systemic Risk

A final related strand of empirical research analyzes the exposure of banks to macroeconomic developments and shows how this contributes to systemic risk. Tarashev et al. (2009a, 2009b) develop a measure of systemic risk which is based on the game-theoretic concept of the so-called Shapley value. This measure ascribes to individual players the average marginal contribution each makes to each possible subgroup in which they participate. They find that the number of banks', their relative size, their probabilities of default, and their exposures to macroeconomic risk factors are drivers of systemic risk. However, the feedback between the banking sector and the macro-economy is not modeled explicitly. As an alternative approach to measure systemic risk, Adrian and Brunnermeier (2009) propose a so-called *CoVar* model

which determines the value at risk (*Var*) of a financial system, given that the individual institution is in distress. The determinants of this risk measure include macroeconomic state variables such as the policy rate or the yield spread which shift the conditional mean and volatility of the *CoVar* measure.

3 Macroeconomic and Bank-Level Data

3.1 Macroeconomic Data

Our set of macroeconomic variables comprises log differences of real GDP, the GDP deflator, real house prices and real stock prices and the level of the effective Federal Funds rate. House prices are measured as the Freddie Mac Conventional Mortgage. Stock prices are measured as the S&P 500, observed at the end of the quarter. House price and stock prices are divided by the GDP deflator to obtain real values. The data are retrieved from the FreeLunch.com, a free internet service provided by Moody's Economy.com.

3.2 Bank-Level Data

Our source for bank-level data is the Consolidated Report of Condition and Income (Call Reports) that all insured banks in the United States submit to the Federal Reserve each quarter. A complete description of all variables and data sources is provided in the data appendix (Table A.1).

The reason for using these data is three-fold. First, the Call Report data have been used frequently in empirical work in banking allowing us to compare our results. Second, the Call Report data are publicly available supervisory data, and we thus need not restrict our analysis to market data which are available for only a relatively small sub-set of (listed) banks. Third, the data are available for a large panel of banks for at least two decades and thus allow analyzing longer-run tendencies.

From the Call Reports, we compile a dataset consisting of quarterly income statements and balance sheet data over the period 1991Q1–2008Q2. We begin our analysis in the year 1991 for the following reasons. First, we exclude the period of the savings and loans crisis of the 1980s which cumulated in the credit crunch of the late-1980s and early-1990s. Second, since we use a balanced dataset, the shorter the time period covered, the more representative the dataset is for today's banking landscape.

A first set of banking variables measuring bank risk, return, and lending is included in a dataset from which we estimate the banking factors. These banking factors, in turn, serve as an input for the FAVAR model that is described in Section 4. A second set of banking variables is used to explain differences in response of banks to macroeconomic factors (see Section 5.3).

The series which are used for the construction of the first type of measures are total assets, total loans, equity capital, non-performing loans, and net income of commercial banks. Following previous literature, we apply a number of screens to exclude implausible and unreliable observations. In particular, we exclude observations with (i) negative or missing values for total assets, (ii) negative total loans, (iii) observations with loan to assets ratios larger than one, (iv) observations with capital to asset ratios larger than one, and (v) banks with gross total assets below \$25 million.¹¹ Overall, these corrections reduce the sample from 13,375 banks in the unbalanced panel to 2,734 banks in the balanced panel. We use only banks that are in business during the entire period under study.¹²

Our measure of banks' returns is return on asset, defined as net income to total assets. Our main risk measure is the share of non-performing in total loans. In addition, we use the (unweighted) capital-asset ratio, measured as equity capital to total assets, since banks with a higher capital ratio are less likely to fail, *ceteris paribus*. Compared to the non-performing loan ratio, the capital-asset ratio has advantages and disadvantages as a risk measure. An advantage is that the capitalization of banks affects the banks' ability to absorb macroeconomic shocks and enhance the stability of the banking system (Angeloni and Faia 2009, Kishan and Opiela 2000, van den Heuvel 2002, Gambacorta and Mistrulli 2004, Meh and Moran 2008). A disadvantage of the capital-asset ratio is that it is, to some extent, determined by regulatory requirements. Also, the degree of capitalization is used by banks as a signaling device, and banks might avoid adjustments in response to macroeconomic shocks. In addition to risk and return, we include the loans-to-asset ratio to account for changes in bank lending activities. We scale loans by total assets to control for the size of banks

The bank-level data are treated in the usual manner for factor analysis. They are seasonally adjusted. We assume that all variables we include are stationary, so there is no need to difference them. Outliers are removed.¹³ Finally, the data are standardized to have a zero mean and a unit variance.

In addition to these variables, we consider several bank-level characteristics which may influence the exposure of banks to macroeconomic factors: the size of banks, internationalization (i.e. whether a bank has foreign affiliates or not), the interconnectedness with other banks, and liquidity.

¹¹ As Berger and Bouwmann (2009) state, banks with total assets below \$25 millions are not likely to be viable commercial banks.

¹² This procedure implies that any bank engaged in a merger is finally dropped from the sample since it includes a missing observation at the time the merger occurred.

¹³ Outliers are defined as observations of the stationary data with absolute median deviations larger than six times the interquartile range. They are replaced by the median value of the preceding five observations. See also Stock and Watson (2005).

The size of banks is measured by the (log) volume of banks' total assets, i.e. assets divided by the GDP deflator. Internationalization is measured by the presence of foreign affiliates. We label a bank "international" if it reports the existence of a foreign affiliate in at least one period (Cetorelli and Goldberg 2008). This procedure results in about 300 international active banks or a little more than 10 percent of the total (balanced) dataset. The degree of interconnectedness of banks is measured using the share of federal funds purchased in total assets as a proxy for the exposure to the interbank market. Finally, liquidity is measured by the ratio of securities to assets, where we follow Kashyap and Stein (2000) as closely as possible. These variables are also seasonally and outlier-adjusted. In addition, the riskiness of banks will be considered as bank-level feature which may influence the exposure of risk (and lending) to macroeconomic factors.

Table 2 compares the unbalanced and the balanced panel since balancing the dataset might result in an unrepresentative description of the banking industry. The medians for the balanced and unbalanced data are close enough to be confident that balancing the panel does not induce a strong bias. As expected, the coefficient of variation in the unbalanced dataset is higher for all variables except for the loans-to-asset ratio. The reason is that balancing drops all banks which defaulted during the time period considered. That is, we exclude banks with presumably high realizations in these risk measures. The same reasoning explains the differences in the measure of liquidity. Considering the descriptive statistics for total assets, balancing reduces the degree of skewness in the data. This result is driven by the interplay of merger treatment and balancing.¹⁴ Finally, Federal Funds purchased exhibits a higher coefficient of variation in the balanced panel since we exclude very small banks which are in general less active in the interbank market.

For our factor model to provide a good description of the data, there needs to be a strong factor structure among the series included, i.e. factors can be accurately estimated if the series strongly comove (Boivin and Ng 2006). We thus assess to what extent the different types of banking variables (risk, return, lending) are correlated. Table 3 shows the correlation coefficients between the medians of the four variables. The medians are, in general, highly correlated. Only return on assets is rather loosely related to the other variables. When removing banks' return on assets from the sample, results for the other variables are not affected. We next examine to what extent banks are related. Table 4 shows the variance shares explained by the first 10 principal components extracted separately from bank-level datasets associated with each of the four variables. The table reveals that there is strong comovement among banks for all banking variables.

¹⁴ This interplay of merger treatment and balancing eliminates some of the largest banks in the U.S., since especially very large banking institutions merged with other banks (or became large due to mergers) during these years. This drawback of our data treatment procedure is our main concern. To check the robustness of our results, we conducted the analysis without merger treatment but a careful outlier treatment only. The results are qualitatively the same.

Finally, we account for specific regional developments by including regional dummies in the cross-sectional regressions of banks' exposure to macroeconomic factors (Section 5.3). An alternative approach would be to directly model regional aspects by decomposing bank-level variables into nation-wide, regional, and bank-specific components (Kose et al. 2003, Mönch et al. 2009, Beck et al. 2009). To test how relevant regional factors are, we separately extract factors from risk, return, and loans to asset ratios associated with each region. We then pool the factors and estimate the first few principal components from the pooled set. These factors are highly correlated with the principal components estimated directly from the entire dataset.

4 The FAVAR methodology

We start from a small-scale macroeconomic VAR model which includes GDP growth (Δy_t), the GDP deflator inflation (Δp_t), the Federal Funds rate (ffr_t), and real asset price (house price Δhp_t and stock price Δsp_t) inflation as endogenous variables. These variables can be summarized in an $M(=5) \times 1$ -dimensional vector $G_t = [\Delta y_t, \Delta p_t, \Delta hp_t, ffr_t, \Delta sp_t]$. GDP growth, inflation and an interest rate represent the standard block of variables included in macroeconomic VARs (Schorfheide and Del Negro 2003, Peersman 2005, Christiano et al. 1996), fewer studies include also assets prices in such a VAR (Jarocinski and Smets 2008, Bjørnland and Leitemo 2009, Bjørnland and Jacobsen 2008).

We augment the vector G_t with a set of "banking factors" B_t which yields the $r \times 1$ -dimensional vector of $F_t = [G_t', B_t']'$ where $r - M \times 1$ is the dimension of the vector of banking factors. The vector of banking factors $B_t = [b_{1t}, \dots, b_{r-Mt}]'$ is unobserved and needs to be estimated, as will be explained below.

We model the joint dynamics of macroeconomic variables and banking factors as a VAR(p) process:

$$A(L)F_t = c + Pw_t, \quad (1)$$

where $A(L) = I - A_1L - \dots - A_pL^p$ is a lag polynomial of finite order p , c comprises deterministic terms,¹⁵ and w_t is a vector of structural shocks which can be recovered by imposing restrictions on P .

Let the elements of F_t be the common factors driving the $N \times 1$ vector X_t which summarizes our four banking variables, i.e. loans to assets, non-performing loans to total loans, return on assets, and equity capital to assets, of 2,734 individual banks. To assess the impact of

¹⁵ We include constants and linear trends.

macroeconomic shocks on the “average” bank we also include in X_t the medians of the four banking variables.¹⁶ Hence, the cross-section dimension is $N = 10,944 (= 2,734 \times 4 + 4)$.

It is assumed that X_t follows an approximate dynamic factor model (Bai and Ng 2002, Stock and Watson 2002):

$$X_t = \Lambda' F_t + \Xi_t, \quad (2)$$

where $\Xi_t = [\xi_{1t} \quad \Lambda \quad \xi_{Nt}]'$ denotes a $N \times 1$ vector of idiosyncratic components.¹⁷ The matrix of factor loadings $\Lambda = [\lambda_1 \quad L \quad \lambda_N]$ has dimension $r \times N$ and $\lambda_i, i = 1, \dots, N$ are of dimension $r \times 1$. Typically, $r \ll N$. Common and idiosyncratic components are orthogonal, the common factors are mutually orthogonal, and idiosyncratic components can be weakly mutually and serially correlated in the sense of Chamberlain and Rothschild (1983).

Equations (1) and (2) represent a FAVAR model as has been introduced by Bernanke et al. (2005).¹⁸

The model is estimated in five steps. First, the dimension of F_t , i.e. the number of common (latent and observable) factors r is determined to be 8, which explain about 70 percent of the variation in the banking data and thus represents a reasonable degree of comovement between the banking variables.

Second, the latent factors summarized in B_t span the space spanned by F_t after removal of the five observable factors. B_t is estimated as follows. We extract the first r principal components from X_t and summarize them in \hat{F}_t . Next, we estimate a regression of the form $G_t = \gamma \hat{F}_t + e_t$ where γ is of dimension $M \times r$. B_t is then estimated as $\hat{B}_t = \hat{\gamma}_\perp \hat{F}_t$ where $\hat{\gamma}_\perp$ is the orthogonal complement of $\hat{\gamma}$. The matrix of factor loadings Λ is estimated by an OLS regression of X_t on $[G_t' \quad \hat{B}_t']'$.¹⁹

Third, a VAR(1) model is fitted to $[G_t' \quad \hat{B}_t']'$. The lag length of $p = 1$ is suggested by the Schwarz information criterion.

¹⁶ To save time and capacity, we will compute confidence bands only for these median variables but will focus on point estimates for individual banks' responses. Point estimates of median impulse response functions are very similar to point estimates of impulse response functions of the median bank.

¹⁷ Note that F_t can contain dynamic factors and lags of dynamic factors. Insofar, equation (2) is not restrictive.

¹⁸ Bernanke et al. (2005) are interested in a monetary policy shock and include the Federal Funds rate as the only observable in the FAVAR. Our model most closely resembles the one used in Eickmeier and Hofmann (2009) which models a set of latent financial factors estimated from a large set of asset prices, interest rates and spreads, and non-financial sector balance sheet items.

¹⁹ Due to the very large cross-section, we do not follow Boivin and Giannoni (2008) who suggest removing the observable from the set of latent factors based on an iterative procedure. One difference between the procedure used here and the one used in Boivin and Giannoni (2008) is that the our procedure yields latent factors which are orthogonal to the observables whereas the method by Boivin and Giannoni procedure yields latent factors that can be (weakly) correlated with the observables.

Fourth, we (loosely) identify macroeconomic (and financial) shocks via a Cholesky decomposition of the covariance matrix of the reduced form VAR residuals. We impose the following ordering: $\Delta y_t \rightarrow \Delta p_t \rightarrow \Delta hp_t \rightarrow \hat{B}_t \rightarrow ffr_t \rightarrow \Delta sp_t$. We label the shocks GDP shocks, price shocks, house price shocks, “banking shocks” (i.e. the Cholesky shocks to the banking factors), monetary policy shocks, and stock price shocks.

The ordering implies that GDP and prices (aggregate prices and real house prices) do not react contemporaneously to financial and monetary shocks, which is fairly standard in SVAR studies. GDP and aggregate prices react with a delay to house price movements (e.g. Jarocinski and Smets 2008). Moreover, we allow the monetary policy instrument to respond contemporaneously to all but stock price shocks. Ordering the policy instrument below the banking factors is probably the most controversial restriction. Reasons for sluggish adjustment could be the need to renegotiate existing contracts or close customer relationships that banks do not want to interrupt. Consistent with this assumption, the empirical banking literature finds that interest rate spells of banks are sticky and do not react quickly to market interest rates (Berger and Hannan 1991). By imposing this restriction, we follow most of the SVAR literature which models macroeconomic and banking variables together (Ciccarelli et al. 2009).²⁰ In future work, we plan to assess the robustness of our results with respect to the ordering of the Federal Funds rate and \hat{B}_t . Stock price inflation is ordered last which is implied by the fact that we use stock prices measured at the end of the quarter.

In the fifth and final step of the estimation, confidence bands of the impulse response functions are constructed using the bootstrap-after-bootstrap technique proposed by Kilian (1998). This technique allows removing a possible bias in the VAR coefficients which can arise due to the small sample size. The number of bootstrap replications equals 1,000. Notice that, since $N > T$, we neglect the uncertainty involved with the factor estimation, as suggested by Bernanke et al. (2005).

5 Empirical Results

We organize the presentation of our empirical results along our three main questions.

First, what is the role of macroeconomic shocks for the banking sector? To answer this question, we focus on a “representative” (median) bank and assess the dynamic transmission and the importance of different macroeconomic shocks for bank risk, return, and lending based on an impulse response analysis and a forecast error variance decomposition.

Second, what is the role of the banking sector for the macroeconomy? We assess the contribution of banking shocks to the variation of macroeconomic variables based on variance

²⁰ Bernanke et al. (2005), in contrast, assume that credit aggregates are fast-moving variables with respect to the monetary policy instrument.

decompositions. Moreover, we plan to carry out a counterfactual experiment to quantify the role of the banking sector for the transmission of macroeconomic shocks. This allows us to quantify the degree of procyclicality of the banking sector.

Third, what are the sources of heterogeneity across banks? How important are idiosyncratic shocks compared to the asymmetry in the propagation of common shocks to individual banks? Which bank-level features affect the exposure of banks to macroeconomic factors? To answer the latter question, we will use the rich cross-sectional information contained in our dataset and explain banks' exposure to macroeconomic factors in bank-level regressions.

5.1 What is the Role of Macroeconomic Shocks for the Banking Sector?

Before responding to the first question, it is useful to have a look at how macroeconomic shocks are transmitted to macroeconomic variables. Figure 1 presents impulse response functions of GDP, the GDP deflator, the Federal Funds rate, house and stock prices to GDP, price, monetary policy, and asset price shocks. We show median responses together with one standard deviation confidence bands to shocks of the size of one standard deviation. After a GDP shock, GDP rises permanently and the GDP deflator falls. The shock thus resembles a supply shock. Unexpectedly higher prices dampen economic activity. The monetary authority reacts by raising interest rates. An expansionary monetary policy shock leads to persistent increases in prices and economic activity. An unexpected increase in real house prices triggers an increase in general prices, but has only a short-lived positive impact on GDP. After about two years, GDP declines. Unexpectedly higher stock prices have no significant impact on GDP. While house prices react significantly, sluggishly and persistently to macroeconomic shocks, stock prices tend to respond more quickly and in a short-lived manner.²¹

To assess the dynamic transmission of macroeconomic (and asset price) shocks to the banking sector, we look at impulse response functions of the median bank (Figure 2). Risk, measured through the ratio of non-performing to total loans, tends to decline following expansionary shocks (i.e. shocks that increase GDP), including monetary policy shocks.²² Hence, for the median bank, there is no evidence for the risk-taking channel. After asset price shocks, the negative effect peaks on impact and vanishes rather quickly (after roughly two quarters). By contrast, the response of risk is delayed after GDP, price and monetary policy shocks and more persistent following the latter shocks. The evolution of the capital-asset ratio tends to mirror-image the evolution of the non-performing loan ratio in qualitative terms. This is not surprising. Better capitalization of a bank is associated with a lower risk of default. Hence, the capital-asset ratio should be inversely related to risk.

²¹ An exception is the reaction of stock prices to monetary policy shocks which is rather delayed and persistent.

²² An exception is the positive risk impact response to price shocks. Our price shocks are contractionary. Since our model is symmetric, an expansionary price shock which lowers prices and raises output has, unlike the other expansionary shocks, a negative impact effect on risk.

One objection to our analysis could be that both, non-performing loans and the capital asset ratio, are balance sheet indicators of risk which might react sluggishly to changes in the true underlying risk compared to more market-based measures. Also, the non-performing loans ratio primarily measures valuation changes for outstanding loan contracts. For these, and in particular for flexible-rate contracts, a monetary loosening should indeed lower risk. In our data, we cannot identify to what extent changes in loans are due to valuation changes on existing loans or changes on the risk of new credits being granted.²³ Altunbas et al. (2009), for instance, find that risk of new credits rises after a monetary policy loosening and that the risk-taking channel is particularly important the longer interest rates have been held low. We do not control for the duration of a particular monetary policy shock but consider “average” shocks over the entire sample period. For these reasons, our results probably understate the risk channel of monetary policy. In future work, it would be interesting to test the robustness of our findings using more market-based measures of risk such as CDS spreads.

Figure 2 also reveals that the responses of banks’ returns are generally positively correlated with the responses of the Fed Funds rate, although the magnitude and timing of the effects differs. The correlation between banks’ risk and return tends to be negative after all but GDP shocks. The risk-return correlation after a house price shock somehow varies with the horizon.

Finally, loans to assets tend to increase after all expansionary shocks,²⁴ as predicted by theory, although the impact effect is negative for supply and stock price shocks. Also, the persistence and dynamics of the effects differ. The positive effect of all but monetary policy shocks quickly evaporates whereas it lasts longer for monetary policy shocks. The medium-term lending response to house price shocks is negative. The reason could be a negative demand effect as reflected by the negative GDP impulse response function at medium horizons as a consequence of a negative wealth effect for house renters.

Table 5 shows the forecast error variance decomposition. Macroeconomic (and asset price) shocks together explain 37 percent of return on assets, 39 percent of the non-performing loan ratio, 27 percent of loans-to-assets, and 19 percent of the degree of capitalization of median banking variables in the short run (the one-year forecast horizon). These numbers increase for all variables by about 5-10 percentage points in the medium run (the five-year horizon). House price shocks play the most important role for risk and returns; GDP shocks account for the greatest share of the variation in loans to assets. Table 5 also reveals that the idiosyncratic (variable-specific) component is by far more important than common banking shocks, in line with other micro-studies.

²³ Note, however, that the positive response of the capital-asset ratio points into a similar direction, namely a decrease in bank risk following a monetary expansion.

²⁴ An exception is again the insignificant loans-to-assets reaction to price shocks.

In sum, we find that macroeconomic shocks play a non-trivial role for (aggregate) developments in the banking sector. Our findings suggest that bank risk for the median bank falls following expansionary macroeconomic shocks. Furthermore, the correlation between banks' risk and return depends on the underlying shock.

5.2 *What is the Role of the Banking Sector for the Macroeconomy?*

Table 3 also reveals that banking shocks are quite important for macroeconomic variables, in particular in the medium run. Banking shocks explain roughly one 1/10 of the forecast error variance of the macroeconomic variables. For house prices, this ratio is even higher (18 percent). The short-term effects are much smaller, ranging between 2 percent (GDP) and 9 percent (stock prices). The rather large share of stock prices is particularly remarkable. Stock prices are generally known to move quite autonomously, which is confirmed by the small fraction explained by macroeconomic shocks (Table 5).

To what extent is the banking sector procyclical? We find that lending increases after expansionary shocks and this could amplify the effects of shocks on GDP. Ciccarelli et al. (2009), for instance, find evidence on positive effects of credit shocks on output. The decline in risk we tend to find after expansionary shocks probably could further amplify the effect of the shocks on real activity. Christiano et al. (2009) and Gilchrist et al. (2009) find that an (unexpected) decline in risk raises real activity. In a next version of the paper we plan to quantify the role of the banking sector as an amplifier of macroeconomic shocks by carrying out a counterfactual experiment. We compare the impulse responses presented above with impulse responses from a model where we have set all feedback coefficients from the banking factors \hat{B}_t to the macroeconomic variables to zero.

5.3 *Heterogeneity of Banks*

In our set-up, bank heterogeneity has two dimensions. First, there may be a substantial idiosyncratic component in bank-level developments. Second, banks may respond differently to the common shocks.

5.3.1 Idiosyncratic Shocks versus Asymmetric Transmission of Common Shocks

Figure 3 shows the dispersion of idiosyncratic and common components of individual banks' risk, return, and lending for the sample period. Note that changes in the dispersion of the common component over time are driven by the changing relative occurrence of common shocks since the factor loadings are constant over time. Generally, the dispersion in the idiosyncratic components of non-performing loans ratio and returns on assets exceeds the dispersion of the common components. For these variables, heterogeneity is mainly due to idiosyncratic shocks. For the loans-to-assets and the capital-to-assets ratios, dispersion across idiosyncratic components and common components is of roughly equal importance. An

interesting pattern that is apparent from Figure 3 is also that the standard deviation of the common components is relatively large at the beginning and the end of the sample suggesting that over these periods the banking sector was hit by common (macroeconomic and/or banking) shocks that triggered more heterogeneous responses than other common shocks which seem to have been more present at the middle of the sample.

To assess to what extent some common shocks are more asymmetrically transmitted than others we show in Figure 4 (the 5th to 95th quantiles of) impulse response functions of individual banks.²⁵ The charts reveal that GDP, price, and house price shocks tend to trigger more heterogeneous responses than monetary policy or stock price shocks. This may explain why, in the middle of the sample period, which can be associated with the dotcom bubble and very volatile stock markets, dispersion across common components was relatively low. Interestingly also, although risk has been shown above to decline on average (i.e. for the median bank) in response to a monetary policy loosening, Figure 4 shows that risk indeed rises for a large fraction of banks. The non-performing loans ratio rises for 33 percent and 30 percent of the banks, and the capitalization ratio declines for 41 percent and 37 percent of all banks at the one- and the two-year horizon, respectively.

Overall, a substantial fraction of heterogeneity in the banking sector can thus be explained – as in any micro-dataset – by idiosyncratic shocks. However, asymmetric transmission is almost equally important. The next subsection sheds light on which bank-level features can explain different exposure to common macroeconomic shocks. While no evidence is found for the existence of the risk-taking channel on average over all banks, risk increases after a monetary policy loosening for a discernible share (roughly one third) of all banks.

5.3.2 Which Bank-Level Features Affect the Exposure of Banks to Macroeconomic Factors?

In a next step, we analyze whether banks' response to macroeconomic shocks differs across banks of different types in any systematic way. Following previous literature, we focus on banks' size, internationalization, liquidity, connectedness with other banks, riskiness (non-performing loans and capitalization), and a full set of regional dummies (unreported) (see also Ssection 3).²⁶ These bank-level variables are averages over the sample period.

We use individual banks' impulse response functions (one- and the two-year horizons) as well as factor loadings as left-hand side variables. Regression results for the loadings are most likely comparable to results from the previous empirical literature which looks at the effects of “reduced-form” constructs (such as our observable factors) on risk. We focus (for now) on

²⁵ We show the 5th to 95th quantiles instead of impulse response functions for better visibility. In charts with impulse responses of all banks, the scaling is dominated by outliers. Moreover, we do not obtain an assessment of the frequency with which banks fall into certain ranges of impulse responses.

²⁶ In a next version of our paper we plan to consider similarity of banks' portfolios as an additional determinant.

the reaction of non-performing loans ratio as a measure of risk and the loans-to-assets to monetary policy. We normalize signs of the loadings associated with the Federal Funds rate for the median bank to represent a monetary expansion. Least absolute deviations regressions are used which are more robust with respect to outliers compared to ordinary least squares. These regressions allow us to interpret results as relative to the response of the median bank.²⁷ We carry out bivariate and multivariate regressions (to account for multicollinearity). Because the results are qualitatively similar, we report only the multivariate regression results in Table 6. We plan, in the next version of the paper, to account in the cross-section regressions for the uncertainty involved with the estimation of loadings and impulse responses.

Size

From a theoretical point of view, we would expect size to dampen the exposure of banks to macroeconomic shocks. Diamond and Rajan (2006) have argued that smaller banks should be more prone to risk-taking than larger banks because of lower net worth, lack of diversification, and funding difficulties. Similarly, the lending channel of monetary policy should be less relevant for large than for small banks since large banks find it less difficult to resort to alternative sources of finance if funding conditions worsen. Moreover, according to Farhi and Tirole (2000), banks increase their exposure to macroeconomic shocks in order to make a (monetary) bail out more likely, i.e. they want to fail when a large number of banks fails. One might conjecture that these incentives are greater *ceteris paribus* for smaller banks since larger banks have a larger probability to be bailed out because of too-big-to-fail considerations. In Zhang (2009), the exposure of banks to macroeconomic risks depends on their ability to write state-contingent contracts. This ability may be positive correlated with the size of banks, which would imply a lower exposure of large banks to macroeconomic shocks.

Overall, these considerations would suggest differences in the responses of large and small banks to macroeconomic shocks. Our results do not confirm this expectation. Although the coefficients have the expected sign, i.e. size is negatively/positively related to the exposure of lending/risk to a monetary policy tightening, we find no significant impact on factor loadings or impulse response functions with regard to monetary policy (Table 6).

Liquidity

Generally, there is a positive correlation between liquidity and the lending capacity of banks. Since banks engage in maturity transformation and finance illiquid long-term projects with liquid short-term funds (see, e.g., Diamond and Rajan 2006), improved access to liquid funds should increase lending. Improved access to liquidity, in turn, could be the result of an expansionary monetary policy. Also, banks should react differently to monetary policy

²⁷ The constant can be interpreted as the conditional median.

shocks. Banks with limited access to alternative sources of funding should react relatively more to a given monetary policy shock than banks that can easily substitute between different Sources of funding. This ability is determined by the size of banks, their net worth, and the degree of information asymmetries.

Consistent with this expectation, we find that liquidity, as measured by the ratio of securities to assets, has a negative and significant impact on the exposure of loans to assets to monetary policy, i.e. more liquid banks tend to expand lending by less in response to a decline in monetary policy rates than less liquid banks. We find no significant impact of liquidity on the response of risk.

Internationalization

Next, we account for the fact that the degree of internationalization of banks could affect their exposure to shocks. If shocks at home and abroad are imperfectly correlated, then banks with foreign affiliates should respond less to domestic shocks than other banks because they have an additional channel of diversification of risk. At the same time, banks with foreign affiliates may be able to take on higher risks at home but lower risk overall.²⁸ Our specification closely follows Cetorelli and Goldberg (2008). These authors show that internationally oriented banks have the potential to lay off domestic macroeconomic shocks through borrowing and lending to their foreign affiliates. Hence, the exposure of internationally active banks to domestic macroeconomic shocks should be smaller than the exposure for purely domestic banks.

We include in our regressions a dummy variable which is one if a bank has foreign affiliates and zero otherwise. Our results show that international banks indeed show different responses to monetary policy shocks than domestic banks.²⁹ Concerning the impact of monetary shocks on the non-performing loans ratio, we find a positive coefficient on the international dummy. The effect is, however, significant only for impulse response functions at the two-year horizon. Furthermore, internationally active banks change their loans-to-assets less in response to monetary policy shocks than domestic banks. Given that, on average, lending increases and risk declines following an expansionary monetary policy shock, the response of international banks is thus muted. As regards lending, this would be consistent with the findings in Cetorelli and Goldberg (2008).³⁰

²⁸ Note that we look at consolidated accounts of domestic headquarters and foreign affiliates. Since we do not have information on the location of the foreign affiliates, we cannot control for the correlation between domestic and foreign shocks.

²⁹ Cetorelli and Goldberg (2008) consider large international and large domestic banks. By including size in our regressions we already control for size.

³⁰ We have also followed Cetorelli and Goldberg (2008) more directly by including an additional interaction term between being international and liquidity, but this term was insignificant.

Connectedness

We measure linkages between banks using banks' exposure to the interbank market. Closer linkages between banks can have two effects. On the one hand, closer linkages allow banks to insure against idiosyncratic shocks, thus lowering risk. On the other hand, closer linkages should increase the exposure to macroeconomic shocks by exposing banks to common shocks hitting the financial system. In Allen and Gale (2000), for instance, excessive liquidity shocks are more likely to be contagious if banks are more closely interlinked together via the interbank market.

We find that banks which are more active on the interbank market lower risk by more in response to monetary policy shocks. The effect on loans is insignificant. Recalling that internationally active banks lower risk by less than the full sample, this result is consistent with the prior that the domestic interbank market allows banks to diversify idiosyncratic, but not domestic macroeconomic risk. Internationally active banks, in contrast, can also diversify domestic macroeconomic risk and thus react less to these risks.

Risk

Finally, we analyze whether bank risk affects the reaction of banks to monetary policy shocks. We find no strong impact of the degree of the capitalization ratio. If anything, the responses for better capitalized banks at the one-year horizon are stronger with regard to lending but weaker with regard to non-performing loans.

Measuring the riskiness of banks through their share of non-performing in total loans gives more clear-cut results. The impact of this variable is negative for loans-to-assets, suggesting that riskier banks increase lending by less following a monetary expansion. The coefficient on the exposure of the non-performing loans ratio is negative and significant as well (except for the factor loadings), hence the more risky a bank, the more risk falls. The interpretation would be that risky banks shy away from expanding their loan portfolios (and potentially accumulating additional non-performing assets) and, at the same time, lower the total risk of their portfolio.

Overall, the exposure of bank risk and lending to monetary policy shocks depends on the riskiness of a bank and whether a bank has foreign affiliates or not. In addition, liquidity matters for lending and the degree of capitalization seems to matter for risk. Other determinants such as a banks' size or its connectedness with other financial institutions do not play a significant role.

6 Summary

In this paper, we use a FAVAR model to analyze feedback effects between banks and the macroeconomy, and we particularly focus on the heterogeneous exposure of over 2,000 U.S.

banks to macroeconomic factors. We make several contributions to the literature, in particular the recent empirical literature on the risk-taking channel of monetary policy: First, we model dynamic responses by taking the endogeneity of macro- and banking factors into account. Second, we allow for and exploit the connection between banks and different banking variables (unlike previous micro studies). Third, we (loosely) identify orthogonal macroeconomic (and asset price) shocks to cleanly decompose banks' common risk into its different sources, and we isolate these shocks from idiosyncratic risk at the bank level.

Our paper has the following main findings.

First, average bank risk measured through non-performing loans to total loans and the capital-asset ratio tends to decline following expansionary shocks, including monetary policy shocks. Results for individual banks, however, reveal that about 1/3 of all banks raise risk after a monetary policy loosening. In this sense, our results are only partly in support of the risk-taking channel of monetary policy. It should be noted that our risk measures do not allow distinguishing the riskiness of the outstanding loan portfolio and new loans. This may thus understate the effects of expansionary shocks on risk because the risk-taking channel operates through increased risk of new loans.

Second, shocks that increase output are associated with an increase in bank lending and are thus in support of the lending channel.

Third, our results add to the microeconomic banking literature studying the link between bank risk and return. Typically, this literature does not take into consideration that the underlying macroeconomic shocks driving risk and return might matter. We find that the correlation between the risk and the return of banks depends on the underlying shock and the time horizon considered.

Fourth, there is a substantial degree of heterogeneity in banks' risk developments. This heterogeneity has two dimensions. As in any study using micro-level data, we find a substantial idiosyncratic component. In addition, we can identify a further source of heterogeneity, namely heterogeneous responses to the same shocks. This source of heterogeneity is perhaps equally important. We have made an attempt to understand the sources of the latter heterogeneity further. Our analysis has shown that the dispersion across banks' impulse response functions is smaller for monetary policy and stock price shocks than for other (GDP, aggregate price and house price) shocks.

Fifth, we study which bank-level feature can explain differences in banks' exposure to monetary policy shocks. The median bank increases lending and reduces risk following an expansionary monetary policy shock. Compared to the median bank, risky banks increase lending by less and reduce risk by more. More internationally oriented banks also increase lending by less but reduce risk by less. Lending of more liquid banks is affected less. Other factors, notably the size of a bank, do not play a significant role

Our findings have important implications for regulatory policy. Theoretical analyses have suggested that tighter regulatory requirements should be established for banks with a larger exposure to macroeconomic factors. Our results show the difficulties of implementing such proposals as they reveal a substantial degree of heterogeneity of banks' responses to macroeconomic factors. The responses differ across banks, and they differ with regard to the macroeconomic factor considered. Moreover, our finding that bank lending increases and risk declines after expansionary shocks could imply that the banking sector amplifies the impact on shocks on real activity. Countercyclical capital buffers as recently proposed by the BIS are an attempt to counteract this feature. Finally, it should be kept in mind that international diversification (which we have shown to yield to lower exposure to macroeconomic (domestic) shocks) works only in the case of imperfect correlation of domestic and foreign shocks. This was not the case during the recent global financial crisis and this will not be the case during future global downturns. Hence, internationalization of banks alone does not guarantee a muted shock impact on banks.

Overall, our results can thus be seen as a first step into the direction of jointly modeling dynamics of the banking sector and the macroeconomy. Our findings suggest that these feedback effects are relevant for both, understanding macroeconomic dynamics as well as the responses of banks. At the same time, our findings show the importance of future research to provide deeper insights into the sources of the substantial bank-level heterogeneity that we document. In addition, a caveat of our analysis is that the FAVAR is a linear model. However, non-linearities, e.g. in the reaction of banks to common (macroeconomic and banking) shocks, may be present in extreme situations such as banking crises. Our model has to be seen as suitable to analyze macro-banking feedbacks in "normal" times. However, an extension to allow for non-linearities would certainly be interesting to pursue in future work.

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8 Appendix 1: Data

Bank-level variables

Variable	Definition
Assets	Call report item rcfd2170 (<i>total assets, gross</i>)
Equity capital/assets	Ratio of equity capital - call report item rcfd3210 (<i>total equity capital</i>) – to total assets
Interconnectedness	Share of interbank borrowing in total balance sheet. Interbank borrowing is measured through the call report entry rcfd3353 (<i>average quarterly of federal funds purchased and securities sold under agreements to repurchase</i>).
Internationalization	Dummy variable indicating the presence of foreign affiliates. Foreign affiliates are identified through a positive entry in any of the call report entries <i>due to foreign affiliates</i> (rcon2941), <i>due from foreign affiliates</i> (rcon2163), <i>total loans of foreign affiliates</i> (rcfn2122) or <i>C&I loans of foreign affiliates</i> (rcfn1766).
Liquidity	Share of securities in total assets. Prior to 1994Q1 our securities measure is constructed as the sum of the call report entries rcfd0390 (<i>total investment securities – book value</i>), rcfd2146 (<i>total assets held in trading accounts</i>) and rcfd1350 (<i>federal funds sold and securities purchased under agreements to resell</i>). After 1994Q1 securities are defined as the sum of the call report entry lines rcfd1754 (<i>held to maturity securities, total</i>) rcfd1773 (<i>available for sale securities, total</i>) rcfd3545 (<i>trading assets, total</i>) and rcfd1350 (<i>federal funds sold and securities purchased under agreements to resell</i>).
Loans/assets	Share of total loans - call report item rcfd1400 (<i>total loans, gross</i>) - in total assets
Nonperforming loans/loans	Share of total nonperforming loans in total loans. Total nonperforming loans is constructed as the sum of call report item rcfd1403 (<i>total loans and lease finance receivbles:nonaccrual</i>) and call report item rcfd1407 (<i>total loans and lease finance receivbles:past due 90 days or more and still accruing</i>).
Return on assets	Ratio of net income - call report item riad4340 (<i>net income</i>) - to total assets.

9 Graphs and Tables

Table 1: Theoretical Hypotheses on Macroeconomic Shocks and the Risk and Return of Banks

	Angeloni / Faia (2009)			Meh / Moran (2008)		Zhang (2009)		
	<u>Monetary</u> <u>policy</u>	<u>Tech-</u> <u>nology</u>	<u>Asset</u> <u>prices</u>	<u>Monetary</u> <u>policy</u>	<u>Tech-</u> <u>nology</u>	<u>Monetary</u> <u>policy</u>	<u>Tech-</u> <u>nology</u>	<u>Bank</u> <u>capital</u> <u>shock</u>
<u>Macroeconomy</u>								
Inflation	+	--	+	+	--	+	--	+
Output	+	+	+	+	+	+	+	+
Interest rates	--	--	+	--	--			
Capital stock	+	+	+					
<u>Banks</u>								
Banks' ROA	--	--	+					
Equity / assets	--	--	--	--	--	+	+	
Deposits / assets	+	+	+					
Loans						-- / +	+	+
Risk	+	+	--	--	--	--	--	--
Banks net worth				+	+			
Bank default rate						--	--	--
Loan default rate						--	--	

Notes: This Table summarizes the implications of the discussion in Section 2.1. Columns (1), (2), (4) are mainly based on the baseline impulse-response functions in Angeloni and Faia (2009) where the change in bank loans corresponds to the investment response, and the implications for the capital-asset ratio are the inverse of the response of the deposit ratio. The qualitative results for banks' returns are identical for return on assets (used in the theoretical model) and return on equity (used in the empirical model). Our proxy for banks risk (non-performing loans / total loans) is positively correlated with the probability of a bank run, which is the theoretical measure for bank risk. The signs reported below give the impact effects. Details on the calibration and underlying assumptions are given in the original paper.

Table 2: Descriptive Statistics

	Balanced Panel				Unbalanced Panel			
	Median	Coef. of variaton	5 th percentile	95 th percentile	Median	Coef. of variation	5 th percentile	95 th percentile
Non-performing loans / loans	0.74	1.28	0.08	3.91	0.68	1.53	0	4.03
Equity capital / assets	9.74	0.32	6.85	16.92	9.16	0.41	6.41	16.48
Return on assets	1.21	0.88	0.27	2.29	1.14	1.42	-0.19	2.25
Loans / assets	59.37	0.26	29.91	79.84	62.25	0.25	31.98	82.85
Assets (2005 \$ millions)	100.67	8.1	40.76	500.42	102.38	15.91	34.73	1120.78
Liquid assets / assets	31.53	0.47	10.08	61.58	28.18	0.53	6.49	58.86
Federal funds purchased to assets	0.02	2.86	0.00	6.52	0.07	2.65	0.00	8.47
Number of banks	2,734				13,375			

Notes: The difference between the balanced and the unbalanced panel stems from the fact that we exclude observations with (i) negative or missing values for total assets, (ii) negative total loans, (iii) observations with loan to assets ratios larger than one, (iv) observations with capital to asset ratios larger than one, and (v) banks with gross total assets below \$25 million. Banks which have been involved in mergers are excluded as well.

Table 3: Correlation Between Median Banking Variables

	Non-performing Loans / loans	Equity capital / assets	Return on assets	Loans / assets
Non-performing loans / loans	1.00			
Equity capital / assets	-0.75	1.00		
Return on assets	-0.13	0.07	1.00	
Loans / assets	-0.75	0.64	-0.38	1.00

Table 4: Cumulated Variance Shares Explained by the First 10 Principal Components calculated from datasets associated with individual banking variables

	Non-performing Loans / loans	Equity capital / assets	Return on assets	Loans / assets
1	0.22	0.29	0.25	0.30
2	0.33	0.45	0.38	0.44
3	0.42	0.54	0.47	0.53
4	0.49	0.61	0.53	0.60
5	0.54	0.66	0.58	0.64
6	0.58	0.70	0.61	0.67
7	0.61	0.73	0.64	0.70
8	0.64	0.75	0.66	0.72
9	0.67	0.77	0.68	0.74
10	0.69	0.79	0.70	0.75

Table 5: Forecast Error Variance Decomposition

	GDP	Price	House price	Monetary policy	Stock price	Common banking	Idiosyncratic
1 year horizon							
GDP	0.84	0.03	0.02	0.05	0.01	0.02	-
GDP deflator	0.02	0.80	0.07	0.01	0.01	0.04	-
House price	0.02	0.06	0.83	0.02	0.00	0.03	-
Federal Funds rate	0.21	0.18	0.21	0.26	0.02	0.05	-
Stock price	0.07	0.02	0.02	0.02	0.68	0.09	-
Non-performing loans/loans	0.03	0.09	0.24	0.01	0.01	0.04	0.56
Equity capital/assets	0.02	0.06	0.10	0.01	0.00	0.04	0.76
Return on assets	0.10	0.10	0.17	0.00	0.00	0.04	0.56
Loans/assets	0.17	0.01	0.07	0.00	0.02	0.04	0.67
5 year horizon							
GDP	0.46	0.09	0.16	0.08	0.01	0.09	-
GDP deflator	0.08	0.53	0.12	0.05	0.01	0.13	-
House price	0.06	0.24	0.34	0.08	0.01	0.18	-
Federal Funds rate	0.17	0.16	0.27	0.19	0.02	0.11	-
Stock price	0.04	0.03	0.08	0.04	0.58	0.10	-
Non-performing loans/loans	0.04	0.09	0.27	0.02	0.01	0.08	0.49
Equity capital/assets	0.02	0.06	0.16	0.01	0.00	0.08	0.66
Return on assets	0.10	0.09	0.25	0.01	0.01	0.08	0.43
Loans/assets	0.15	0.01	0.11	0.01	0.02	0.06	0.61

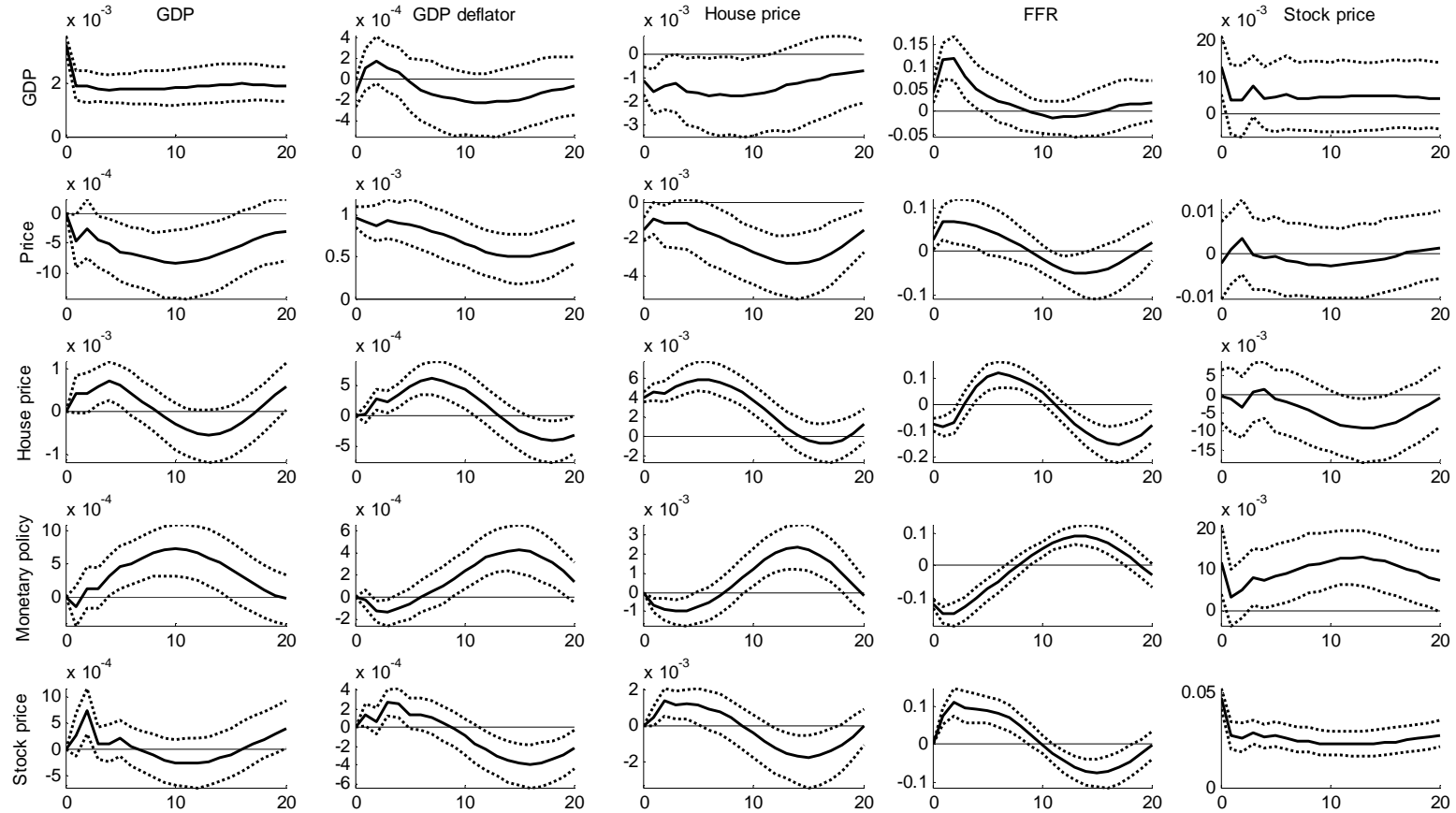
Notes: The forecast error variance of the banking variables refers to the median bank.

Table 6: Regression Results

	Loans / assets			Non-performing loans / loans		
	Loadings	IRF, 1 yr.	IRF, 2 yrs.	Loadings	IRF, 1 yr.	IRF, 2 yrs.
Size	-0.003 (0.007)	-0.010 (0.010)	-0.005* (0.003)	0.005 (0.005)	0.000 (0.001)	0.000 (0.000)
Liquidity	-0.337*** (0.048)	-0.680*** (0.065)	-0.150*** (0.017)	0.018 (0.031)	-0.003 (0.008)	0.004 (0.003)
Internationalization	-0.093* (0.053)	-0.128* (0.070)	0.038** (0.019)	0.063* (0.032)	0.012 (0.008)	0.008** (0.003)
Connectedness	0.133 (0.149)	0.246 (0.218)	-0.068 (0.058)	-0.171* (0.100)	-0.034 (0.026)	-0.020** (0.009)
Capital-to-asset ratio	0.003 (0.002)	0.005* (0.003)	0.001 (0.001)	0.000 (0.001)	0.001** (0.000)	0.000 (0.000)
Non-performing loans / loans	-0.015*** (0.006)	-0.029*** (0.008)	-0.004* (0.002)	-0.004 (0.004)	-0.008*** (0.001)	-0.002*** (0.000)
Constant	0.152 (0.098)	0.326** (0.131)	0.101*** (0.035)	-0.035 (0.063)	-0.004 (0.016)	0.001 (0.006)
Number of banks	2,734	2,734	2,734	2,734	2,734	2,734
R ² (from OLS, robust)	0.10	0.13	0.13	0.06	0.06	0.06

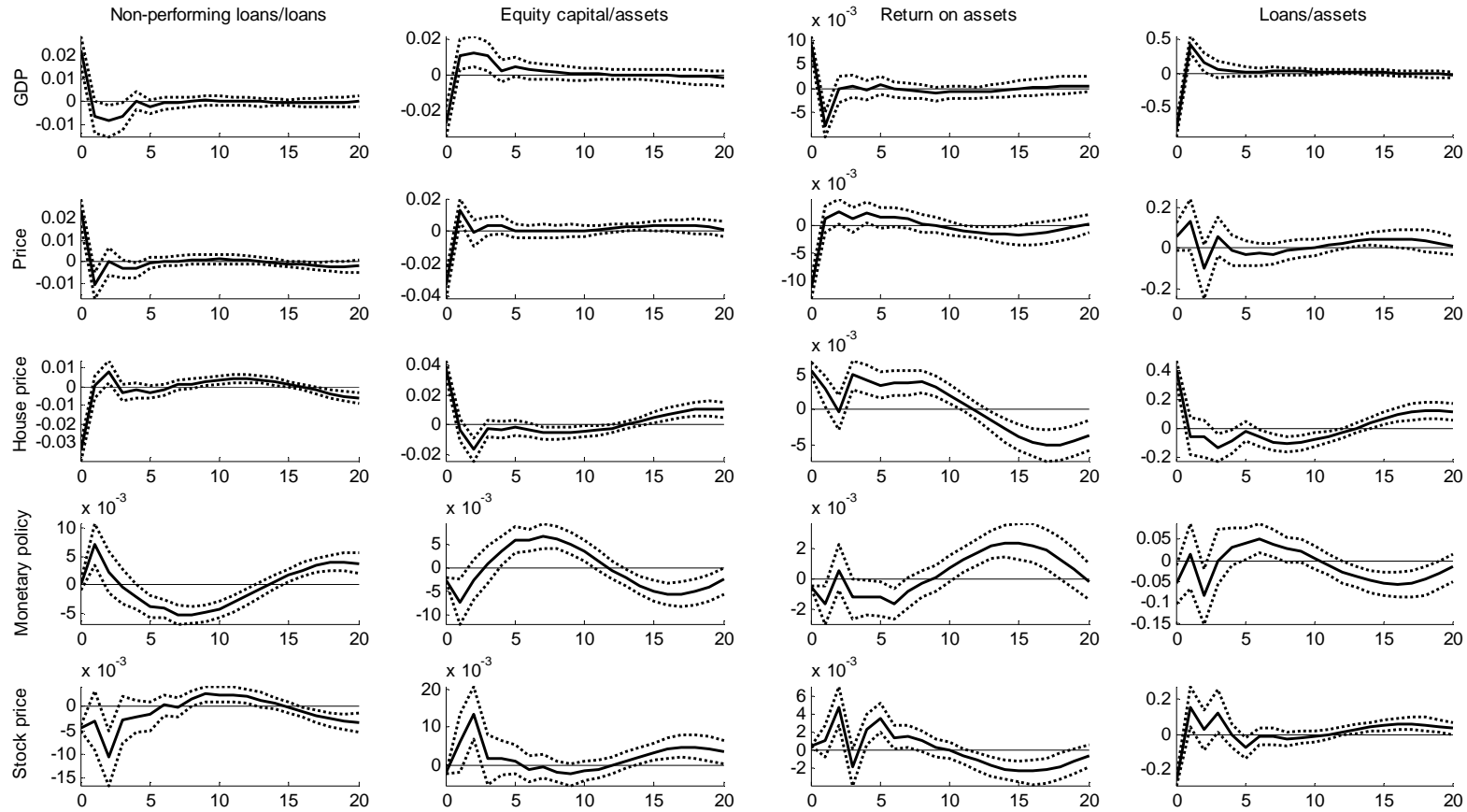
Notes: This Table presents results from quantile regressions at the sample median. The dependent variable is the exposure to monetary policy (= (normalized) loadings or impulse response functions) for risk (non-performing loans/loans) and loans/assets. Explanatory variables are banks size (log of the volume of assets) and other bank characteristics as defined in Section 3.2. Internationalization is a 1/0-dummy indicating whether a given bank has foreign affiliates, connectedness gives the volume of Federal Funds purchased. A full set of regional dummies is included. ***, **, * = significance at the 1%, 5%, 10%-level. Standard deviations are in parentheses.

Figure 1: Impulse Response Functions of Macroeconomic Factors



Notes: We show the median and the one standard deviation confidence bands.

Figure 2: Impulse Response Functions of Median Banking Variables



Notes: We show the median and the one standard deviation confidence bands.

Figure 3: Cross-Sectional Standard Deviation of Banks' Common and Idiosyncratic Components

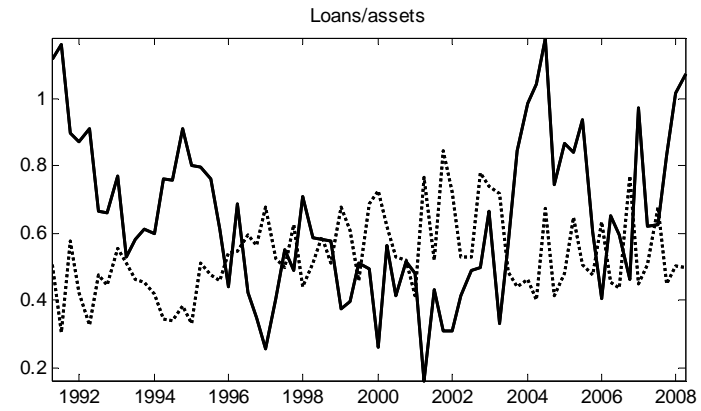
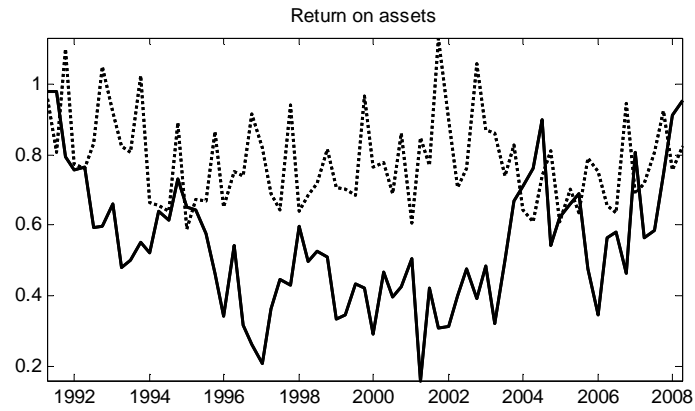
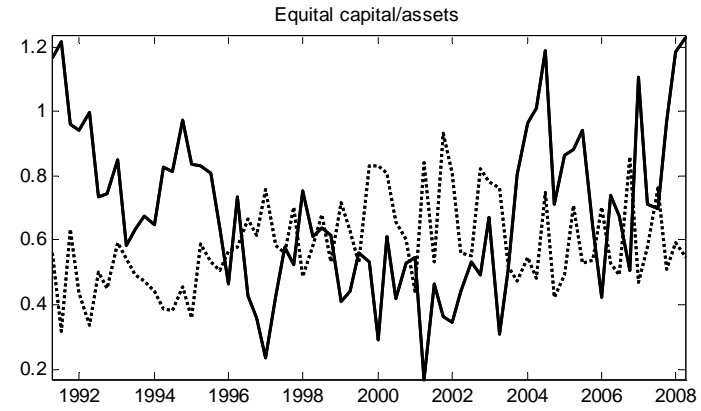
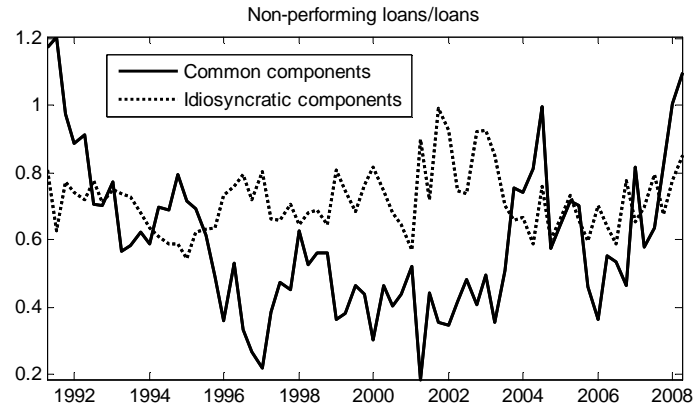
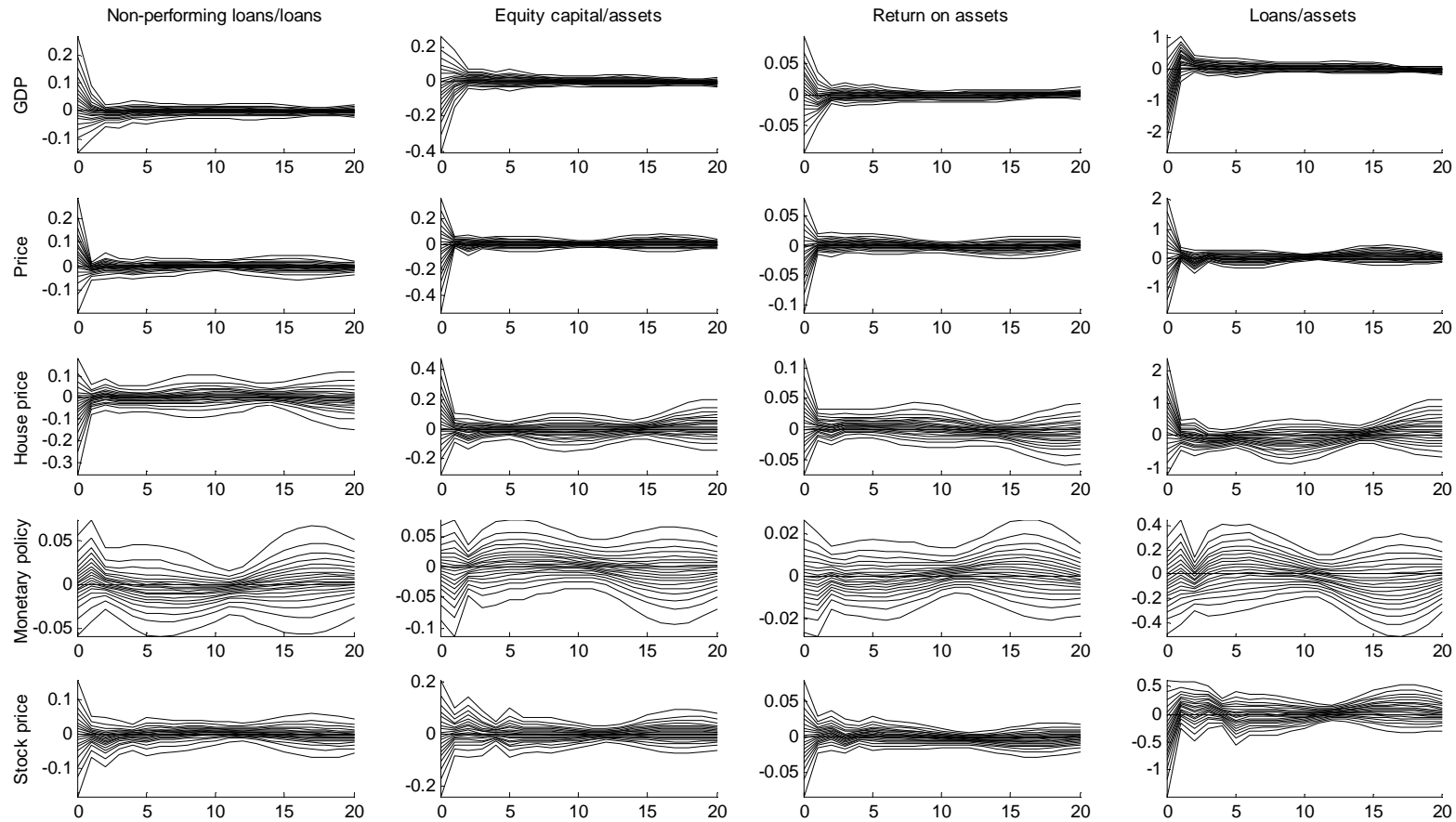


Figure 4: Impulse Response Functions of Individual Banks (5th to 95th Quantiles)



Notes: Point estimates of impulse response functions to one standard deviation shock.